King Fahd University of Petroleum & Minerals

College of Environmental Design

Construction Engineering & Management Department

CEM 530

Construction Equipment & Methods

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Scrapers

- **An earthmoving equipment designed to load, haul, and dump loose material.**

Scraper operating parts

Bowl

- The loading and carrying component of a scraper.
- It has a cutting edge that extends across the front bottom edge.
- The bowl is lowered for loading and raised during travel.

Scraper operating parts

Apron

- The front wall of the bowl.
- It is independent of the bowl.
- It is raised during loading and dumping operations to allow the soil to flow into or out of the bowl.
- It is lowered during hauling to prevent material spillage.

Scraper operating parts

Ejector

- It is the rear wall of the bowl.
- It is in the rear position during loading.
- During spreading, it is moved forward to discharge material in the bowl.

Scraper operation

Loading operation

- Lower the front end of the bowl until the cutting edge 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.

Scraper operation

Loading operation

- When the bowl is filled, the bowl is raised and the apron is lowered to prevent spillage during the haul.

- During the haul, the bowl should be kept just high enough to clear the ground.

Scraper operation

Dumping operation

- Lower the cutting edge to the desired height above the fill.

- Raise the apron.

- Force the material out by means of the ejector.

Scrapers

- Designed to load, haul, and dump loose material.
- Scrapers are available with loose-heaped capacities up to about 44 cy
- The greatest advantage of the scraper is its versatility.
- Scrapers can be used in a wide range of material types.
- Economical over a wide range of haul lengths and haul conditions.
- Self-loading so, if the loading machine in the spread experience a breakdown, it will not shut down the job.

Scrapers

- Scrapers are compromise between machines designed exclusively for either loading or hauling.
- They are not superior to function-specific equipment in either hauling or lauding.
- Loaders and excavators surpass scrapers in loading.
- Trucks surpass scrapers in hauling.

Scrapers

- Off-highway situations having hauls of less than a mile, a scraper's ability to both load and haul gives an advantage.

- The ability to deposit loads in layers of uniform thickness facilitates compaction operations.

Scraper types

Primarily classified according to the number of powered axles or by the method of loading. Machines include:

- **Pusher-loaded (conventional)**

  Single-powered axle.

  Tandem-powered axles.

- **Self-loading**

  Push-pull, tandem-powered axles.

  Elevating.

  Auger.

Pusher-loaded scraper

Single-powered axle scraper:

Comes with only one axle connected to the engine.

- **Has the potential for high travel speeds on favorable haul roads (about 33 mph when fully loaded).**

- **Scrapers at a disadvantage of individually providing the high tractive effort required for economical loading,**

- **Only about 50-55% of total loaded weight bears on the drive wheels.**

Pusher-loaded scraper

- For most soils, the coefficients of traction are low.
- It is necessary to supplement the loading power of these scrapers.
- The external source of loading power is usually a crawler pusher.
- Single-powered axle pusher-loaded scrapers become uneconomical when:

  Haul grades are greater than 5%.

  Return grades are greater than 12%

Pusher-loaded scraper

Tandem-powered axles scraper

Comes with two engines connected to two axles.

- **These scrapers normally require help loading.**
- **Tandem-powered units have an initial cost that is about 25% more than that for a single-powered axle scraper.**
- **Good for working at extremely adverse grades or soft ground conditions.**

Self-loading scrapers

Push-Pull scrapers.

- Two tandem-powered-axle units hooked to each other to assist one another during loading.
- The trailing scraper pushes the lead scraper as it loads.
- Then, the lead scraper pulls the trailing scraper to assist it in loading

Self-loading scrapers

Elevating scrapers

A completely self-contained loading and hauling scraper with a chain elevator that serves as the loading mechanism.

Loading operation

- **It is equipped with horizontal flights operated by two endless elevator chains, to which the ends of the flights are connected.**
- **As the scraper moves forward with its cutting edge digging into the earth, the flights rake the material upward into the bowl.**

Elevating scrapers

- The pulverizing action of the flights permits a complete filling of the bowl and enhances uniform spreading of the fill.

- Economical in short-haul situations where the ratio of haul time to load time remains low.

- Economical in dressing up utility works when shifting materials during fine-grading is needed.

- No pusher is required, so there is never a mismatch between pusher and the number of scrapers.

Auger scrapers

- A completely self-contained loading and hauling scraper with an auger that is located in the center of the bowl.
- The rotating auger lifts the material off the scraper cutting edge and carries it to the top of the load, creating a void that allows new material ti enter the bowl.
- This action reduces the cutting edge resistance, enabling the wheel-tractor scraper to continue moving through the cut.
- Eliminate dust clouds that were created by other scraper types.

Volume of a scraper

Loose capacity:

- **Struck capacity when material is stuck off even at the top of the bowl.**
- **Heaped capacity when material is at a repose slope of 1:1 above the sides of the bowel.**

Bank measure capacity:

- **Approximated by multiplying the loose volume by a swell factor.**
- **For push-loaded scrapers the swell factor is increased by 10% to account for the compaction during bowel loading.**

Volume of a scraper

Example:

A push-loaded scraper hauls a heaped load measuring 22.5 cy. The approximate swell factor is 0.8.

Calculate the bank measure volume of the payload

Solution:

B.M capacity = 22.5×0.8×1.1 = 19.8 cy

Scraper performance charts

- Manufacturers provide specifications and performance charts for each of their units.
- Charts are used to analyze the performance under various operating conditions.
- The following figures show the specifications and performance chart, and retarding performance chart for Caterpillar 631E single-powered axle scraper.

Scraper production cycle

Six operations are involved:

Loading

Haul travel

Dumping and spreading

Turning

Return travel

Turning and positioning

Scraper production cycle

- Loading time is fairly consistent (about one minute).
- Haul and return times depend on the distance traveled and scraper speed.
- Speed should be calculated for each segment of the route if the route has multiple grades and rolling resistance.
- To account for acceleration/deceleration time at pit and dump areas, a distance of 200 ft at a speed of 5 mph is appropriate.

Scraper production estimating

- **Systematic analysis of the scraper cycle under the existing conditions.**

- **Format to analyze scraper production:**

CAT 631E scraper, specifications in Table 7.1, and performance charts in Figs. 7.8, and 7.9

Haul route is of 4,000 ft with segments:
1,200 ft +4% grade
1,400 ft +2% grade
1,400 ft -2% grade

Soil is clay with unit weight is 3,000 lb per bcy

Scraper production estimating

Rolling resistance is 80 lb per ton or 4%.

A 50 min. per hour efficiency is used.

Loading time is on average 0.85 min. The expected load as in the load growth curve is 96% of heaped capacity.

Scraper production estimating

STEP 1: Weight

Empty weight (EVW) = 96,880 lb.

Load volume = 0.96 × 31 cy = 29.8 loose cy

Swell factor for clay (Table 4.3) = 0.74

Load volume = 29.8 × 0.74 × 1.1 = 24.3 bcy

Weight of load = 24.3 × 3,000 = 72,900 lb

Gross weight (GVW) = 169,780 lb

Scraper production estimating

STEP 2: Rolling resistance

Rolling resistance of 80 lb per ton or 4%.

STEP3: Grade resistance or assistance

1,200 ft	80 lb per ton	+4% grade
1,400 ft	40 lb per ton	+2% grade
1,400 ft	-40 lb per ton	-2% grade

STEP 4: Total resistance/assistance

To account for acceleration, 200 ft at the beginning of the first segment on both haul and return routes will be at a reduced speed.

Scraper production estimating

STEP 5: Total resistance/assistance

Scraper production estimating

STEP5: Travel speed

If total resistance is positive use performance chart, if negative use retarder chart.

Scraper production estimating

STEP 6: Travel time

Sum of times it takes the scraper to traverse each segment of the haul and return routes.

$$Travel\ \ time\,(\min .) = \frac{Segment\ \ dis\tan ce(\ ft\,)}{88 \times travel\ \ speed\ (mph\,)}$$

Scraper production estimating

STEP 7: Load time

Loading curve reveals that:

- **During the first 0.5 min. the scraper loads 85% of loads.**
- **During the next 0.5 min. it loads an additional 12%.**
- **The gain in volume during the last 0.4 min. is 3%.**

Scraper production estimating

STEP 7: Load time

Loading time affects production rate

Scraper production estimating

STEP 7: Load time

Economical loading time is a function of haul distance.

Loading time = 0.85 min.

Scraper production estimating

STEP 8: Dump time

The table shows that dump time depends on scraper type and capacity.

A 631 scraper, single-engine machine, with a rated heaped capacity of 31 cy, the dump time will be 0.37 min.

Scraper production estimating

STEP 9: Turning times

According to studies

The average turn time in the cut is 0.3 min.,

The average turn time in the fill is 0.21 min.

Turning time in the cut is higher since scrapers spot for pushers.

Scraper production estimating

STEP 10: Total cycle time

Step 6:	Travel time	5.03 min.
Step 7:	Load time	0.85 min.
Step 8:	Dump time	0.37 min.
Step 9:	Turn time fill	0.21 min.
	Turn time cut	0.30 min.
Step 10:	Total cycle time	6.76 min.

Scraper production estimating

STEP 11: Pusher cycle time

- **Pusher cycle time includes the time of pushing a scraper and time to move into position to load next scraper.**
- **Loading methods**

Back-track loading.

Chain loading.

Shuttle loading.

Scraper production estimating

Loading methods:

Scraper production estimating

STEP 11: Pusher cycle time

- Back-track loading offers the advantage of always being able to load in the direction of the haul.
- Chain loading can be used when the excavation is conducted in a long cut.
- Shuttle loading is used when scrapers can haul in opposite directions from the cut.

Scraper production estimating

STEP 11: Pusher cycle time

- The most common in the back-track
- The pusher cycle time is T_p:

$T_p = 1.4L_t + 0.25$

Where L_t is the scraper load time.

Tp = 1.4(0.85) + 0.25 = 1.44 min.

Scraper production estimating

STEP 12: Balanced fleet

- The number of pushers must be matched with the number of scrapers.

$$N = \frac{T_s}{T_p}$$

Where N is the number of scrapers served by one pusher, Ts is the cycle time of the scraper.

$$N = \frac{6.76 \ \text{min}}{1.44 \ \text{min}} = 4.7$$

Economics of using either four or five scrapers should be investigated.

Scraper production estimating

STEP 13: Efficiency

- The average number of minutes per hour that the machine will operate.

- A 50-min hour average would yield a 0.83 (50/60) efficiency factor.

- For the example, a 50-min hour efficiency factor has been assumed.

Scraper production estimating

STEP 14:Production
If four scrapers are used, (scrapers are controlling)

$$\text{Production} = \frac{50 \quad \text{min}/\ hr}{6.76 \quad \text{min}} \times 4 \times 24.3 bcy = 719\, bcy\ /\ hr$$

If five scrapers are used, (pusher is controlling)

$$\text{Production} = \frac{50 \quad \text{min}/\ hr}{1.44 \quad \text{min}} \times 24.3 bcy = 844\, bcy\ /\ hr$$

Scraper production estimating

STEP 15:Cost

Cost for a four-scraper spread

4 scrapers @ $89/hr + 1 pusher @ $105/hr = $461/hr
4 operators @ $12/hr + 1 operator @ $20/hr = $68/hr
Total $529/hr

Cost for a five-scraper spread

5 scrapers @ $89/hr + 1 pusher @ $105/hr = $550/hr
5 operators @ $12/hr + 1 operator @ $20/hr = $80/hr
Total $630/hr

Scraper production estimating

STEP 15:Cost

Unit cost to move the material using a four-scraper spread

$$\frac{\$529 \ / \ hr}{719 \ bcy \ / \ hr} = \$0.736 \ / \ bcy$$

Unit cost to move the material using a five-scraper spread

$$\frac{\$630 \ / \ hr}{844 \ bcy \ / \ hr} = \$0.746 \ / \ bcy$$

Scraper production estimating

STEP 15:Cost

Final decision is based on:
-Total quantity of materials.
- Mobilization costs of equipment.
- Overhead costs.

Scraper selection

- Distances between 500-3000ft are typical for scrapers.
- The selected type of scraper depends on the type of soil