CHAPTER

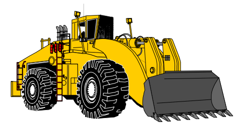
Construction Planning, Equipment, and Methods

Sixth Edition

6

DOZERS

A. J. Clark School of Engineering •Department of Civil and Environmental Engineering



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ENCE 420 – Construction Equipment and Methods

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DOZERS

DOZERS

DOZERS USES

- 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.

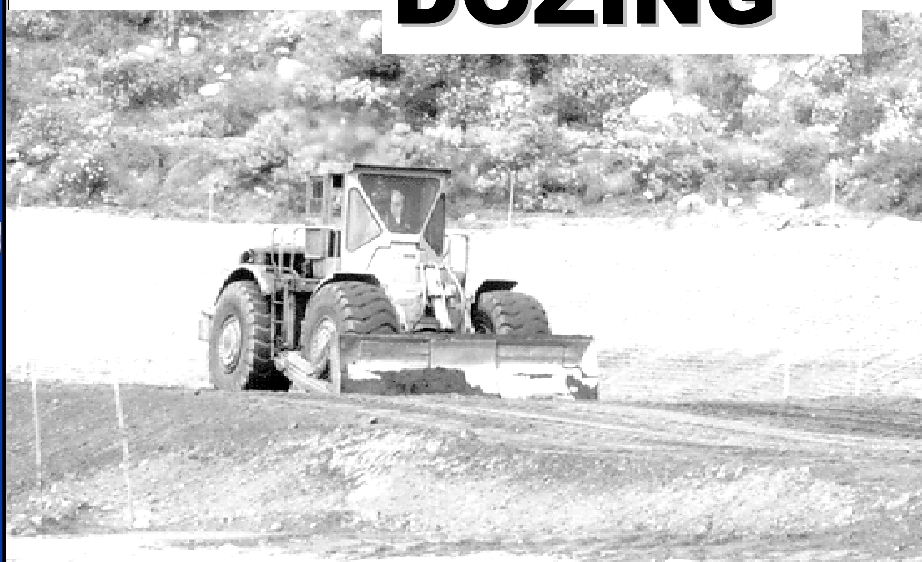
DOZERS USES

- 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.

DOZERS USES

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

DOZING



Pushing material

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

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.

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

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

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

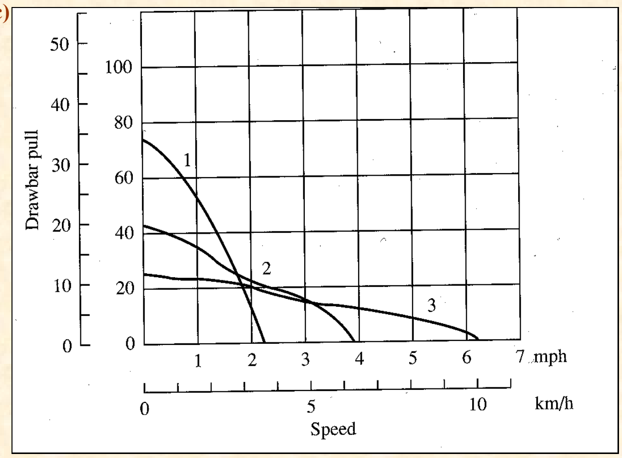
Approximate operating weight (lb)	18,300			32,000			47,000		
Flywweel (hp)	93			160			235		
Drawbar (hp)	75			128			187		
Ratio (lb/hp)	197			200			200		
Performance Data									
	Speed		Drawbar pull	Speed		Drawbar pull	Speed		Drawbar pull
	mph	fpm	(lb)	mph	fpm	(lb)	mph	fpm	(lb)
Gear, forward									
First	1.7	150	17,240	1.5	132	32,500	1.5	132	44,400
Second	2.7	238	10,470	2.2	193	22,700	1.9	132	34,500
Third	3.7	326	7,090	3.1	272	15,000	2.7	238	24,100
Fourth	5.2	458	4,670	4.6	405	9,390	3.5	307	17,750
Fifth	6.8	598	3,190	5.9	518	6,770	4.6	405	13,000
Six							6.3	555	8,450
Gear, reverse									
First	2.1	185	13,670	1.8	158	28,470	1.5	132	43,700
Second	3.3	290	8,180	2.5	220	18,935	2.0	176	33,900
Third	4.6	405	5,440	3.7	325	12,390	2.7	238	23,700
Fourth	6.4	563	3,480	5.4	475	7,620	3.6	317	17,400
Fifth							4.6	405	12,700
Six							6.4	563	8,250

Note: Usable pull will depend on weight and traction of fully equipped tractor

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)	32,2000	17,740
Engine (hp)	275	180
Ratio (lb/hp)	117	198
Tire Sizes (in)	24 X 29	21 X 25

Performance Data

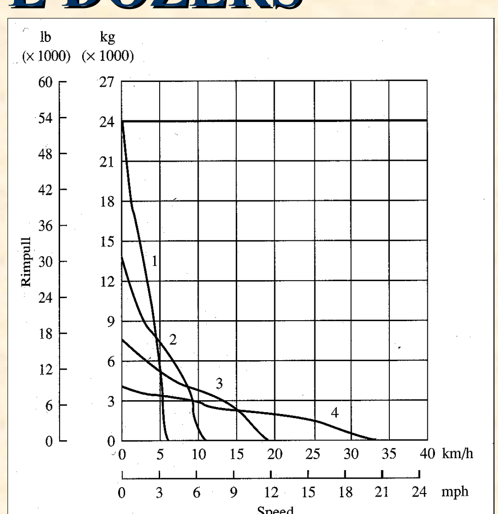
Speed Gear	Speed		Rimpull	Speed		Rimpull
	mph	Km/h	(lb)	mph	Km/h	(lb)
First	2.16	3.48	25,000	3.41	5.50	15,850
Second	4.18	6.73	17,100	7.25	11.70	7,450
Third	7.15	11.50	10,050	12.63	20.35	4,280
Fourth	12.18	19.60	5,880	22.28	35.90	2,420
Fifth	20.00	32.20	3,580	35.03	56.35	1,540
Reverse	2.79	4.49	25,000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

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

PERFORMANCE DATA - WHEEL-TYPE DOZERS

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)

COMPARISON OF PERFORMANCE

Table 2

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

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.

PUSHING MATERIALS

- General Information
  - ✓**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.**

PUSHING MATERIALS

- General Information
  - ✓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 us
    - **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.

PUSHING MATERIALS

- 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.

Dozer's Blade

Dozer's Blade

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

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.

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.

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.

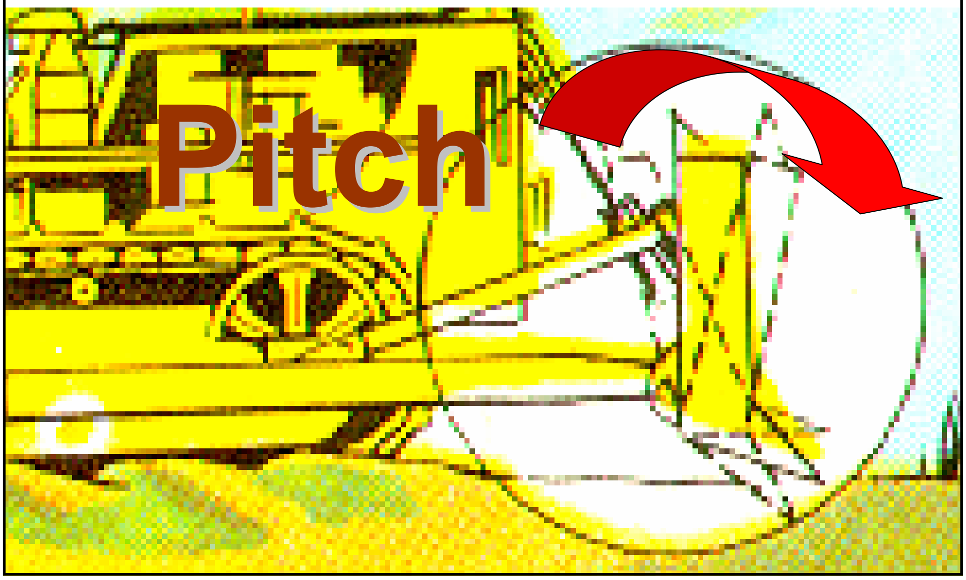
Blade Adjustments

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

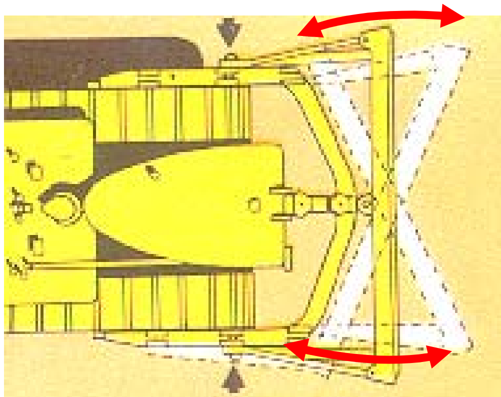


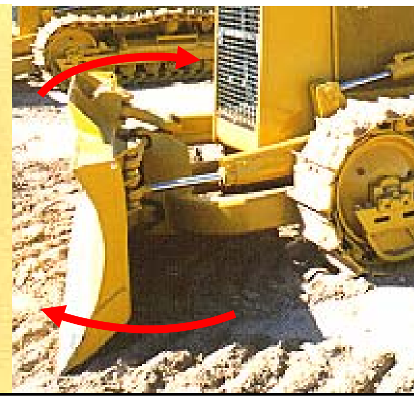
BLADE ADJUSTMENTS

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"

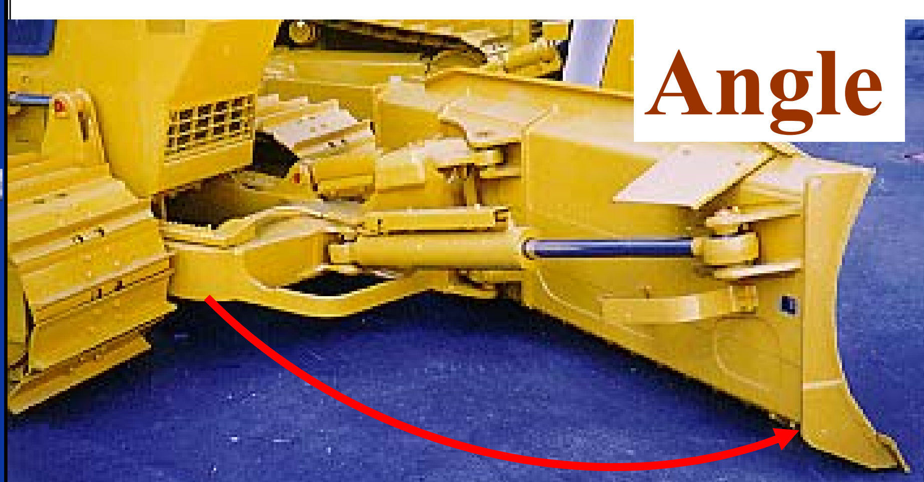
Blade Adjustments

Angle





Blade Adjustments



Dozer Operation

GPS and computer graphics

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.

DOZER PRODUCTION ESTIMATING

- 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

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

DOZER PRODUCTION ESTIMATING

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

$$V_s = 0.8\, W H^2$$
$$V_u = V_s + ZH(W - Z) \tan x^{o}$$

Where

V_s	=	capacity of straight or angle blade, in lcy
V_u	=	capacity of universal blade, in lcy
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

FIELD MEASUREMENT

- 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.

FIELD MEASUREMENT

- ✓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.

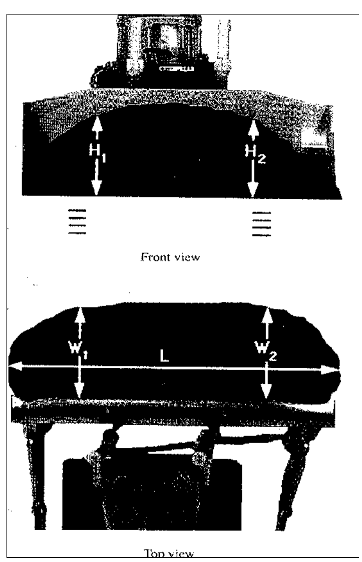
FIELD MEASUREMENT

✓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

$$\boxed{\textbf{Blade load (lcy)} = \textbf{0.0139}\ H\ W\ L}$$

FIELD MEASUREMENT



Example 2

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

$$H = \frac{4.9 + 5.2}{2} = 5.05 \text{ ft}, \qquad W = \frac{6.9 + 7.0}{2} = 6.95$$

$$\text{Blade Load (lcy)} = 0.0139HWL = 0.0139(5.05)(6.95)(12.6) = 6.15 \text{ lcy}$$

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.**

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

CYCLE TIME

- 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?

$$\text{Blade load} = 6.15 \text{ lcy (Example 2)}$$

$$\text{Push Time}: \quad 2 \text{ mph (sandy material)}$$

$$\text{Push Time} = \frac{90 \text{ ft}}{5280 \dfrac{\text{ft}}{\text{mi}}} \times \frac{1}{2 \dfrac{\text{mi}}{\text{hr}}} \times 60 \frac{\text{min}}{\text{hr}} = 0.51 \text{ min}$$

Example 3 (cont'd)

$$\text{Return Time: (see performance chart)}$$

$$\text{Maximum speed} = 4 \text{ mph (second gear, less than 100 ft)}$$

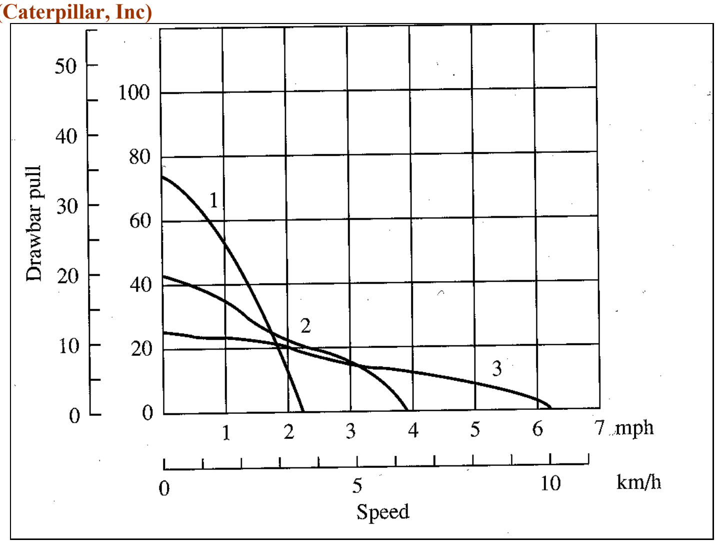
$$\text{Return Time} = \frac{90 \text{ ft}}{5280 \dfrac{\text{ft}}{\text{mi}}} \times \frac{1}{4 \dfrac{\text{mi}}{\text{hr}}} \times 60 \frac{\text{min}}{\text{hr}} = 0.26 \text{ min}$$

$$\text{Adjusted Return Time} = 0.26 + 0.05 = 0.31 \text{ min}$$

$$\text{Production} = \frac{60 \text{ min} \times 6.15 \text{ lcy}}{0.51 \text{ min} + 0.31 \text{ min} + 0.05} = 424 \frac{\text{lcy}}{\text{hr}}$$

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)

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

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

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

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 as a rule-of thumb formula for a power-shift crawler tractor:**

PRODUCTION FORMULAS

International Harvest (IH) Formula

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

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 lcy production which can be expected for this operation.

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

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

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

- 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 CURVES

- 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.

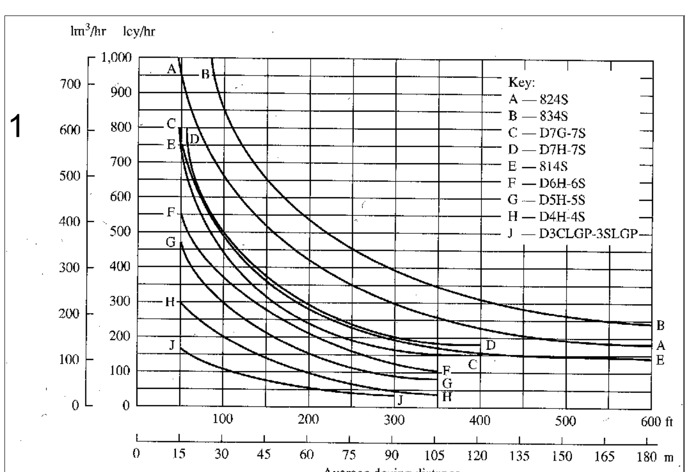
PRODUCTION CURVES

- Ideal conditions (cont'd)
  - ✓Coefficient of traction:
    - Track machines, 0.5 or better
    - Wheel machines, 0.4 or better
  - ✓Hydraulic-controlled blades

PRODUCTION CURVES

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

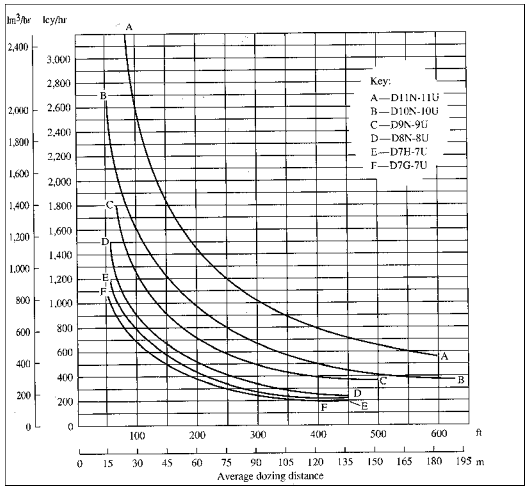
Figure 1



PRODUCTION CURVES

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

Figure 2



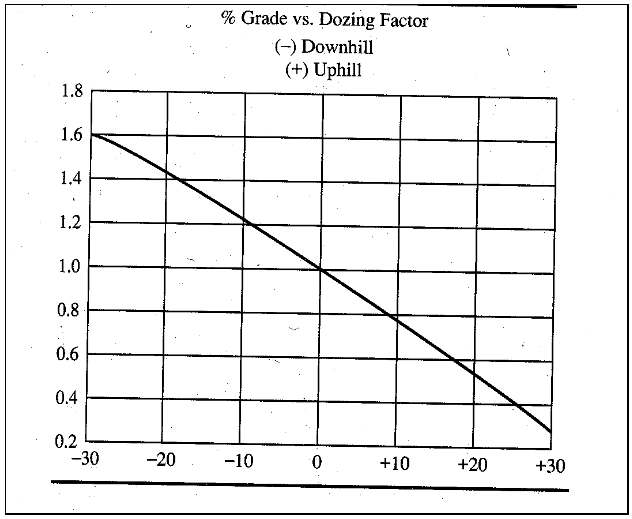
CORRECTION FACTORS FOR DOZER PRODUCTION

Table 1

	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

Figure 3



CALCULATION OF PRODUCTION RATE

- 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

$$\text{Production (lcy)} = \text{max production from curve} \times \text{total correction factor}$$

where

total factor = 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 108 pcf 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 (-10^0)	1.24

Material Weight Correction:
γ_B =108 pcf = 108 X27=2,916 lb/bcy
Swell = 12%, therefore, 2916/ 1.12 = 2604 lb/lcy
Standard Condition is 2,300 lb/lcy
hence,

Material Weight Correction = (2300 / 2604) 0.88

Example 6 (cont'd)

Total Correction = 0.75 X 0.80 X 1.20 X 0.83 X 1.24 X 0.88 = 0.652

$$\text{Production (lcy)} = \text{max production from curve} \times \text{total correction factor}$$

$$\text{Production} = 170\,\frac{\text{lcy}}{\text{hr}} \times 0.652 = 111\,\frac{\text{lcy}}{\text{hr}} = \frac{111}{1.12} = 99\,\frac{\text{bcy}}{\text{hr}}$$

Cost:

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

Total Cost =$43.35 per hour

$$\text{Direct Production Cost} = \frac{43.35}{99} = \$0.44 \text{ per bcy}$$

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 & 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.

Clearing

Clearing

LAND-CLEARING OPERATIONS

- 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:

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 are used for removing roots.

Rakes are used for removing roots.

Rakes

LAND-CLEARING PRODUCTION ESTIMATING

- 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.

LAND-CLEARING PRODUCTION ESTIMATING

- **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.**

LAND-CLEARING PRODUCTION ESTIMATING

- 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:

$$\text{Production (acre/hr)} = \frac{\text{width of cut (ft)} \times \text{speed (mph)} \times 5280\text{(ft/mi)} \times E}{43{,}560\ (\text{ft}^3/\text{acre})}$$

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

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

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?

$$\text{Production (acre/hr)} = \frac{\text{width of cut (ft)} \times \text{speed (mph)}}{10} = \frac{8 \times 0.9}{10} = 0.72\,\frac{\text{acre}}{\text{hr}}$$

$$\text{Time to knock down vegetation} = \frac{12\text{ acre}}{0.72\text{ acre/hr}} = 16.7\text{ hours}$$

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.

Ripping

Ripping

RIPPING ROCK

- 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

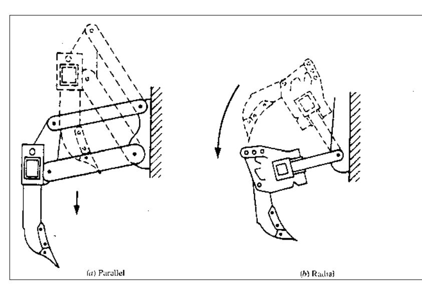


Figure 4

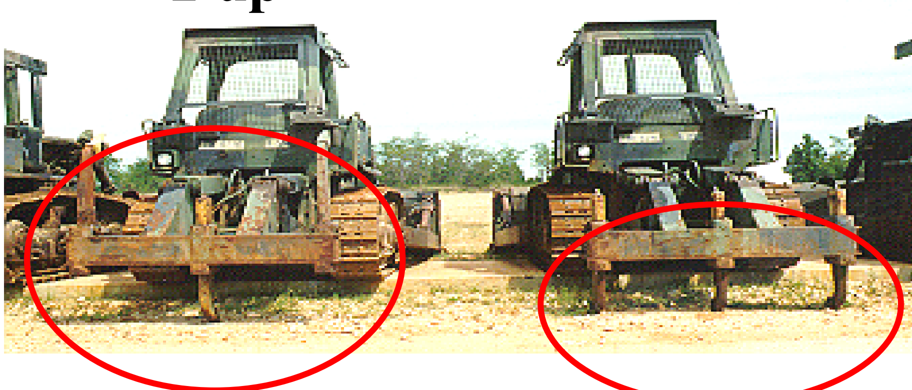
Rear mounted ripper

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 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.

RIPPABILITY OF ROCK

- ***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 are used to determine 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

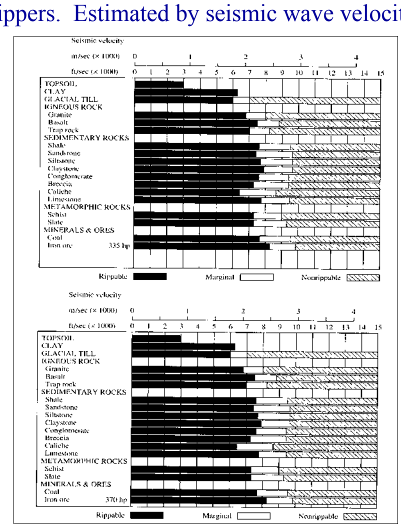
RIPPABILITY OF ROCK

- 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.)

Figure 5



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.

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

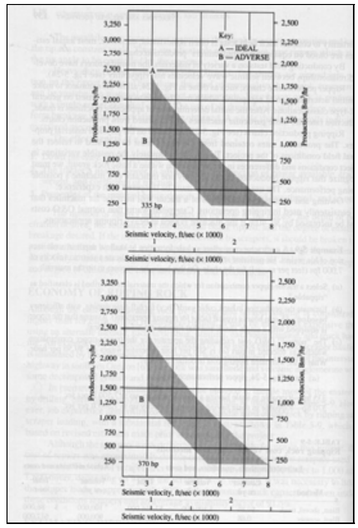
- Ripper performance charts allow the estimator to make an initial determination of equipment which may be able to perform based off general rock-type classifications. After the initial determination of applicable machines is made, production rates for those particular machines are calculated front production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

ESTIMATING RIPPING PRODUCTION

- Ripping production charts are based on the physical material properties. The production rates obtained from the charts must be adjusted to reflect tile actual field conditions of the project.
- According to Caterpillar, O&O cost should be increased by 30-40 %

ESTIMATING RIPPING PRODUCTION

Figure 6



Example 8

A contractor encounter 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 450min 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

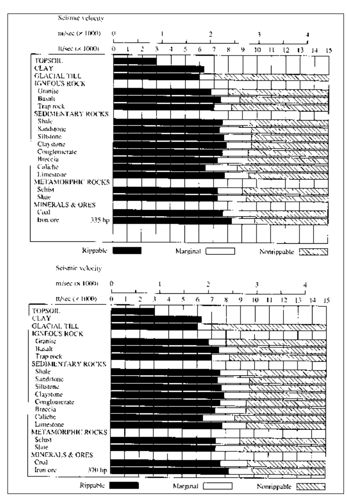
Ideal production 370-hp tractor = 560 bcy/hr

Adjusted production = 560 X (45/60) = 420 bcy/hr

Example 8 (cont'd)

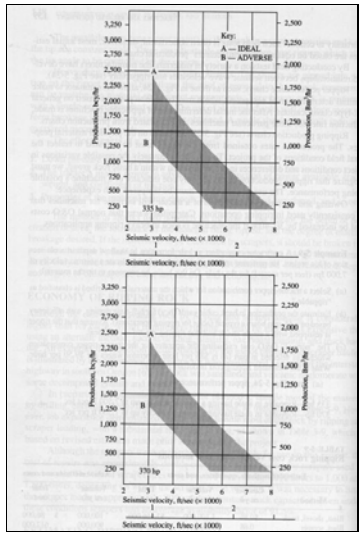
Ripper Performance for Caterpillar 335 and 370 HP Crawler Tractors with Multi and or Single-shank Rippers. Estimated by seismic wave velocities (Caterpillar Inc.)

Figure 5



Example 8 (cont'd)

Figure 6



Example 8 (cont'd)

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

$86 X 1.35 =$116.10 per hour

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

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