CHAPTER 7. SCRAPERS

TRACTORS-PULLED SCRAPERS

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

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CHAPTER 7. SCRAPERS

SCRAPERS

APPLICATIONS

Dozer: short haul, less than 300ft

Scraper: medium haul up to 3,000 ft
TRACTORS-PULLED SCRAPERS

- They can be used in a wide range of material types (including shot rock) and are economical over a wide range of haul lengths and haul conditions.
- To the extent that they can self-load, they are not dependent on other equipment.

If one machine in the spread experience a temporary breakdown it will not shut down the job, as would be the case for a machine which is used exclusively for loading. If the loader breaks down, the entire job must stop until repairs can be made.
TRACTORS-PULLED SCRAPERS

- Scrapers are available with loose-heaped capacities up to about 44 cu yd, although in the past a few machines as large as 100 cu yd have been offered.
- For off-highway situations having hauls of less than a mile, scrapers ability both to load and haul gives them an advantage.

TYPES OF SCRAPERS

- There are several types of scrapers, primarily classified according to the number of powered axles or by the method of loading.
- Scrapers are all wheel-tractor-pulled machines.
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
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TYPES OF SCRAPERS

Many models can achieve speeds up to 30 mph when fully loaded. This extends the economic haul distance of the units.

Push-loaded scrapers are at a disadvantage when it comes to individually providing the high tractive effort required for economical loading. For the single-powered axle scraper only a portion, on the order of 50-55% of the total loaded weight, bears on the drive wheels.

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TYPES OF SCRAPERS

Conventional (push-loaded) single engine scrapers become uneconomical when:

Haul grades > 5%
Return grades > 12%
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.
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CONFIGURATIONS

Tandem powered twin engine

TYPES OF SCRAPERS

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

TYPES OF SCRAPERS

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.
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CONFIGURATIONS

Auger
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TYPES OF SCRAPERS

Auger scrapers can self-load in difficult conditions, laminated rock or granular materials. The auger adds weight to the scraper during travel and it is more costly to own and operate than a conventional scraper.

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VOLUME OF A SCRAPER

The volumetric load of a scraper may be specified as either the struck or heaped capacity of the bowl expressed in cubic yards.

The struck capacity is the volume that a scraper would hold if the top of the material were struck off even at the top of the bowl.
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**BOWL**

The load-carrying part of a scraper.

**VOLUME OF A SCRAPER**

In specifying the *heaped capacity* of a scraper, manufacturers usually specify the slope of the material above the sides of the bowl with the designation SAE. The Society of Automotive Engineers (SAE) specifies a repose slope of 1:1 for scrapers.
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VOLUME OF A SCRAPER

- The SAE standard for other haul units and loader buckets is 2:1.
- Actual repose slope will vary with the type of material handled.
- The capacity of a scraper, expressed in cubic yards bank measure (bcy), can be approximated by multiplying the loose volume in the scraper by an appropriate swell factor.

Because of the compacting effect on the material in a push-loaded scraper, resulting from the pressure required to force additional material into the bowl, the swell is usually less than that for material dropped into a truck by a hoe or loader.
VOLUME OF A SCRAPER

- Tests indicate that the swell factors specified in tables should be increased by approximately 10% for material push-loaded into a scraper.

- When computing the bank measure volume for an elevating scraper, no correction is required for the factors specified by the tables.

SWELL FACTORS FOR DIFFERENT TYPES OF SOIL

Table 1

<table>
<thead>
<tr>
<th>Material</th>
<th>Bank weight</th>
<th>Loose weight</th>
<th>Percent swell</th>
<th>Swell factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb/cu yd</td>
<td>kg/m³</td>
<td>lb/cu yd</td>
<td>kg/m³</td>
</tr>
<tr>
<td>Clay, dry</td>
<td>2,700</td>
<td>1,600</td>
<td>2,000</td>
<td>1,185</td>
</tr>
<tr>
<td>Clay, wet</td>
<td>3,000</td>
<td>1,780</td>
<td>2,200</td>
<td>1,305</td>
</tr>
<tr>
<td>Earth, dry</td>
<td>2,800</td>
<td>1,660</td>
<td>2,240</td>
<td>1,325</td>
</tr>
<tr>
<td>Earth, wet</td>
<td>3,200</td>
<td>1,895</td>
<td>2,580</td>
<td>1,528</td>
</tr>
<tr>
<td>Earth and gravel</td>
<td>3,200</td>
<td>1,895</td>
<td>2,600</td>
<td>1,575</td>
</tr>
<tr>
<td>Gravel, dry</td>
<td>2,800</td>
<td>1,660</td>
<td>2,490</td>
<td>1,475</td>
</tr>
<tr>
<td>Gravel, wet</td>
<td>3,400</td>
<td>2,020</td>
<td>2,980</td>
<td>1,765</td>
</tr>
<tr>
<td>Limestone</td>
<td>4,400</td>
<td>2,610</td>
<td>2,750</td>
<td>1,630</td>
</tr>
<tr>
<td>Rock, well blasted</td>
<td>4,200</td>
<td>2,490</td>
<td>2,640</td>
<td>1,565</td>
</tr>
<tr>
<td>Sand, dry</td>
<td>2,600</td>
<td>1,542</td>
<td>2,260</td>
<td>1,340</td>
</tr>
<tr>
<td>Sand, wet</td>
<td>2,700</td>
<td>1,600</td>
<td>2,360</td>
<td>1,400</td>
</tr>
<tr>
<td>Shale</td>
<td>3,500</td>
<td>2,075</td>
<td>2,480</td>
<td>1,470</td>
</tr>
</tbody>
</table>
SWELL FACTORS FOR DIFFERENT TYPES OF SOIL

**Example**

If a push-loaded scraper hauls a heaped load measuring 22.5 cu yd and the swell factor from the previous table (Table 1) is 0.8, the calculated bank measure volume will be

\[ 22.5 \text{ cu yd} \times (0.8 \times 1.1) = 19.8 \text{ bcy} \]

Note: 10% increase in for swell factor

SCRAPER OPERATION

*A scraper is loaded* by lowering the front end of the bowl until the cutting edge, which is attached to and extends across the width of the bowl enters the ground. At the same time, the front apron is raised to provide an open slot through which the earth can flow into the bowl. As the scraper moves forward, a horizontal strip of material is forced into the bowl. This is continued until the bowl is filled, at which point the cutting edge is raised and the apron is lowered to prevent spillage during the haul.
The dumping operation consists of lowering the cutting edge to the desired height above the fill, raising the apron, and then forcing the material out by means of a movable ejector mounted at the rear of the bowl.

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.

SCRAPER SELECTION

Three main factors:

- Job size, volume of material to move and maneuver room.
- Scraper configuration.
- Job conditions, grades, rolling resistance and material type.
SCRAPER SELECTION

COST:
Cost must consider all hourly cost for the entire pusher-scraper fleet.

ECONOMIC ZONES OF APPLICATION

SEVERITY OF CONDITIONS

HAUL DISTANCE

TANDEM POWERED AND PUSH PULL

CONVENTIONAL

ELEVATING
The cycle time for a scraper is the time to load, haul, dump, turn, return, and turn back into position to pick up another load:

\[ T_s = \text{load}_t + \text{haul}_t + \text{dump}_t + \text{turn}_t + \text{return}_t + \text{turn}_t \]  

(1)
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WORK CYCLE

LOAD

HAUL

RETURN

DUMP

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CYCLE TIME FOR A SCRAPER

- Average load time for push-loader scrapers in common earth is 0.85 min.
- Both haul and return times depend on the distance traveled and the scraper speed.
CYCLE TIME FOR A SCRAPER

*Dump* times vary with scraper size but project conditions will affect the duration. Average values for dump time are presented in tables.

The average *turn* time in the cut is 0.30 min and on the fill the average time is 0.21 min.

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### Table 2. Scraper Dump Cycle Times (U.S. Department of Transportation, FHWA)

<table>
<thead>
<tr>
<th>Scraper Size (cu yd)</th>
<th>Single Engine (min)</th>
<th>Tandem-powered (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25</td>
<td>0.30</td>
<td>-</td>
</tr>
<tr>
<td>25 to 34</td>
<td>0.37</td>
<td>0.26</td>
</tr>
<tr>
<td>35 to 44</td>
<td>0.44</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Example 1

Calculate the total time required for a single-engine 31-cu-yd scraper to complete a 2,000-ft haul cycle.

\[ T_s = \text{load}_t + \text{haul}_t + \text{dump}_t + \text{turn}_t + \text{return}_t + \text{turn}_t \]

<table>
<thead>
<tr>
<th>Component</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>0.85</td>
</tr>
<tr>
<td>Haul</td>
<td>0.57</td>
</tr>
<tr>
<td>Dump</td>
<td>0.37</td>
</tr>
<tr>
<td>Turn</td>
<td>0.21</td>
</tr>
<tr>
<td>Return</td>
<td>0.28</td>
</tr>
<tr>
<td>Total Cycle Time</td>
<td>5.52 min</td>
</tr>
</tbody>
</table>

OPERATING EFFICIENCY AND PRODUCTION

If the scraper cycle time of 5.52 min (Example 1) could be maintained for a period of 60 min, the unit would make

\[ \frac{60}{5.52} = 10.9 \text{ trips per hour} \]
The volume of material hauled would equal the product of the number of trips and the average volume per load.

Reality is different from this perfect production. Delays occur on the job; machines break down; men stop for water, or machines cluster causing a queue in the cut for the pusher.

EFFICIENCY FACTOR

- 50 min-hr efficiency
Studies of scraper operations suggest that the average productive time is 69% of a perfect 60-min hour (excluding weather delays to the job).

The actual number of trips in the real world would be

\[ 10.9 \times 0.69 = 7.5 \text{ trips per work hour} \]

The estimator should always try to visualize the work site before applying a factor:

- **If the pit will not be congested** and if the dump area is wide open, a 55-min hour may be appropriate.
- **If the cut involves a tight area**, such as a ditch, the estimator should consider a 45-min hour.
PUSH TRACTORS REQUIRED

- If push-loaded tractor scrapers are to attain their volumetric capacities, they need the assistance of a push tractor during the loading operation.

- Push tractor assistance will reduce the loading-time duration, and thereby will reduce the total cycle time.

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PUSH TRACTORS REQUIRED

- When using push tractors, we should match the number of pushers with the number of scrapers available at a given time. If either the pusher or the scraper must wait for the other, operating efficiency is lowered and production costs are increased.
Caterpillar recommends calculating backtrack push-tractor cycle time, $T_p$, by the formula

$$T_p = 1.4L_t + 0.25 \quad (2)$$

where $L_t$ is the scraper load time (pusher contact time).

The formula is based on the concept that pusher cycle time is a function of four components:

- Load time of the scraper
- Boost time, time assisting the scraper out of the cut, 0.15 min.
- Maneuver time, 40% of load time.
- Positioning for contact time, 0.10 min.
The number of scrapers that a push tractor can serve is the ratio of the scraper cycle time to the pusher cycle time:

\[ N = \frac{T_s}{T_p} \]  

where \( N \) is the number of scrapers per one pusher.

Rolling resistance varies with haul-road conditions. A well maintained haul road permits faster travel speeds and reduces the costs of maintenance and repairs for the scrapers.
The following figure is from field study of scraper haul times:

- Shaded area represents the range of average travel times.
- Good haul roads are indicated by the lower boundary.
- Poor haul roads are indicated by the upper boundary.

Figure 1. Average Travel Times Single-powered Axle Scrapers, Capacity < 25 cy (U.S. Department of Transportation, FHWA)
Example 2

Based on the scraper specified in the following figures (Figures 4-8, 4-10, and 6-9 of the textbook), and for haul conditions as stated below, what is the probable production of the scraper?

Given that the total length of haul when moving from the cut to the fill is 4,000 ft as follows:

1,200 ft +4% grade
1,400 ft +2% grade
1,400 ft -2% grade

Soil: Clay 3,100 lb per bcy
Rolling Resistance 80 lb per ton

Assumptions:

average load time = 0.85 min
load of 96% of the capacity (Figure 2, or Figure 7.10 Textbook)

Example 2 (cont’d)

Figure 2 (for Example 2)
**Example 2 (cont’d)**

**Figure 3 (for Example 2)**

<table>
<thead>
<tr>
<th>Engine: flywheels power 450</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission: semiautomatic power shift, eight speeds</td>
</tr>
<tr>
<td>Capacity of scraper: Struck - 21 cu yd</td>
</tr>
<tr>
<td>Heaped - 31 cu yd</td>
</tr>
<tr>
<td>Weight distribution: Empty Drive axle - 67%</td>
</tr>
<tr>
<td>Rear axle - 33%</td>
</tr>
<tr>
<td>Loaded Drive axle - 53%</td>
</tr>
<tr>
<td>Rear axle - 47%</td>
</tr>
<tr>
<td>Operating weight: Empty - 96,880 lb(^1)</td>
</tr>
<tr>
<td>Rated load: Loaded - 75,000 lb</td>
</tr>
<tr>
<td>Top Speed: Loaded - 33 mph</td>
</tr>
</tbody>
</table>

1 Includes coolant, lubricants, full fuel tank, ROPS canopy, and operator.

**Figure 4 (for Example 2)**

<table>
<thead>
<tr>
<th>Gear weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load:</td>
</tr>
<tr>
<td>Speed:</td>
</tr>
</tbody>
</table>

1. 1st gear torque converter drive
2. 2nd gear torque converter drive
3. 3rd gear cluster drive
4. 4th gear cluster drive
5. 5th gear cluster drive
6. 6th gear cluster drive
7. 7th gear cluster drive
8. 8th gear cluster drive
9. Loaded 70,000 lb (31,800 kN)
Example 2 (cont’d)

Actual Load = 0.96 X 31 = 29.8 lcy

Swell Factor = 0.74,  clay (Table 1, or Table 4-1 in Textbook)

Load Volume in Bank Measure = 29.8 X (0.74 X 1.1) = 24.3 bcy

Weight of Load  = 24.3 (3,100) = 75,330 lb

Weight of Scraper (empty) = 96,880 lb  (see Figure 3)

Gross Weight = 172,210 lb

Rolling Resistance = \[
\frac{\text{Rolling Resistance in lb/ton}}{20 \text{ lb/ton}} = \frac{80}{20} = 4\%
\]
Example 2 (cont’d)

Table 3. Haul and Return Speeds

<table>
<thead>
<tr>
<th>Distance (ft)</th>
<th>Grade (%)</th>
<th>Total Resistance (%)</th>
<th>Speed (mph)</th>
<th>Travel Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haul (172,210 lb):</td>
<td>300 acceleration</td>
<td>4</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>900</td>
<td>4</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1,400</td>
<td>2</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>1,200</td>
<td>-2</td>
<td>2</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>200 deceleration</td>
<td>-2</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>3.40</td>
</tr>
<tr>
<td>Return (96,880 lb):</td>
<td>200 acceleration</td>
<td>2</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>1,200</td>
<td>2</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>1,400</td>
<td>-2</td>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>1,000</td>
<td>-4</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>200 deceleration</td>
<td>-4</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>1.93</td>
</tr>
</tbody>
</table>

Calculate the total time required for a single-engine 31-cu-yd scraper to complete a 4,000-ft haul cycle.

Load, = 0.85 min
Haul, = 3.40 min
Dump, = 0.37 31 cu yd (Table 2)
Turn, = 0.21 min @ fill
Return, = 1.93 min
Turn, = 0.30 min @ cut

Hence, Total Cycle Time = T = 7.06 min
Example 2 (cont’d)

Number of trips per 50 - min hour = \( \frac{50}{7.06} = 7.08 \) trips

Volume per scraper per 50 - min hour = 24.3(7.08) = 172 \( \frac{\text{bcy}}{\text{hr}} \)

Pusher time = \( T_p = 1.4L_t + 0.25 = 1.4(0.85) + 0.25 = 1.44 \) min

Number of Scrapers Required = \( \frac{T}{T_p} = \frac{7.06}{1.44} = 4.9 \approx 5 \) scrapers

Pusher Contacts per a 50 - min hour = \( \frac{50}{1.44} = 34.7 \) contacts

Production = 34.7 (24.3) = 843 \( \frac{\text{bcy}}{\text{hr}} \)

Example 2 (cont’d)

Alternatively,

Production = 172 \times 4.9 = 843 \( \frac{\text{bcy}}{\text{hr}} \)

If, mistakenly, the scraper had been thought to control, then

Production = 172 \times 5 = 860 \( \frac{\text{bcy}}{\text{hr}} \), this is wrong estimate.