ADDIS ABABA UNIVERSITY

AAiT, SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

CENG 5213: CONSTRUCTION EQUIPMENT

CHAPTER-2

CONSTRUCTION EQUIPMENT AND PLANTS

PART I- PRODUCTIVITY OF EARTH WORK EQUIPMENTS

CONTENTS

- ***Determination of Production of an Equipment***
- ***Productivity of Shovel Family and Excavator***
  - *General*
  - *Productivity of Face Shovel*
  - *Productivity of Dragline*
  - *Productivity of Clamshell*
  - *Productivity of Hoe/Excavator*

- ***Productivity of Heavy Earth Moving and Grading Equipments***
  - *Productivity of Loader*
  - *Productivity of Dozer*
  - *Productivity of Scraper*
  - *Productivity of Grader*

1. Determination of Production of an Equipment

Terminologies

- ***Peak Productivity***: is the ***theoretical productivity*** governed by design limitations only.

$$Q_p = V x\, f_s x\, f_f$$

Where: Q_p = *Peak Productivity*

V = *Volume carried/ bucket capacity*

f_s = *Bank Volume/loose volume*

f_f = *Bucket fill factor*

- ***Actual Productivity***: Productivity of an equipment after taking care of ***effective working hours*** and ***job management factor*** on the peak productivity.

1. Determination of Production of an Equipment

Terminologies

- *Actual Productivity*:

$$Q_a = Q_p \times f_w \times f_j$$

Where: Q_a = *Actual Productivity*

Q_p = *Peak Productivity*

f_w = *Factor to take care of effective working hours*

f_j= *Factors to take care of the management conditions*

- The computation of the actual production of construction equipment is complex. But through idealization, approximation and in general simplification, one can arrive at an optimum result.

CONSTRUCTION EQUIPMENTS

1. Determination of Production of an Equipment

- Equipments can be broadly classified into two based on equipment productivity concepts:
  - ***Cyclic Operating*** or
  - ***Continuously Operating***.
- ***Cyclic operating equipments***: These are machines which are intentionally or unintentionally influenced by their operators. The actual productivity can be computed from:

$$\boxed{Q_a = V_n x\, n_o x\, \eta}$$

Where: Q_a = Actual Productivity (Bm^3/hr)

V_n = Volume per cycle (Bm^3)

η= Efficiency of the equipment

n_o = number of cycle /Unit Time (usually Time in hours), if T_o is theoretical cycle time $\quad n_o = \dfrac{60}{T_o}$

1. Determination of Production of an Equipment

- ***Continuously operating equipments***: These are machines that continuously operate, like pumps, conveyor belts, etc. For these kinds of machines:

$$Q_a = V_n \times a \times n_o \times 60 \times \eta$$

Where: Q_a = *Actual Productivity* (Bm^3/hr)

V_n = *Volume per bucket*

a = *Number of buckets*

η = *Efficiency of the equipment*

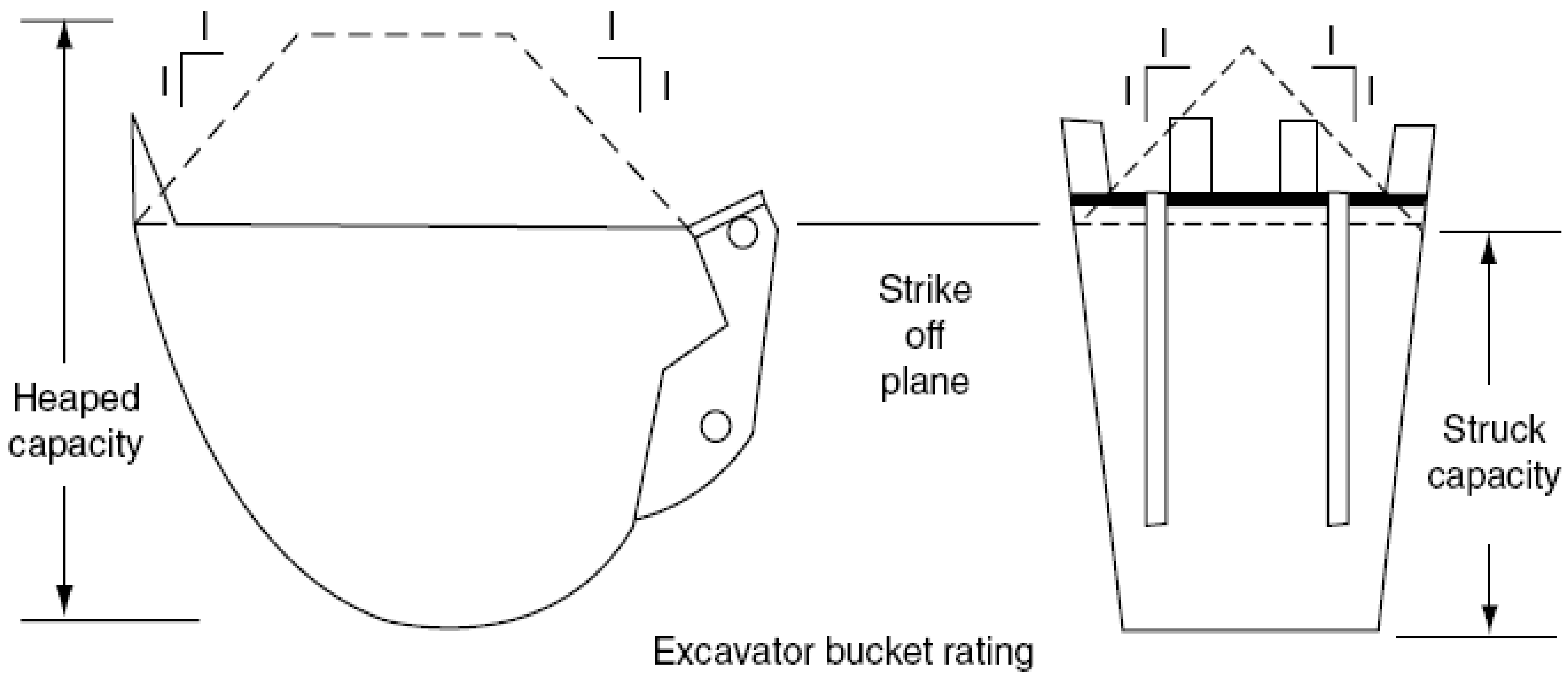
n_o = *number of cycle /Unit Time (usually Time in hours)*

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

- ***Q_a*** - Shovel family is dependent on the actual ***volume per cycle*** and ***the cycle time***.
- ***V_n*** – Volume per bucket.
  - ***Plate line capacity*** is the bucket volume contained within the bucket when following ***the outline of the bucket sides***.
  - ***Struck capacity*** is the bucket capacity when the load is ***struck off flush*** with the bucket sides.
  - ***Water line capacity*** assumes a level of material flush with the lowest edge of the bucket (i.e., the material level corresponds to the ***water level*** that would result if the bucket were filled with water).
  - ***Heaped volume*** is the ***maximum volume*** that can be placed in the bucket ***without spillage*** based on a specified angle of repose for the material in the bucket.

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

- Figure – Struck and Heaped Bucket Capacity (Caterpillar Inc.)



2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

Machine	Rated Bucket Capacity
Backhoe and shovel	
Cable	Struck Volume
Hydraulic	Heaped Volume at 1:1 angle of repose
Clamshell	Plate line or water line volume
Dragline	90% of struck volume
Loader	Heaped volume at 2:1 angle of repose

Rated bucket capacity for different machine

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

- Commonly - ***Bucket ratings*** for the cable shovel, dragline, and cable backhoe are based on ***struck volume***:
  - Thus it is often assumed that the heaping of the buckets will compensate for the swell of the soil. That is, a ***5 m^3 bucket*** would be assumed to actually hold ***5 Bank m^3*** of material.
  - A better estimate of the volume of material in one bucket load will be obtained if the nominal bucket volume is ***multiplied by a bucket fill factor*** or ***bucket efficiency factor***.
  - If desired, the bucket load may be converted to ***bank volume by multiplying its loose volume by the soil's load factor***. Refer Example 2 – 1.

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

Example 2.1

Estimate the actual bucket load in bank cubic meters for a loader bucket whose heaped capacity is 3.82 m^3. The soil's bucket fill factor is 0.9 and its load factor is 0.8.

Solution

Bucket load = Bucket Volume x B.F.F x $f_L = 3.82Lm^3 x0.9x0.8 = 2.75Bm^3$

Material	Bucket Fill Factor
Common Earth, loam	0.80 – 1.10
Sand and Gravel	0.90 – 1.00
Hard Clay	0.65 – 0.95
Wet Clay	0.50 – 0.90
Rock well blasted	0.70 – 0.90
Rock, poorly blasted	0.40 – 0.70

Table 2 – 2- Bucket Fill Factors for Excavators

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

- ***CYCLE TIME (n_o)*** = Number of cycle /Unit Time = 60/T_c ,
  - Where T_c – cycle Time in minutes

$$T_C = T_F + T_V$$

Where

- T_V =***Variable Cycle Time*** - Variable time represents those components of cycle time related with ***travel time***.
  - ***Variable Cycle time*** is the time required to excavate and travel to load and travel to return to original position after loading.
- T_F = ***Fixed Cycle Time*** - Fixed time represents those components of cycle time ***other than travel time***.
  - ***Fixed Cycle time*** represents the time required to maneuver, change gears, start loading, and dump.

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

A. Productivity of Face Shovel (Power Shovel)

- The production capacity or output of a shovel is expressed in cubic meter per hour.
- The output varies for various type of materials to be digged. The following are the main factors which affect the out put of face shovel:
    - Nature of the soil
    - Height or Depth of cut
    - Type of material
    - Angle of swing
    - Capacity of hauling unit and continuity of work
    - Mechanical condition of shovel
    - Efficiency of the operator
    - Relative positions of the shovel and hauling unit
    - Type of machine such as crawler or wheeled

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

A. Productivity of Face Shovel (Power Shovel)

- Output of a shovel can be calculated using the following formula:

  Hourly production (m^3/hr) = q x (3600/C) x Efficiency

  Where: q = production in m^3 per cycle

  = Heaped capacity x Swell factor x Bucket factor.

- Manufacturer of the equipment used to provide a graph b/n bucket size Vs Production/hr.
- Since this gives production in ideal conditions, the figures thus obtained should be scaled down to expected production by using ***efficiency factor*** and ***bucket fill factor***.

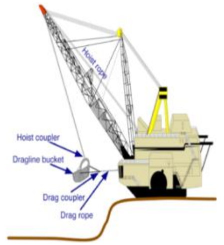
Excavation Efficiency Factor	
Sand, gravel, common earth	60%
Clay	50%
Blasted rock	40%

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

A. Productivity of Face Shovel (Power Shovel)

Bucket Factor	
Sand, gravel, common earth	90%
Well blasted rock	70%
Poorly blasted rock	50%

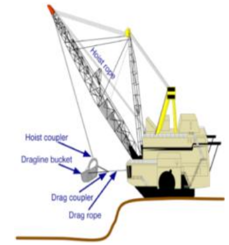
- The above figures are for crawler type of tractor shovel, however for wheel shovels, bucket factor is about 10% lesser than those mentioned above.



2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

B. Productivity of Dragline

- Output or performance of dragline depends on the following factors:
  - Nature of the soil.
  - Depth of cut.
  - Angle of swing.
  - Capacity of hauling units, if employed.
  - Mechanical condition of the dragline.
  - Efficiency and skill of the operator.
  - Management conditions.
  - Size and type of bucket.
  - Working cycle



2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

B. Productivity of Dragline

- Data are taken from “Liebher’s Technical Hand Book Earth moving Product line”.

Drag Line Production = Dragline Capacity (m^3) x C x f

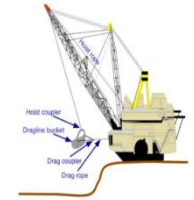
Where, C = Theoretical Cycles/hr = 120 Cycles/hr

f = Correcting factor

$$= f_1 \times f_2 \times f_3 \times f_4 \times f_5 \times f_6 \times f_7$$

f_2 – Digging factor				
Boom Length (m)	12	18	24	30
Digging factor, f_2	0.86	0.79	0.72	0.65

f_3 – Hoist factor				
Boom Length (m)	12	18	24	30
Hoist factor, f_3	0.95	0.92	0.90	0.87



2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

B. Productivity of Dragline

f_1 - Fill factor		
	Class	Fill factor
1	Sand or fine gravel a) Dry b) Damp c) Wet	 1.1 to 1.2 1.0 to 1.1 0.9 to 0.8
2	Clay a) Sandy clay, dry b) Cohesive, dry c) Very cohesive, hard	 0.95 to 1.0 0.9 to 0.95 0.88 to 0.9
3	Earth with sand or gravel, dry	0.85 to 0.88
4	Top Soil a) Sandy clay b) Clay damp	 0.82 to 0.85 0.80 to 0.82
5	Clay with sand or gravel, damp	0.75 to 0.80
6	Slatelike rock, gravel	0.72 to 0.75
7	Gravel with clay, hard	0.70 to 0.72
8	Clay with large size gravel, damp	0.68 to 0.70

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

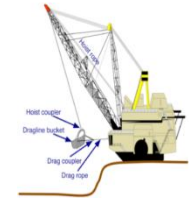
B. Productivity of Dragline

f_4 – Swing factor (Simultaneous swing and hoist)			
Angle of Swing (deg)	90°	120°	180°
Swing factor, f_4	0.98	0.95	0.91

f_5 – Loading factor			
Method of dumping	Truck	Hopper	Stock pile
Loading factor, f_5	0.96	0.95	1.0

f_6 – Job efficiency factor			
Actual working time	60 min/hr	50 min/hr	40 min/hr
Job efficiency factor, f_6	1.0	0.83	0.67

f_7 – Operator factor			
Operator	Experienced	Average	Beginner
Operator factor, f_7	1.0	0.95	0.85



2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

B. Productivity of Dragline

Example 2.2

- An experienced operator has to excavate 'wet gravel' with a dragline capacity of 2.3 m^3. The boom length is 18m and the swing angle will be 120 degrees. The material is dumped onto stockpile. Actual working time is 50 min per hour.

Solution

Drag line production = Bucket capacity x C x f.

where C = theoretical cycles/hr = 120 cycles/hr

$= 2.3 \times 120 \times f$

where $f = f_1 \times f_2 \times f_3 \times f_4 \times f_5 \times f_6 \times f_7 = 0.8 \times 0.79 \times 0.92 \times 0.95 \times 1.0 \times 0.83 \times 1.0$

$= 0.4588$

Therefore, Drag line production $= 2.3 \times 120 \times 0.4588$

$= 126.4\ m^3/hr$

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

C. Productivity of Clamshell

- Data are taken from "Liebher's Technical Hand Book Earth moving Product line".

  Clamshell Production (m³/hr)= Clamshell Capacity (m³) x C x f

  Where, C = *Theoretical Cycles/hr = 120 Cycles/hr*

  f = *Correcting factor*

  $= f_1 \times f_2 \times f_3 \times f_4 \times f_5 \times f_6 \times f_7$

Correction factors

- f_1 – Fill factor
  - Same as those for dragline.

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

C. Productivity of Clamshell

f_2 – Digging factor					
Clamshell capacity (m^3)	1	2	3	4	5
Digging factor, f_2 =	0.98	0.97	0.96	0.96	0.95

f_3 – Hoist factor (considering average rope speed of 50m/min)				
Digging depth (m)	5	10	15	20
Hoist factor, f_3 =	0.88	0.76	0.64	0.52

f_4 – Swing factor				
Swing Angle (deg)	60	90	120	180
Swing factor, f_4=	1.2	1.0	0.98	0.90

f_5 – Dump factor			
Method of dumping	Truck	Hopper	Stock pile
Dump factor, f_5 =	0.90	0.95	1.0

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

C. Productivity of Clamshell

f_6 – Job efficiency factor			
Actual working time	60 min/hr	50 min/hr	40 min/hr
Job efficiency factor, f_6 =	1.0	0.83	0.67

f_7 – Operator factor			
Operator	Experienced	Average	Beginner
Operator factor, f_7 =	1.0	0.95	0.85

Example 2.3

- An average operator has to excavate 'damp sand' with a clamshell of 2.0 m^3. The digging depth is 10m and the swing angle will be 120 degrees. The sand is added into trucks and actual working time is 50 min/hr.

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

C. Productivity of Clamshell

Solution

Clamshell production = Clamshell capacity x C x f.

where C = theoretical cycles/hr

$= 2.0 \times 120 \times f$

where, $f = f_1 \times f_2 \times f_3 \times f_4 \times f_5 \times f_6 \times f_7$

$= 1.0 \times 0.97 \times 0.76 \times 0.98 \times 0.9 \times 0.83 \times 0.95$

$= 0.5127$

Therefore, Clamshell Production $= 2.0 \times 120 \times 0.5127$

$= 123.0\ m^3/hr$

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

- Steps for estimating production of Excavator/hoe:
  - ***Step-1***: Obtain the ***heaped bucket load*** volume (in Lm^3) from the manufacturers' data sheet.
    - Heaped bucket capacity ratings for Excavator buckets assume a 1:1 material angle of repose
  - ***Step-2***: ***Material Type***
  - ***Step-3***: Apply a ***bucket fill factor*** based on the type of machine and the class of material being excavated. Refer Table D-1.

Table D-1 Fill factor for hydraulic Hoe (Caterpillar Inc.)	
Moist loam/ sandy clay	100-110%
Sand and gravel	95-100%
Rock-poorly blasted	40-50%
Rock-well blasted	60-75%
Hard, tough clay	80-90%

Construction Equipments

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

- Steps for estimating production of Excavator/hoe:
  - ***Step-4***: Estimate ***cycle time*** (load, swing, dump and swing empty). Refer Table D-2.
    - Swing is influenced by job conditions such as ***obstructions*** and ***clearances***.

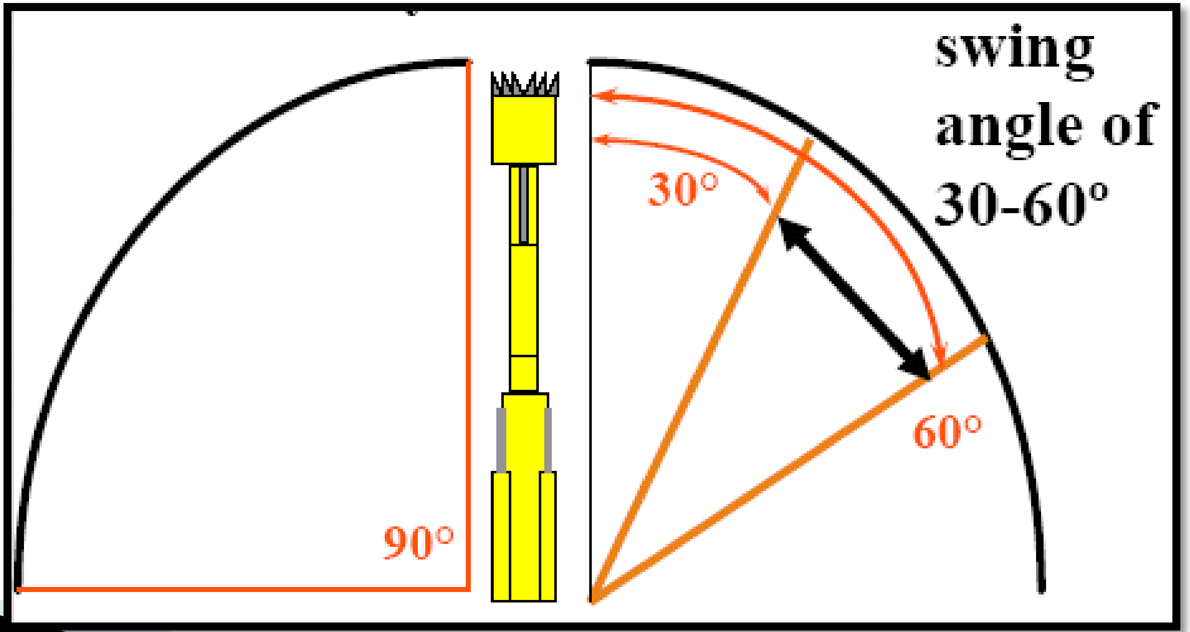
Table D-2 Excavation Cycle times for hydraulic crawler hoes under average condition

Bucket Size (cy)	Load Bucket (sec)	Swing Loaded (Sec)	Dump Bucket (Sec)	Swing empty (sec)	Total cycle (sec)
<1	5	4	2	3	14
1-1 ½	6	4	2	3	15
2-2 ½	6	4	3	4	17
3	7	5	4	4	20
3 ½	7	6	4	5	22
4	7	6	4	5	22
5	7	7	4	6	24

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

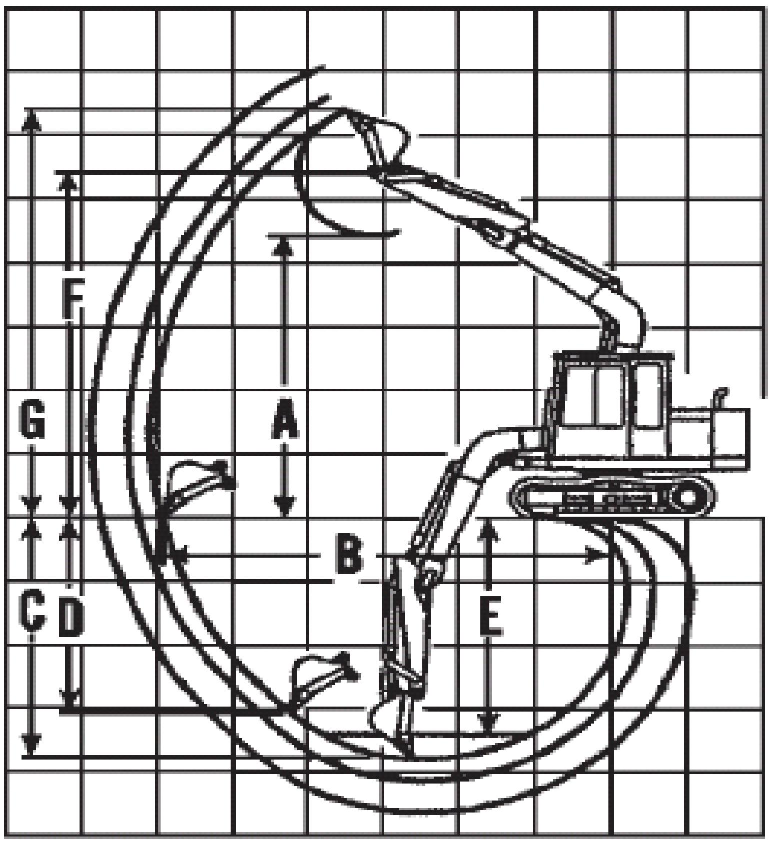
- Steps for estimating production of Excavator/hoe:
  - ***Step-4***:
    - Small machines swing faster than large ones.
    - Cycle times are based on swing angle of ***30-60°***.



2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

- ***Step-5***: Check ***depth of cut***. Refer Table D-3.
  - Typical cycle times are for depth of cut between ***40-60% of maximum digging depth***.



A Maximum loading height of bucket with teeth

B Maximum reach at ground level

C Maximum digging depth

D Maximum vertical wall

E Maximum depth of cut for 2.44 m (8'0") level bottom (straight clean up)

F Maximum bucket hinge pin height

G Maximum height, to bucket teeth at highest arc

Construction Equipments

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

- ***Step-5***:

Table D-3: Representative dimensions, loading clearance, and filling capacity, hydraulic crawler Hoe

Size bucket (cy)	Stick length (ft)	Maximum reach @ ground level (ft) "B"	Maximum digging depth (ft) "C"	Maximum loading height (ft) "A"	Lifting capacity at 15 ft: Short stick, Front (lb)	Lifting capacity at 15 ft: Short stick, Side (lb)	Lifting capacity at 15 ft: Long stick, Front (lb)	Lifting capacity at 15 ft: Long stick, Side (lb)
$\frac{3}{8}$	5–7	19–22	12–15	14–16	2,900	2,600	2,900	2,600
$\frac{3}{4}$	6–9	24–27	16–18	17–19	7,100	5,300	7,200	5,300
1	5–13	26–33	16–23	17–25	12,800	9,000	9,300	9,200
$1\frac{1}{2}$	6–13	27–35	17–21	18–23	17,100	10,100	17,700	11,100
2	7–14	29–38	18–27	19–24	21,400	14,500	21,600	14,200
$2\frac{1}{2}$	7–16	32–40	20–29	20–26	32,600	21,400	31,500	24,400
3	10–11	38–42	25–30	24–26	32,900*	24,600*	30,700*	26,200*
$3\frac{1}{2}$	8–12	36–39	23–27	21–22	33,200*	21,900*	32,400*	22,000*
4	11	44	29	27	47,900*	33,500*		
5	8–15	40–46	26–32	25–26	34,100†	27,500†	31,600†	27,600†

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

- Steps for estimating production of Excavator:
  - ***Step-6***: Check ***loading height***
    - Does the selected Excavator/hoe have the reach capability to load the haul unit. Refer table D-3.
  - ***Step-7***: ***Efficiency factor***
    - The three primary conditions that control the efficiency of excavator loading operations are:
      - ***Bunching***: In actual operation cycle times are never constant. When loading haul units they will sometimes bunch. The impact of bunching is a function of the number of haul units.
      - ***Operator efficiency***: How good is the operator.
      - ***Equipment availability***: Are the haul units in good condition and repair? They will be available *x% of the time*.

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

- ***Step-8***: ***Calculation***.

$$\text{Step } 1 \times \text{Step } 3 \times \frac{\text{Step } 7}{\text{Step } 4} = \text{LCY / hr}$$

- ***Step-9***: Convert production to ***Bank Volume*** (BCY)

Table D-4 Swell factor

Material	Bank weight lb/cu yd	Bank weight kg/m³	Loose weight lb/cu yd	Loose weight kg/m³	Percent swell	Swell factor
Clay,dry	2,700	1,600	2,000	1,185	35	0.74
Clay, wet	3,000	1,780	2,200	1,305	35	0.74
Earth, dry	2,800	1,660	2,240	1,325	25	0.80
Earth, wet	3,200	1,895	2,580	1,528	25	0.80
Earth and gravel	3,200	1,895	2,600	1,575	20	0.83
Gravel, dry	2,800	1,660	2,490	1,475	12	0.89
Gravel, wet	3,400	2,020	2,980	1,765	14	0.88
Limestone	4,400	2,610	2,750	1,630	60	0.63
Rock, well blasted	4,200	2,490	2,640	1,565	60	0.63
Sand, dry	2,600	1,542	2,260	1,340	15	0.87
Sand, wet	2,700	1,600	2,360	1,400	15	0.87
Shale	3,500	2,075	2,480	1,470	40	0.71

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

- **Production formula**

$$\text{Production} = \frac{3{,}600\ \text{sec} \times Q \times F \times (\text{AS:D})}{t}\left(\frac{E}{60-\text{min hr}}\right)\left(\frac{1}{\text{Vol. Correction}}\right)$$

Where, Q = Heaped Capacity

F = Bucket Fill Factor

AS:D = Angle of swing and depth (height) of cut correction

t = Cycle time in seconds

E = Efficiency min/hr

Volume correction for loose volume to bank volume:

$$\frac{1}{1+\text{swell factor}}$$

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

Example 2.3

- A crawler hoe having a ***3½-cy bucket*** is being considered for use on a project to excavate ***very hard clay*** from a borrow pit. The clay will be loaded into trucks having a ***loading height of 9 ft 9 in***. Soil- boring information indicates that below ***8 ft***, the material changes to an unacceptable silt material. What is the estimated production of the hoe in cubic yards bank measure, if the ***efficiency factor*** is equal to ***50-min/hour***?

Solution

- Step-1: Size of bucket = 3½-cy
- Step-2 : Bucket fill factor, Table D-1 gives 80-90%, Use average

Bucket fill factor = (80+90)/2 = 85%

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

Solution cont.

- Step-3: Typical cycle element times
  - Optimum depth of cut is 30-60% of maximum digging depth. From Table D-3 for a 3½ -Cy size Hoe, maximum digging depth is 23-27 ft , Depth of excavation 8 ft.

    (8ft/23ft) x 100 = 34% ≥ 30% okay!

    (8ft/27ft) x 100 = 30% ≥ 30% okay!
  - Therefore under average conditions and for 3½-Cy Size hoe, cycle times from Table D-2:

1. Load Bucket	7sec	Very hard clay
2. Swing with load	6sec	Load trucks
3. Dump load	4sec	Load trucks
4. Return swing	5sec	
Cycle time	**22sec**	

2. PRODUCTIVITY OF SHOVEL FAMILY AND EXCAVATORS

D. Productivity of Excavator/Hoe

Solution cont.

- Step-4: Efficiency factor, 50 min/hour
- Step-5: Class of material, hard clay Swell 35% (Table D-4)
- Step-6: Probable production

$$\frac{3{,}600 \text{ sec/hr} \times 3\tfrac{1}{2} \text{ cy} \times 0.85}{22 \text{ sec/cycle}} \times \frac{50 \text{ min}}{60 \text{ min}} \times \frac{1}{(1 + 0.35)} = 300 \text{ bcy/hr}$$

- Check maximum loading Height to ensure the hoe can service the trucks . From Table D-3, 21 to 22 *ft*.

21ft > 9ft 9in. Okay!

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

A. Productivity of Loader

- The following example demonstrates the process for estimating loader production.

Example 3-1

- A ***4-cy wheel loader*** will be used to load trucks from a quarry stock pile of ***processed aggregate*** having a maximum ***aggregate size of 1¼ in***. The haul distance will be negligible. The aggregate has a ***loose unit weight of 3,100***. Estimate the loader production in tons based on ***50-min/hour efficiency factor***. Use a conservative fill factor.

Solution

- Step-1: ***Size of bucket*** = 4-cy
- Step-2: ***Bucket fill factor*** (***Table A-1***), aggregate over 1in., 85-90%, use 85% conservative estimate

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

A. Productivity of Loader

Solution cont.

Table A-1 Bucket fill factors for wheel and truck loader

Material	Wheel loader fill factor (%)	Track loader fill factor (%)
Loose material		
Mixed moist aggregates	95–100	95–100
Uniform aggregates		
up to $\frac{1}{8}$ in.	95–100	95–110
$\frac{1}{8}-\frac{3}{8}$ in.	90–95	90–110
$\frac{1}{2}-\frac{3}{4}$ in.	85–90	90–110
1 in. and over	85–90	90–110
Blasted rock		
Well blasted	80–95	80–95
Average	75–90	75–90
Poor	60–75	60–75
Other		
Rock dirt mixtures	100–120	100–120
Moist loam	100–110	100–120
Soil	80–100	80–100
Cemented materials	85–95	85–100

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

A. Productivity of Loader

Solution cont.

- Step-2: Bucket fill factor

  Check tipping:

  Load weight: 4-cy x 0.85 = 3.4 lcy

  3.4 lcy x 3,100 lb/lcy (loose unit weight of material) = 10,540 lb.

  From ***Table A-2***, 4-cy machine static tipping load at full turn is 25,000 lb, Therefore operating (***50% static tipping*** at full turn) is

  0.5 x 25,000 lb = 12,500 lb

  10,540 lb actual load < 12,500 lb operating load; therefore okay!

- Step-3: ***Typical fixed time*** (***Table A-4***) 4-cy wheel loader, 30 to 33 sec; use 30 sec.

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

A. Productivity of Loader

Solution cont.

Table A-2 Representative specifications for wheel loader

Size, heaped bucket capacity (cy)	Bucket dump clearance (ft)	Static tipping load, @ full turn (lb)	Maximum forward speed				Maximum reverse speed				Raise/dump/lower cycle (sec)
			First (mph)	Second (mph)	Third (mph)	Fourth (mph)	First (mph)	Second (mph)	Third (mph)	Fourth (mph)	
1.25	8.4	9,600	4.1	7.7	13.9	21	4.1	7.7	13.9	—	9.8
2.00	8.7	12,700	4.2	8.1	15.4	—	4.2	8.3	15.5	—	10.7
2.25	9.0	13,000	4.1	7.5	13.3	21	4.4	8.1	14.3	23	11.3
3.00	9.3	17,000	5.0	9.0	15.7	26	5.6	10.0	17.4	29	11.6
3.75	9.3	21,000	4.6	8.3	14.4	24	5.0	9.0	15.8	26	11.8
4.00	9.6	25,000	4.3	7.7	13.3	21	4.9	8.6	14.9	24	11.6
4.75	9.7	27,000	4.4	7.8	13.6	23	5.0	8.9	15.4	26	11.5
5.50	10.7	37,000	4.0	7.1	12.4	21	4.6	8.1	14.2	24	12.7
7.00	10.4	50,000	4.0	7.1	12.7	22	4.6	8.2	14.5	25	16.9
14.00	13.6	98,000	4.3	7.6	13.0	—	4.7	8.3	14.2	—	18.5
23.00	19.1	222,000	4.3	7.9	13.8	—	4.8	8.7	15.2	—	20.1

CONSTRUCTION EQUIPMENTS

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

A. Productivity of Loader

Table A-3 Representative specification for truck loaders

Size, heaped bucket capacity (cy)	Bucket dump clearance (ft)	Static tipping load (lb)	Maximum forward speed (mph)	Maximum reverse speed (mph)	Raise/ dump/ lower cycle (sec)
1.00	8.5	10,500	6.5	6.9	11.8
1.30	8.5	12,700	6.5	6.9	11.8
1.50	8.6	17,000	5.9*	5.9*	11.0
2.00	9.5	19,000	6.4*	6.4*	11.9
2.60	10.2	26,000	6.0*	6.0*	9.8
3.75	10.9	36,000	6.4*	6.4*	11.4

Table A-4 Fixed cycle time for loaders

Loader size, heaped bucket capacity (cy)	Wheel loader cycle time* (sec)	Track loader cycle time* (sec)
1.00–3.75	27–30	15–21
4.00–5.50	30–33	—
6.00–7.00	33–36	—
14.00–23.00	36–42	—

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

A. Productivity of Loader

Solution cont.

- Step-4: Efficiency factor, 50 min/hour
- Step-5: Class of material, aggregate 3,100 lb per lcy.
- Step-6: Probable production

$$\frac{3{,}600 \text{ sec/hr} \times 4 \text{ cy} \times 0.85}{30 \text{ sec/cycle}} \times \frac{50 \text{ min}}{60 \text{ min}} \times \frac{3{,}100 \text{ lb/lcy}}{2{,}000 \text{ lb/ton}} = 527 \text{ ton/hr}$$

Example 3-2

- The loader in example 3.1 will also be used to charge the aggregate bins of an asphalt plant that is located at the quarry. The one way ***haul distance*** from the 1¼ in. Aggregate stockpile to the cold bins of the plant is ***220ft***. The asphalt plant uses ***105 tons per hour*** of 1 ¼ in. Aggregate. Can the loader meet the requirement?

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

A. Productivity of Loader

Solution

- Step-3: Typical fixed cycle time (***Table A-4***) 4-cy wheel loader, 30 to 33 sec, use 30 sec.

  From ***Table A-2*** , Travel speeds ***forward***:

  First, 4.3 mph; second, 7.7 mph; third, 13.3 mph.

  Travel speed ***reverse***:

  First, 4.9 mph; second, 8.6 mph; third, 14.9 mph.

  Travel loaded: 220 ft, because of short distance and required time to accelerate and brake, use 80% first gear maximum speed.

$$\frac{4.3\text{ mph} \times 80\% \times 88\text{ fpm/mph}}{60\text{ sec/min}} = 5.0\text{ ft/sec}$$

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

A. Productivity of Loader

Solution

- Step-3:

  Return empty: 220 ft, because of short distance and required time to accelerate and brake, use 80% second gear maximum speed.

$$\frac{7.7 \text{ mph} \times 80\% \times 88 \text{ fpm/mph}}{60 \text{ sec/min}} = 9.0 \text{ ft/sec}$$

1.	Fixed time	30 sec	4-cy wheel loader
2.	Travel with load	44 sec	220 ft, 80% first gear
3.	Return travel	24 sec	220 ft, 80% second gear
	Cycle time	98 sec	

- Step-6: Probable production

$$\frac{3{,}600 \text{ sec/hr} \times 4 \text{ cy} \times 0.85}{98 \text{ sec/cycle}} \times \frac{50 \text{ min}}{60 \text{ min}} \times \frac{3{,}100 \text{ lb/lcy}}{2{,}000 \text{ lb/ton}} = 161 \text{ ton/hr}$$

161 tons/hr > 105 tons/hr requirement

The loader will meet the requirement.

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

- The production of dozer mainly depend upon the following factors:
  - i. Size and condition of the dozer
  - ii. Distance traveled by the dozer
  - iii. Speed of operation
  - iv. Characteristic of soil being handled
  - v. Surface on which dozer is operating
  - vi. Efficiency
- A dozer has no set volumetric capacity. There is no hopper or bowl to load; instead, the amount of material the dozer moves is dependant on the quantity that will remain in front of the blade during the push.

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

- The major factors that control dozer production rate are:
  1. Condition of the material
  2. Blade type
  3. Cycle time

1. Condition of the material

- The type and condition of the material being handled affects the shape of the pushed mass in front of the blade.
  - Cohesive materials (clays) will ‘boil’ and heap.
  - Materials that exhibit a slippery quality or those that have high mica content will ride over the ground and swell out.
  - Cohesionless materials (sands) are known as “dead” materials because they do not exhibit heap or swell properties.

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

1. Condition of the material

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

2. Blade type

- Blade capacity is a function of a ***blade type*** and ***physical size***.

Blade volumetric load

- 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

i. Manufacturers Blade rating

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

CONSTRUCTION EQUIPMENTS

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

2. Blade type

i. Manufacturers Blade rating

$$\boxed{\begin{aligned} V_s &= 0.8\, W H^2 \\ V_u &= V_s + ZH(W - Z) \tan x^{\circ} \end{aligned}}$$

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

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

2. Blade type

Blade volumetric load

ii. Previous experience

- Properly documented past experience is an excellent blade load estimating method.

iii. Field measurement

- A procedure for measuring blade loads is as follow:
  - 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.

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

2. Blade type

Blade volumetric load

iii. 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.
- 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

$$\text{Blade load (lcy)} = 0.0139\, H\, W\, L$$

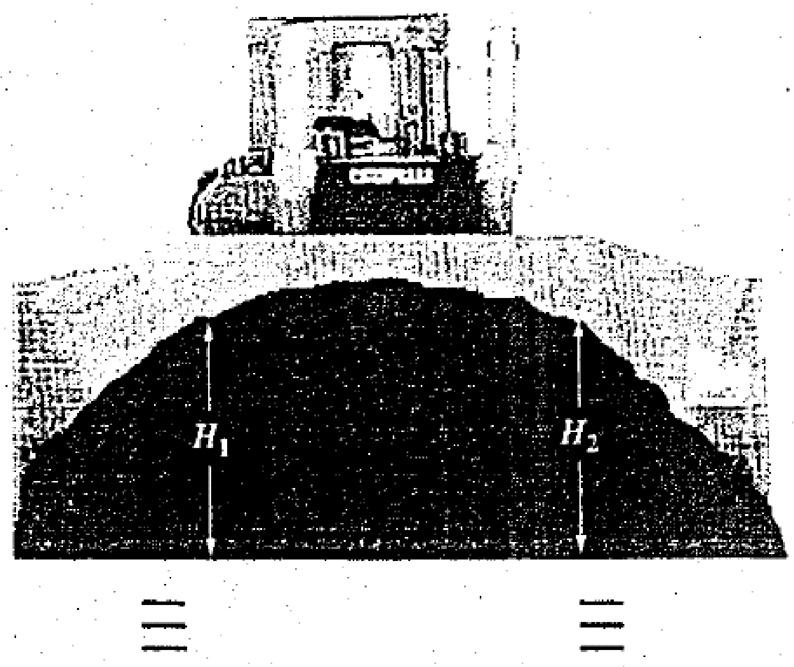
3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

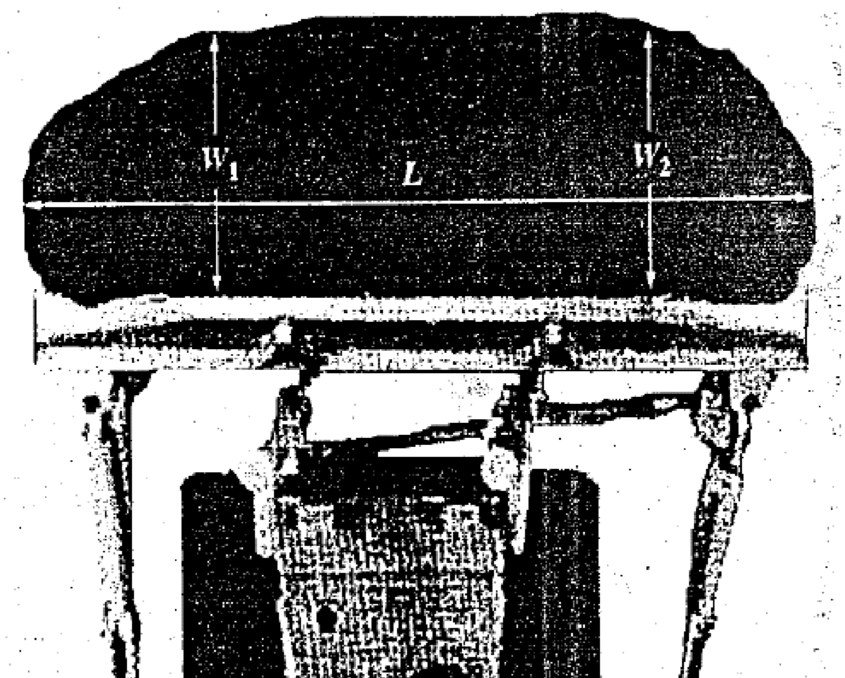
2. Blade type

Blade volumetric load

iii. Field measurement



Front view



Top view

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

2. Blade type

Example 3.3

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?

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

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

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

3. 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.
- 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.

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

- The following example demonstrates the process for estimating dozer production.

Example 3.4

- A ***power-shift crawler*** tractor has a rated ***blade capacity of 7.65Lm³***. The dozer is excavating ***loose common earth*** and pushing a ***distance of 200ft (61m)*** with speed of ***4km/hr***. Maximum ***reverse speed*** in third range is ***8 km/hr***. Estimate the production of the dozer, if job ***efficiency*** is ***50 min/hr***.

Solution

- Fixed time = 0.05 min (From ***Table B-1***)
- Dozing speed = 4.0 km/hr given but can be obtained from ***Table B-2***.

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Solution cont.

- Dozing time = 61m /(4 km/hr x 16.7 m/min) = 0.91 min

  Note: 1km/hr = 16.7 m/min
- Return time = 61m /(8 km/hr x 16.7 m/min) = 0.45 min
- Cycle time = (0.05+0.91+0.45)min = 1.41min
- Production = 7.65 Lm^3 x [(50min/hr)/(1.41min)] = 271 Lm^3/hr

Table B-1 Typical dozer fixed cycle times

Operating condition	Time (min)
Power-shift transmission	0.05
Direct-drive transmission	0.10
Hard digging	0.15

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Table B-2 Typical dozer operating speeds	
Operating conditions	**Speeds**
Dozing	
Hard materials, haul 30m or less	2.4 Km/hr
Hard materials, haul over 30m	3.2 Km/hr
Loose materials, haul 30m or less	3.2 km/hr
Loose material haul over 30m	4.0 km/hr
Return	
30m or less	Max reverse speed in second range (power shift) or reverse speed in gear used for dozing (direct drive)
Over 30m	Max reverse speed in third range (power shift) or highest reverse speed

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

- Other methods of computing production are:

1. $$Q_o = V_0 \left(\frac{60}{T_0}\right) f_F \cdot f_s \cdot f_L \ \left(Bm^3/h\right)$$

Q_0 = theretical productivity $\left(Bm^3 \text{per hour}\right)$

V_0 = blade load $\left[m^3\right]$

T_0 = basic cycle time $[\text{min}]$

f_F = fill factor

f_S = shape factor (for Blades)

f_L = load factor

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Actual production

$$Q_A = Q_0 \left\{ \frac{t_N}{60.f_T} \right\} \cdot f_Z \qquad \left[Bm^3/h \right]$$

t_N = effective working time $\left[min/h \right]$

$$= 60 - (t_n + t_z + t_a)$$

t_n = time for side works like assembling, change of place, etc $[min]$

t_z = time for additional work like uprooting roots, trunks, etc. $[min]$

t_a = time for hinderance etc. $[min]$

f_z = time factor to take care of overlapping times

$$= \left(1 - t_p/60\right) \cdot \left(1 - t_s/60\right)$$

t_p = time for personal stoppages

t_s = time for stoppages due to breakages $\left[min/sec \right]$

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

2. The productivity of a dozer, specifically for ***levelling*** and ***spreading*** work can be calculated by:

$$Q_a = B * m * f_e * V' * 60 * f_N * f_Z \left(\mathrm{m^3}/\mathrm{h}\right)$$

Where: B = reduced blade width (25% overlap) [m]

m = thickness of material spread, after compaction [m]

f_e = spreading factor to take care of the rolling and spread ability characteristics of the soil

Type of soil	Rolling	Coarse materials like coarse grained gravel	Mixed earth	Cohesive soil	Rock
f_e	0.8 – 1.0	0.7 – 0.8	0.8–0.95	0.6 – 0.7	0.3 -0.5

V' = calculated speed [m/min]

f_N = efficiency factor, a product of site management factor and the factor taking care of operator's motivation and experience

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

f_z = product of time factors taking care of matrial rolling on the side of the blade, blade form, site management conditions, experience and motivation of operator

$V' = d/T$

Where: d = length of strip (usually 15 -30 cm)

T = time for spreading strips of length d

$= N_p*t_f*0.06[d/V_{spread} + (N_p-1)(d)/V_{leveling}]$ [min]

N_p = number of passes per strip (usually 2 to 4)

t_f = fixed cycle time (usually 0.1 to 0.2 min)

V_{spread} = speed by spreading and rough leveling (usually 4 to 5 km/hr)

$V_{leveling}$ = speed by fine leveling (usually 4 to 6 km/hr)

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Use of graphs, charts and curves for estimating production

- 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.
- The bulldozer production curves give ***maximum uncorrected production*** for universal, semi-universal, and straight blades and are based on the following conditions:
  - 100% efficiency (60 minute hour — level cycle).
  - Power shift machines with 0.05 min. fixed times.
  - Machine cuts for 15 m (50 feet), then drifts blade load to dump over a high wall. (Dump time — 0 sec.)
  - Soil density of 1370 kg/Lm^3 (2300 lb/LCY).

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Use of graphs, charts and curves for estimating production

$$\begin{array}{r}\text{Production (Lm}^3\text{/hr)}\\ \text{(LCY/hr)}\end{array} = \begin{array}{c}\text{Maximum}\\ \text{production}\end{array} \times \begin{array}{c}\text{Correction}\\ \text{factors}\end{array}$$

- To obtain estimated production in bank cubic meters or bank cubic yards, appropriate load factor from the Tables section should be applied to the corrected production as calculated above.

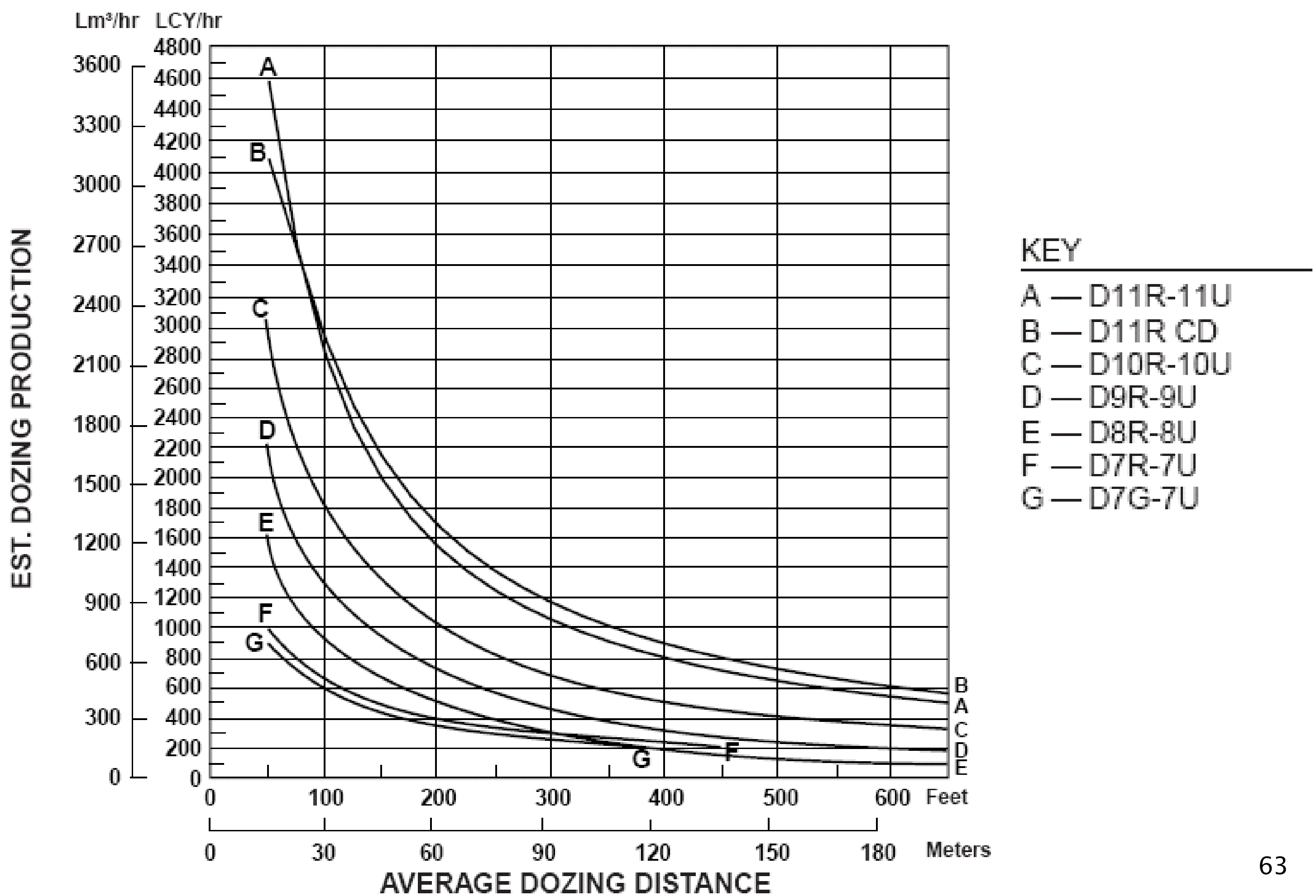
$$\begin{array}{r}\text{Production Bm}^3\text{/hr}\\ \text{(BCY/h)}\end{array} = \begin{array}{r}\text{Lm}^3\text{/hr} \times \text{LF}\\ \text{(LCY/h)} \times \text{LF}\end{array}$$

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Use of graphs, charts and curves for estimating production

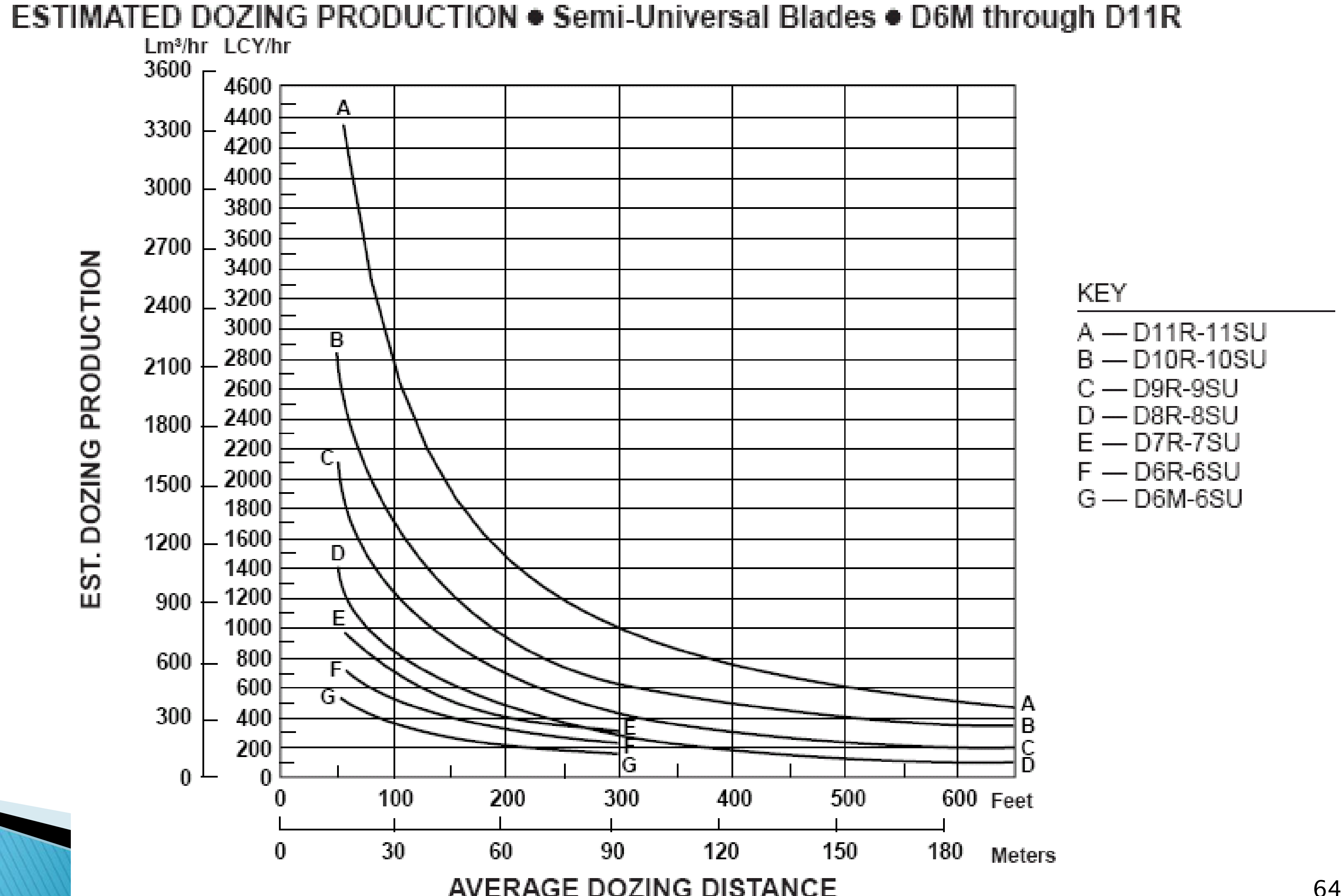
ESTIMATED DOZING PRODUCTION • Universal Blades • D7G through D11R



3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Use of graphs, charts and curves for estimating production

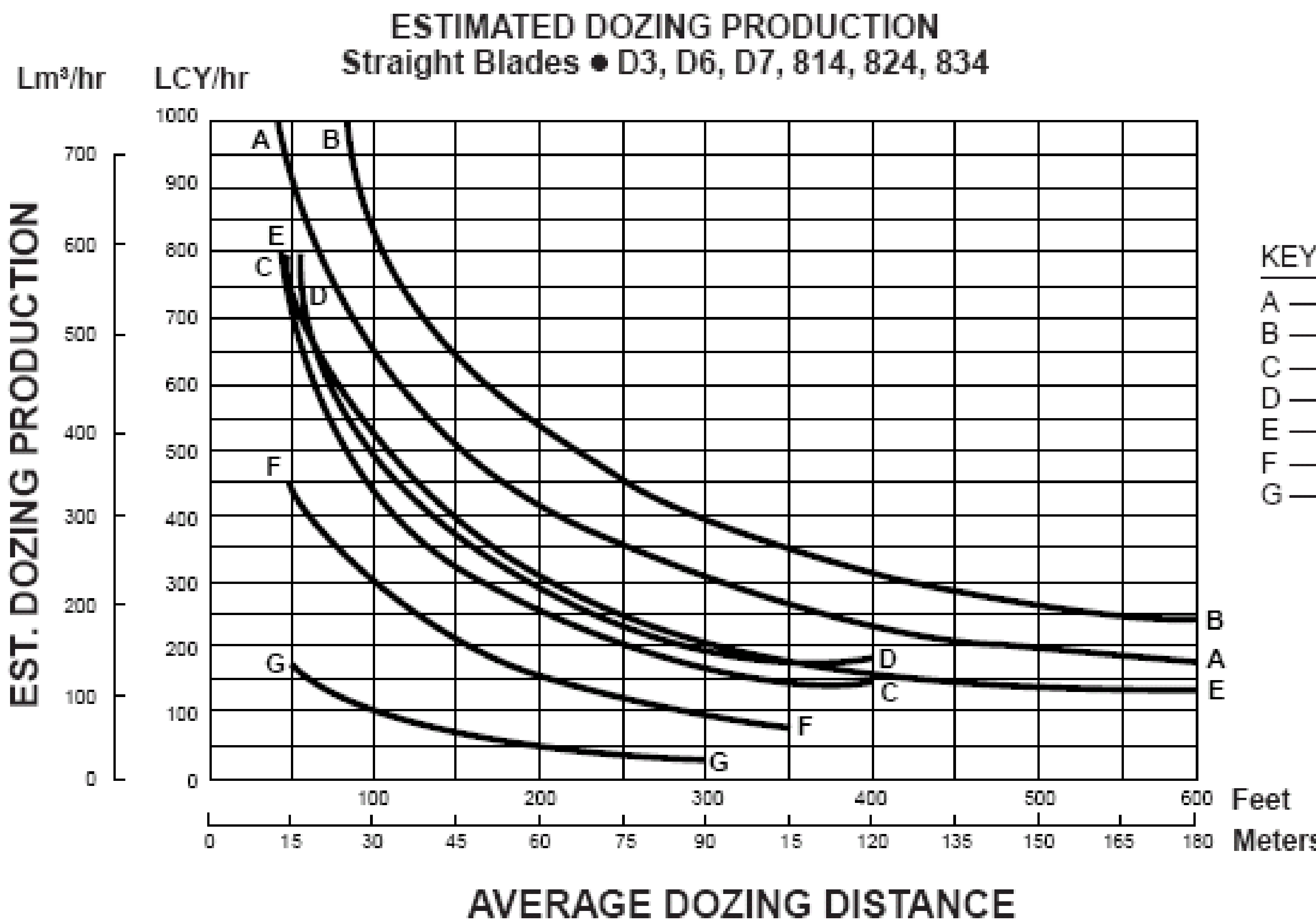


Construction Equipments

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Use of graphs, charts and curves for estimating production

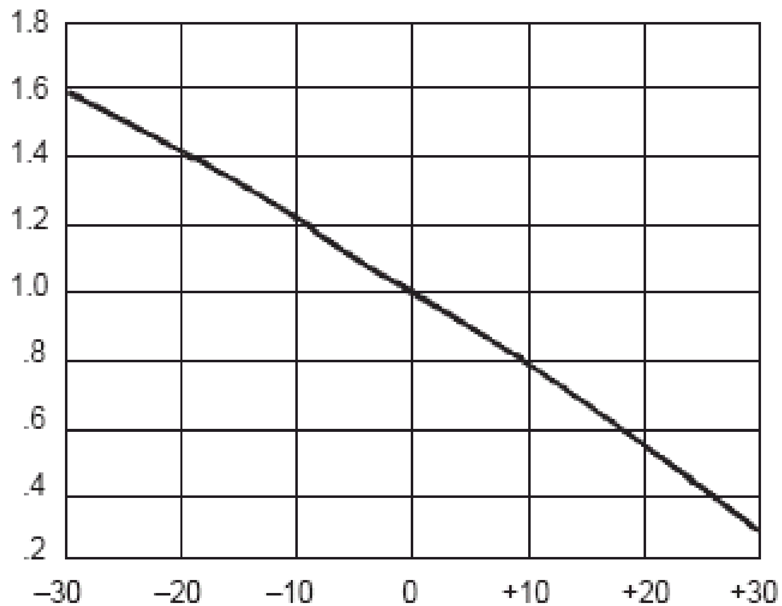


3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

% Grade vs. Dozing Factor

(–) Downhill
(+) Uphill



JOB CONDITION CORRECTION FACTORS

	TRACK-TYPE TRACTOR	WHEEL-TYPE TRACTOR
OPERATOR —		
Excellent	1.00	1.00
Average	0.75	0.60
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; "dead" (dry, non-cohesive material) or very sticky material	0.80	0.80
Rock, ripped or blasted	0.60-0.80	—
SLOT DOZING	1.20	1.20
SIDE BY SIDE DOZING	1.15-1.25	1.15-1.25
VISIBILITY —		
Dust, rain, snow, fog or darkness	0.80	0.70
JOB EFFICIENCY —		
50 min/hr	0.83	0.83
40 min/hr	0.67	0.67
BULLDOZER*		
Adjust based on SAE capacity relative to the base blade used in the Estimated Dozing Production graphs.		
GRADES — See following graph.		

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Use of graphs, charts and curves for estimating production

Example 3.3

- Determine average hourly production of a D8R/8SU (with tilt cylinder) moving hard-packed clay an average distance of 45 m (150 feet) down a 15% grade, using a slot dozing technique.

  Estimated material weight is 1600 kg/Lm3 (2650 lb/LCY). Operator is average. Job efficiency is estimated at 50 min/hr.

Solution

- Uncorrected Maximum Production — 458 Lm^3/hr (600 LCY/hr) from Estimated dozer production graph for Semi universal blade.

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Use of graphs, charts and curves for estimating production

Solution cont.

Applicable Correction Factors:

Hard-packed clay is "hard to cut" material –0.80
Grade correction (from graph) . . . .–1.30
Slot dozing . . . .–1.20
Average operator . . . .–0.75
Job efficiency (50 min/hr) . . . .–0.83
Weight correction . . . .(2300/2650)–0.87

Production = Maximum Production × Correction Factors
= (600 LCY/hr) (0.80) (1.30) (1.20) (0.75) (0.83) (0.87)
= 405.5 LCY/hr

To obtain production in metric units, the same procedure is used substituting maximum uncorrected production in Lm^3.

= 458 Lm^3/h × Factors
= 309.6 Lm^3/h

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

B. Productivity of a Dozer

Productivity of Rippers

- Out put of rippers depend upon characteristic of soil, size of the dozer, speed of the machine, shape and size of the ripper tooth, number of shanks used, and depth and width of ripping pass.
- However, the following are the formulae used in general for calculating the out put of ripper.

Production per hour = (Bank volume ripped per pass) x (No. of passes per hour)

Where, Bank volume ripped per pass = (Length of pass)x(Width of ripping pass)x(Depth of penetration)x(Efficiency)

No. of passes per hour = 60/(Time for making one pass in min.)

Time taken in one pass = (Length of pass/Traveling speed) + Turn round

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

C. Productivity of Scraper

- Out put of scrapers depends on the following main factors:
  - i. Size and mechanical condition of the scraper
  - ii. Hauling distance
  - iii. Condition of the haul road
  - iv. Characteristics of soil and work area.
  - v. Efficiency
- Steps for determining production of scraper are summarised as follow:
  - ***Step-1***: Determination of weight (Empty vehicle weight, load weight and gross vehicle weight)
  - ***Step -2***: Rolling resistance
  - ***Step-3***: Grade resistance/assistance
  - ***Step-4***: Total resistance/assistance

3. PRODUCTIVITY OF EARTH MOVING EQUIPMENTS

C. Productivity of Scraper

- Steps for determining production of scraper are summarised as follow:
  - ***Step-5***: Travel speed
  - ***Step-6***: Travel time
  - ***Step-7***: Load time
  - ***Step-8***: Dump time
  - ***Step-9***: Turning time
  - ***Step-10***: Total cycle time
  - ***Step-11***: Pusher cycle time
  - ***Step-11***: Total resistance/assistance
  - ***Step-12***: Balance fleet time
  - ***Step-13***: Efficiency
  - ***Step-14***: Production

..\..\..\scrapers.pdf

4. PRODUCTIVITY OF GRADING EQUIPMENTS

- Out put of a motor grader depends upon the following main factors:
  1. Size and mechanical condition of the motor grader
  2. Size of the blade
  3. Speed of travel
  4. Characteristics of soil being handled
  5. Efficiency of the operator
- In the majority of the cases, as the grader has multiple applications, the computation of its productivity is not always possible. It can, however, be estimated, case by case.

Method-1

- Average actual productivity for ***levelling and spreading*** can be computed as follow:

4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-1

$$Q_a = B \times L \times f_N \times f_Z \times 60/T \; [m^2/hr]$$

$$B = l \times \cos A$$

Where, B = width per strip with due consideration of over lapping

l = length of blade

A = Angle of blade width respect to the axis (refer Table 4.1)

L = lift thickness after compaction

f_N = factor to take care of site conditions, operator effectiveness (refer Table 4.2)

f_Z = time factor (refer Table 4.3)

T = Cycle time, $T = 0.06\sum(P * D)/V$, D = distance

P = number of passes

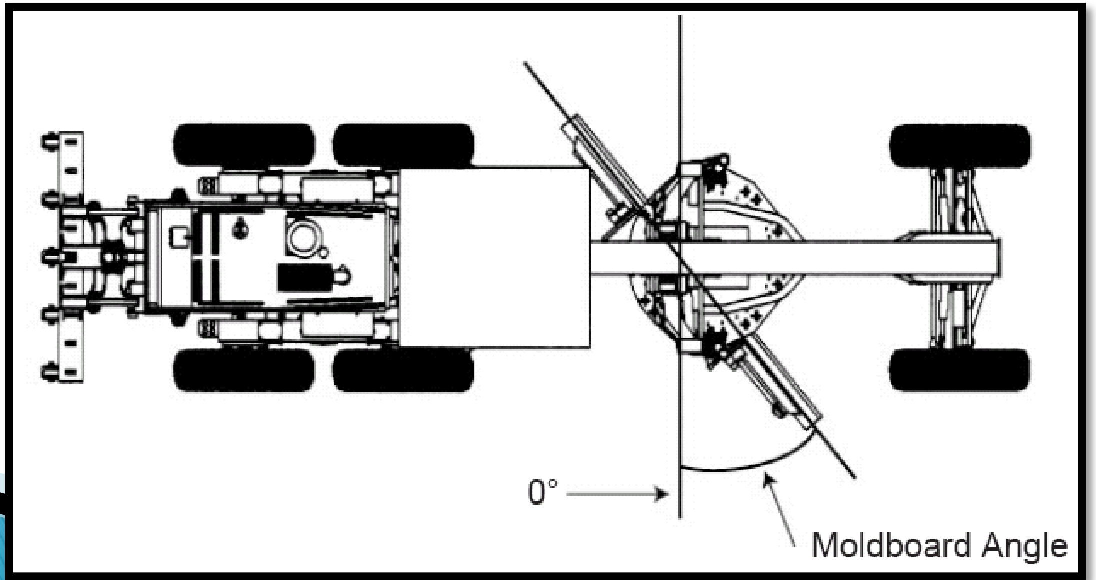
V = forward and back ward average speed

4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-1

Table 4.1 Blade angle for different operation

Type of earth/operation	Angle A in degrees
Normal	30
Hard earth	45
Loose and light material	20
Scarify, mix and spreading across	30-50
Fine levelling and spreading along	0-30



4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-1

Table 4.2 f_N- factor to take care of site conditions and operator effectiveness

	Very good	good	Average	Poor
Site condition	0.95	0.9	0.8	0.6
Operator effectiveness	1.0	0.85	0.75	0.6

Table 4.3.A Average speed for different operation

Type of operation	**Speed in Km/hr**
Road maintenance	4-9
Mix	8
Spread	4-9
Sub base work	4-8
Fine levelling	9-22
Cutting slopes	7-9
Ditching	4-8
Back ward and idle non operational speed	10-Vmax as per manufacturers Spec.

4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-1

Table 4.3.B Average speed for different operation	
Type of operation	**Speed in Km/hr**
Bank slopping	4.0
Ditching	4-6
Finishing	6.5-14.5
Grading and road maintenance	6.4-9.7
Mining	14.5-32.2
Snow removal	19.3-32.2
Spreading	9.7-14.5

4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-2

- Grader production is also calculated as area covered by motor grader per hour.

$$A = B \times V_{av} \times \eta$$

Where, B = width per strip (m)

$= 0.8 \times l \times \cos A$

l = length of blade

A = Angle with respect to axis

V_{av} *= Average speed (m/hr)*

η *= efficiency*

- Time required to complete a roadway project can be calculated by

$$T = \frac{\text{Number of passes x Distance (Km)}}{\text{Average speed (Km/hr) x Efficiency factor}}$$

4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-3 (CAT Performance handbook)

- One method expresses a motor grader's production in relation to the area covered by the moldboard.

$$A = S \times (L_e - L_o) \times 1000 \times E \text{ (Metric)}$$

$$A = S \times (L_e - L_o) \times 5280 \times E \text{ (English)}$$

where, A = *Hourly operating area* (m^2/h *or* ft^2/h)

S = *Operating speed (Km/h or mph)*

L_e = *Effective blade length (m or ft)*

L_o = *Width of overlap (m or ft)*

E = *Efficiency*

4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-3 (CAT Performance handbook)

- ***Operating speeds:*** typical operating speeds by operation are provided as follow:

Finish Grading:	0-4 km/h	(0-2.5 mph)
Heavy Blading:	0-9 km/h	(0-6 mph)
Ditch Repair:	0-5 km/h	(0-3 mph)
Ripping:	0-5 km/h	(0-3 mph)
Road Maintenance:	5-16 km/h	(3-9.5 mph)
Haul Road Maintenance:	5-16 km/h	(3-9.5 mph)
Snow Plowing:	7-21 km/h	(4-13 mph)
Snow Winging:	15-28 km/h	(9-17 mph)

- ***Effective blade length***: Since the moldboard is usually angled when moving material, an effective blade length must be computed to account for this angle. This is the actual width of material swept by the moldboard.

4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-3 (CAT Performance handbook)

- ***Effective blade length***:

Moldboard Length, m (ft)	Effective Length, m (ft) 30 degree blade angle	Effective Length, m (ft) 45 degree blade angle
3.658 (12)	3.17 (10.4)	2.59 (8.5)
3.962 (13)	3.43 (11.3)	2.80 (9.2)
4.267 (14)	3.70 (12.1)	3.02 (9.9)
4.877 (16)	4.22 (13.9)	3.45 (11.3)
7.315 (24)	6.33 (20.8)	5.17 (17.0)

- ***Width overlap***: The width of overlap is generally ***0.6 m*** (2.0 ft). This overlap accounts for the need to keep the tires out of the windrow on the return pass.

4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-3 (CAT Performance handbook)

- ***Job Efficiency***: Job efficiencies vary based on job conditions, operator skill, etc.
- A good estimation for efficiency is approximately ***0.70 to 0.85***, but actual operating conditions should be used to determine the best value.

Example 4-1

- A 140H motor grader with a 3.66 m (12 ft) moldboard is performing road maintenance on a township road. The machine is working at an average speed of 13 km/h (8 mph) with a moldboard carry angle of 60 degrees. What is the motor grader's production based on coverage area?

  Note: Due to the long passes involved in road maintenance- fewer turnarounds - a higher job efficiency of 0.90 is chosen.

4. PRODUCTIVITY OF GRADING EQUIPMENTS

Method-3 (CAT Performance handbook)

Solution

- From the table, the effective blade length is 3.17 m (10.4 ft).

Metric

- Production, $A = S \times (L_e - L_o) \times 1000 \times E$

  A = 13 km/h x (3.17 m - 0.6 m) x 1000 x 0.90

  A = 30,069 m^2/hr (3.07 hectars/hr)

English

- Production, $A = S \times (L_e - L_o) \times 5280 \times E$

  A = 8 mph x (10.4 ft - 2 ft) x 5280 x 0.90

  A = 319,334 ft^2/hr (7.33 acres/hr)

THANK YOU!