**Chapter three**

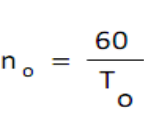
Equipment Productivity

Equipment Productivity: implies the output or efficiency of the equipment while it is in  
operation. The majority of the work in heavy construction projects is handling and  
processing large quantities of bulk materials. The constructor must select the proper  
equipment to relocate and/or process these materials economically. To do these, the  
engineer has to take into account both the properties of the material to be handled and  
the mechanical capabilities of the machine.  
The primary material considerations are:  
– Total quantity of material and  
– Size of the individual pieces  
Other considerations:-  
– Time constraints  
– Weather influence  
– Type and size and number of machines available

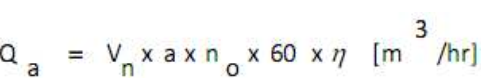
General Introduction and Principles  
Peak Productivity: - is the theoretical productivity governed by design limitations only.  
Actual Productivity: ‐is the productivity of an equipment after due consideration  
of the differently influencing factors.

  
Equipment’s can be broadly classified into two based on equipment productivity  
concepts: Cyclic Operating or Continuously Operating.

A. Cyclic Operating Equipments  
These are machines which are intentionally or unintentionally influenced by their  
operators. The theoretical productivity can be computed from:  
  
Where Qa – Actual Productivity  
 Vn – Volume per cycle  
 η ‐ Efficiency of the equipment  
 no – number of cycle /Unit Time (usually Time in hours)

  
Where To – theoretical cycle time  
The term “volume per cycle” should represent the average volume of material  
moved per equipment cycle. Thus the nominal capacity of the excavator or hauler unit  
must be modified by the appropriate fill factor based on the type of materials and the  
equipment involved. The term “number of cycle per hour” must include any  
appropriate efficiency factors, so that it represents the number of cycles actually  
achieved (or excepted to be achieved) per hour.

B. Continuously Operating Equipments  
These are machines that continuously operate, like pumps, conveyer belts, etc. For  
these kinds of machines:

  
Where Qa – Actual Productivity  
 Vn – Volume per bucket  
 a ‐ Number of buckets  
 η ‐ Efficiency of the equipment  
 no – number of cycle /Unit Time (usually Time in hours)

Productivity of Shovel Family and Excavators  
The actual productivity of the shovel family is dependent on the actual volume per cycle and  
the cycle time. Thus, to compute the actual productivity one should be able to make a good  
estimate of the actual bucket capacity (which depends on the soil characteristics) and the  
cycle time.  
The actual productivity is necessary to know the volume of material actually contained in one bucket load. The methods by which excavator bucket and dozer blade capacity are rated are given in Table Plateline 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.

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

Since bucket ratings for the cable shovel, dragline, and cable backhoe are based on struck  
volume, it is often assumed that the heaping of the buckets will compensate for the swell of  
the soil. That is, a 5 m3 bucket would be assumed to actually hold 5 bank m3 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.  
Suggested values of bucket fill factor for common soils are given in Table. The most  
accurate estimate of bucket load is obtained by multiplying the heaped bucket volume (loose  
measure) by the bucket fill factor. If desired, the bucket load may be converted to bank volume by multiplying its loose volume by the soil’s load factor. This procedure is illustrated in  
Q a = Vnxnoxη  
18  
  
Table : Bucket Fill Factors for Excavators

|  |  |
| --- | --- |
| 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 |

It should be noted that a cycle time is the sum of fixed cycle time and variable cycle time.  
Variable time represents those components of cycle time related with travel 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. Variable  
Cycle time is the time required to excavate and travel to load and travel to return to original  
position after loading.

**Excavator production**

Production = volume per cycle x cycles hr x E

We need to know the volume of material actually contained in one bucket load:

* Plate line capacity
* Struck capacity
* Water line capacity
* Heaped volume

**Plate line capacity**

* Bucket volume contained within the bucket whenfollowing the outline of the bucket sides.

**Struck capacity**

Bucket capacity when the load is struck off flush with the bucket sides; no allowance for bucket teeth.

**Water line capacity**

* Assume a level of material flush with the lowest edge of the bucket
* Material level corresponds to the water level that would result if the bucket were filled with water.

**Heaped line capacity**

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.

Bucket fill factors were developed to make it easier for us to estimate the volume of material in one bucket load.

The nominal bucket volume is multiplied by a bucket fill factor (bucket efficiency factor) to estimate the volume of material in one bucket load.

The most common form is backhoe

* Primarily designed to excavated below grade
* Positive digging action
* Precise lateral control
* It digs by pulling the bucket back toward the machine.

The backhoe is widely used for trenching work

* Excavating trenches
* Laying pipe bedding
* Placing pipe
* Pulling trench shields
* Backfilling the trench

The best measure of production in trench excavation is the length of trench excavated per unit of time therefore, the dipper width should be chosen which matches the required trench width as closely as possible.

Mini excavator

Advantages;

* Compact size
* Hydraulic power
* Light weight
* Maneuverability
* Versatility
* Ability to operate with full 360-degree swing
* Low ground pressure

Production estimating

Production(Qa) = C x S x V x B x E

Where:

C = cycles/hr

S= swing depth factor

V = heaped bucket volume (LCM)

B= bucket fill factor

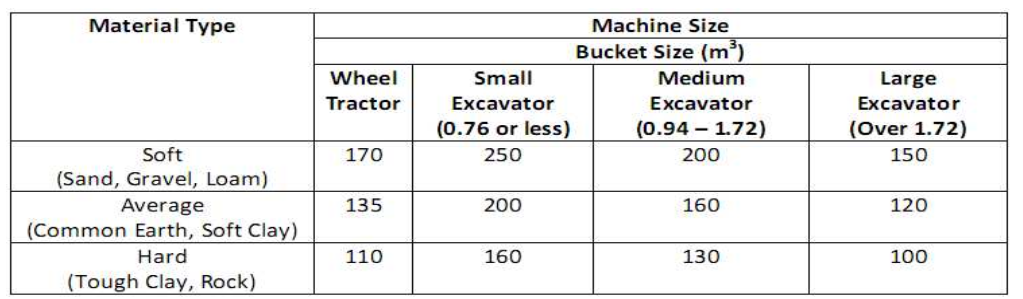
E = job efficiency

**Finding “cycles per hour”**

Prepared from manufacturing data

“C’ depend on

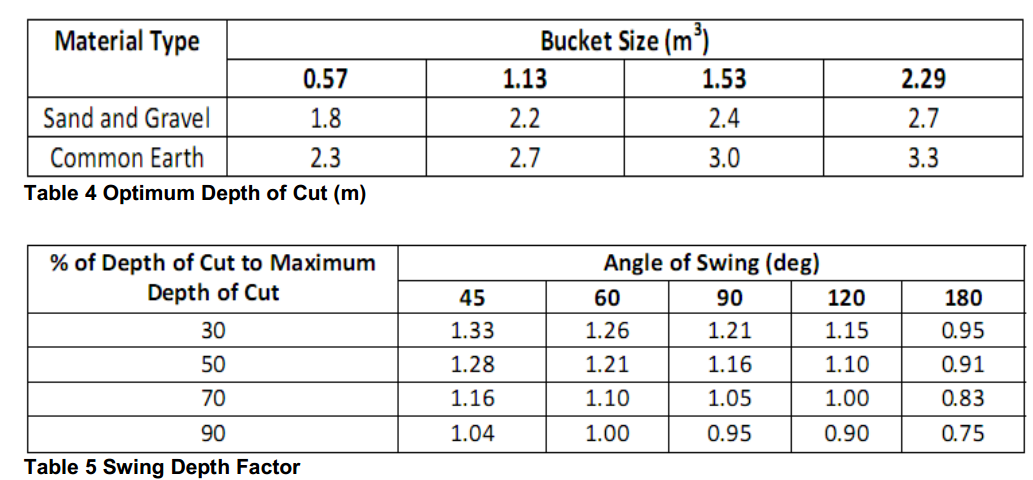
* Type of material
* Machine size



Find “swing –depth factor”

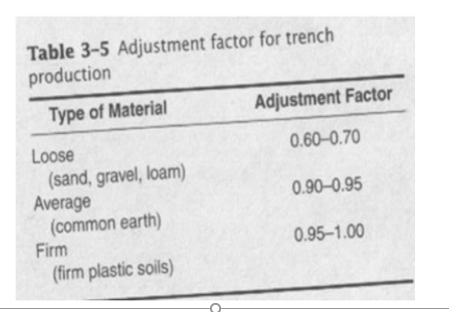
“S” depend between digging and dumping position. The smaller the angle, the higher the production. on

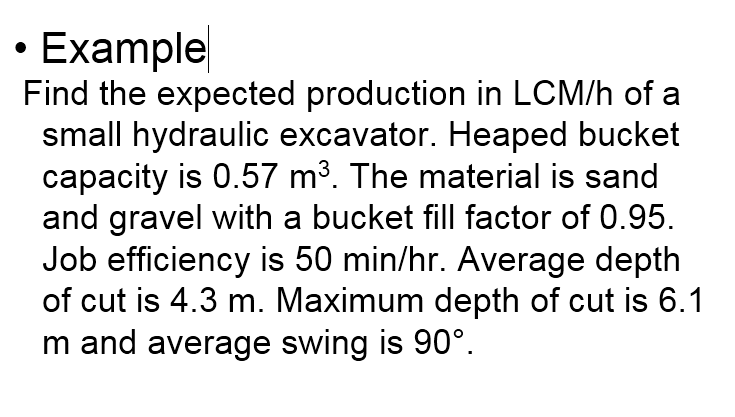
* Depth of out as a % of maximum
* Angle of swing; angle

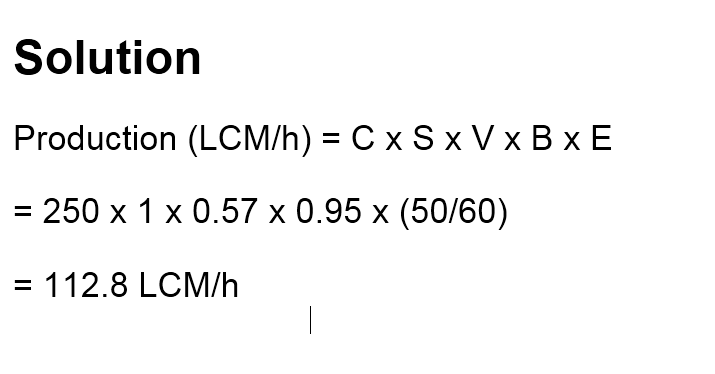


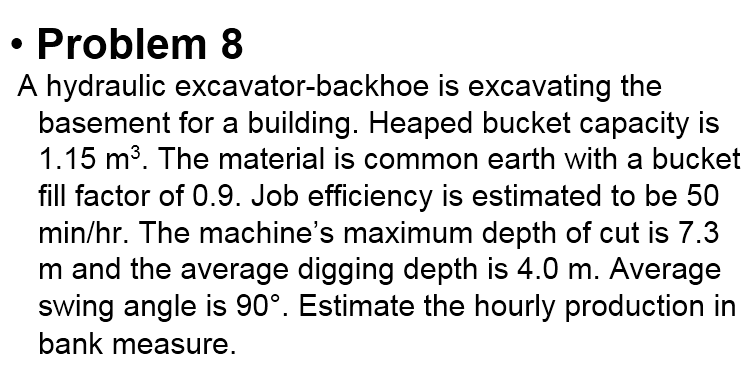
Adjustment factor for trench production

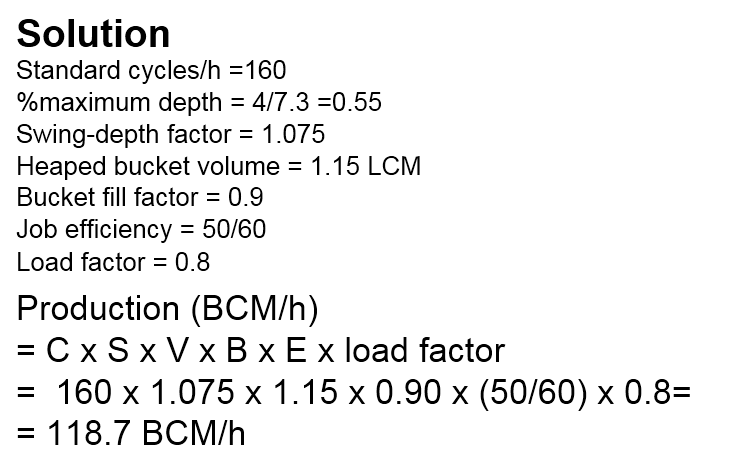
* In trench work, a fall-in factor should be applied to excavator production to account for the work required to clean out material that falls back into trench from the trench wall.
* Production should be multiplied by adjustment factor.

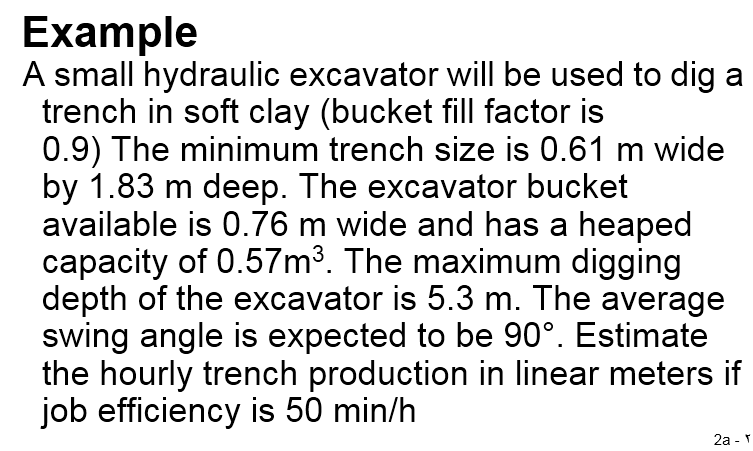


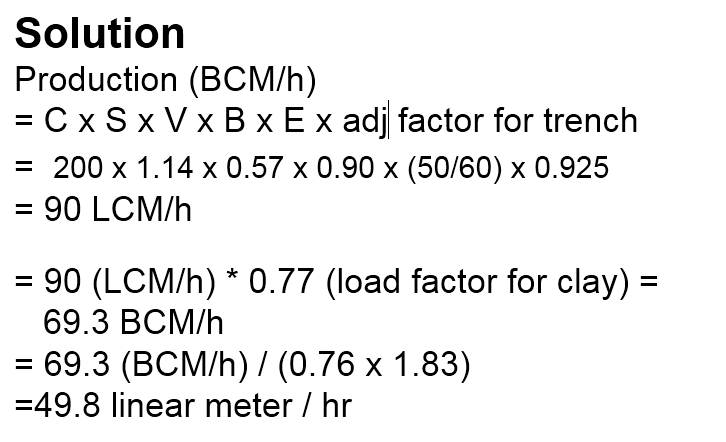


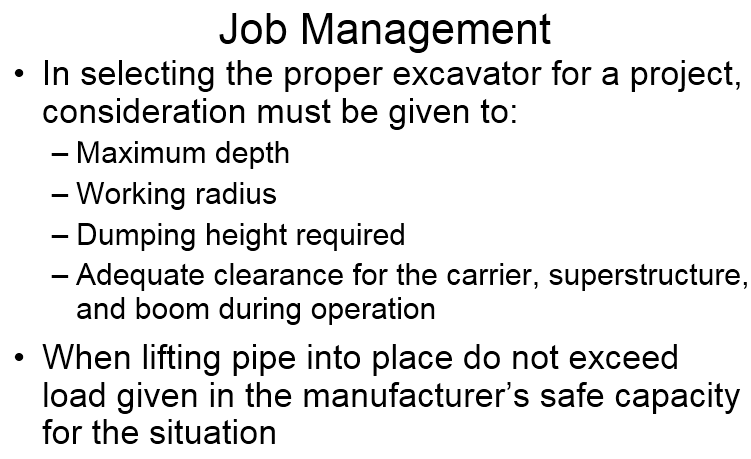












Productivity of DozersThe basic earth moving production equation may be applied in estimating dozer  
production. This method requires an estimate of the average blade load and the dozer  
cycle time. There are several methods available for estimating average blade load,  
including the blade manufacturer’s capacity rating, previous experience under similar  
conditions, and actual measurement of several typical loads.  
Blade volume can be computed by using equation:



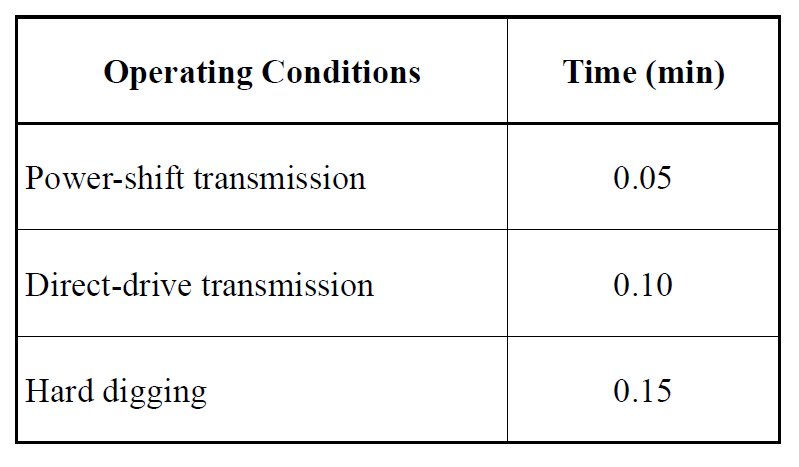
Production = volume per cycle x cycles per hour

Estimation a full blade load, then lift the blade while moving forward on a level surface until an even pile is formed:

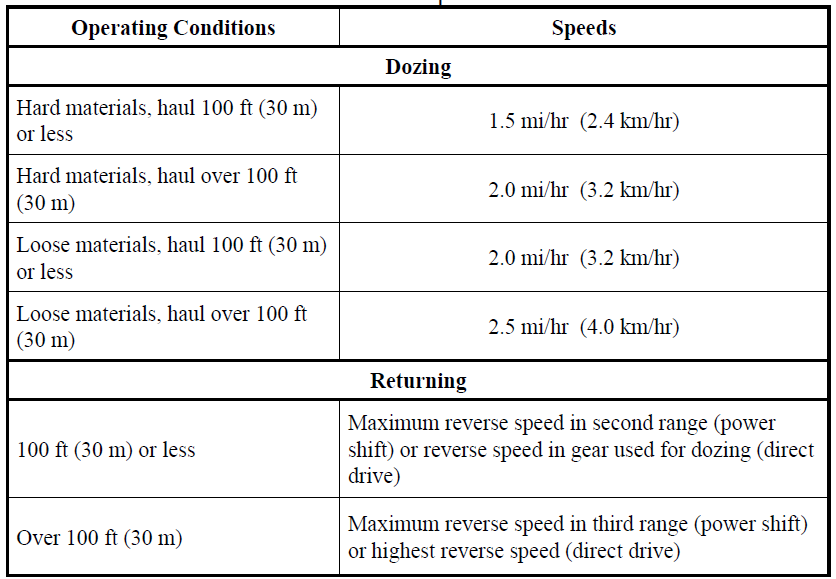
* measure the width (W) of the pile.
* Measure the height (H) of the pile
* Measure the length (L) on the pile

Dozer cycle time = fixed time + variable cycle time

* Fixed cycle time represents time for maneuvering, changing gears, start loading and dump.
* Variable cycle time is the time required to doze and return.



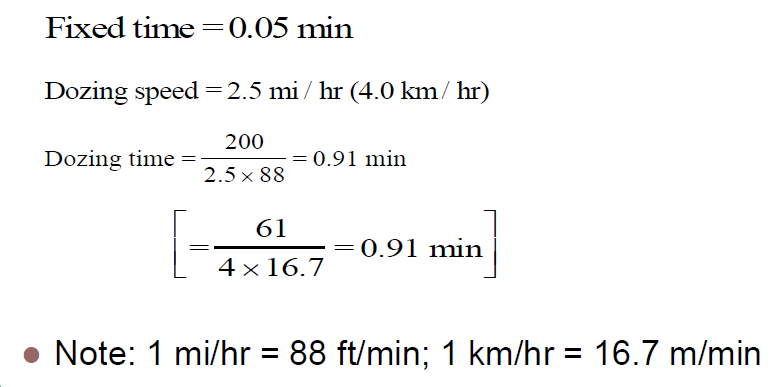
**Typical dozer operating speeds**

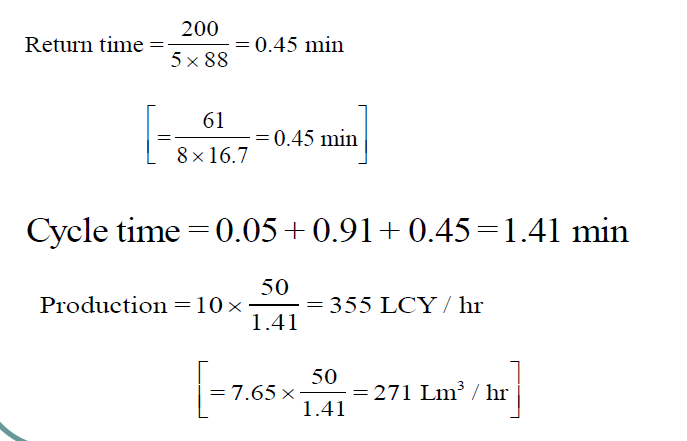


**Example**

A power-shift crawler tractor has a rated blade capacity of 10 LCY (7.65 Lm3). The dozer is excavating loose common earth and pushing it a distance of 200 ft. (61 m). Maximum reverse speed in third range is 5 mi/h(8km/h).

Solution





Productivity of LoadersLoader production can be estimated as the product of average bucket multiplied by cycles per hour. Basic cycle time for a loader includes the time required for loading, dumping, making four reversals of direction, and travelling a minimum distance (less than 5 m for track loaders). The important aspect is determining the actual travel time. Travel times shall be determined from manufacturer’s performance curves.

A tractor equipped with a front end bucket, called a loader, front end loader or bucket loader. Both wheel loaders and track loaders are available.

- to excavate soft to medium hard material

- loading haul units and hopers

- stockpiling material

- backfilling ditches

- moving concrete and other construction materials

**Wheel Loaders;**

**-** higher speed (25 mil/hr or more)

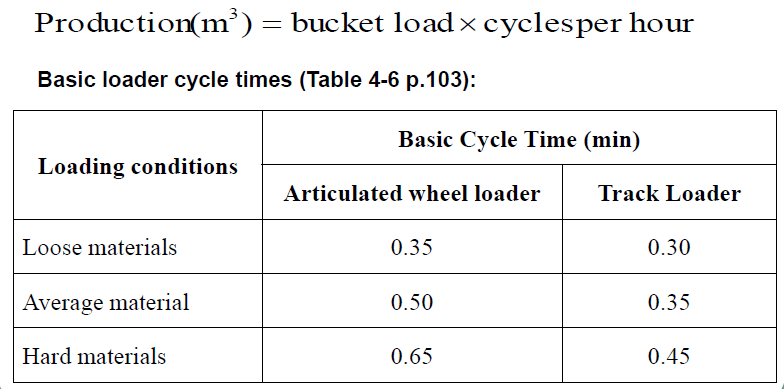
- good job mobility

- articulated (hinged between front and rear axles to provide great maneuverability)

**Truck Loaders;**

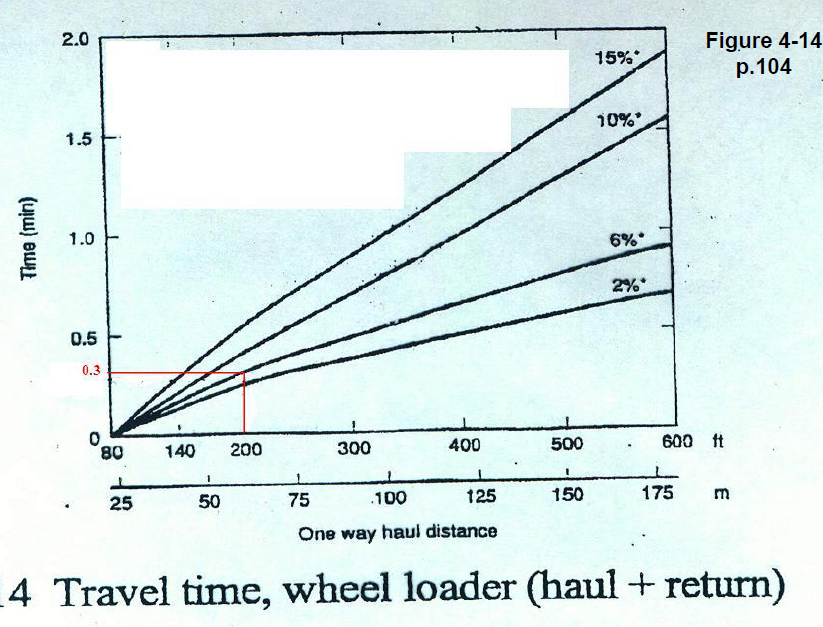
* overcoming steeper grades
* operating in areas of higher side slopes
* low ground pressure and high tractive effect
* lower speed than has wheel loaders

**Estimating Loader Production**

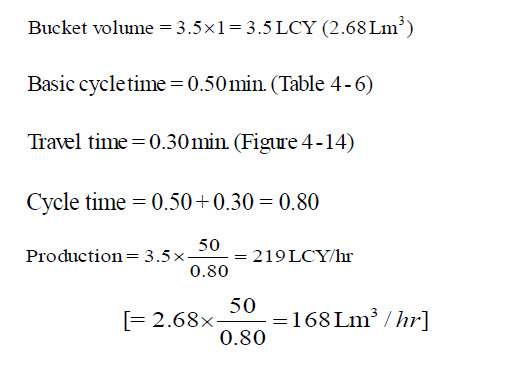


**Example**

Estimate the hourly production in loose volume (LCY or Lm3) of a 3½ yd (2.68 m3) wheel loader excavating sand and gravel (average material) from a pit and moving it to a stockpile. The average haul distance is 200 ft (61 m), the effective grade is 6%, the bucket fill factor is 1.00, and job efficiency is 50 min/hr.



**Solution**



Productivity of GradersGrader production is usually calculated on a linear basis (kilometers completed per  
hour) for a road way projects and on an area basis (square meters per hour) for general  
construction projects.

* Productivity: (in areal material placing per unit time
* A = V\*W\*of\*N
  + Where
  + V- Speed of grader
  + Is usually variable depending on function and gear. See manufacturer manual. On average for a cat machine
  + W- The grading width, may be less than blade width(often W = (Le-Lo)
    - Le-Effective blade width
    - Le (approx) = COS [Radians (Blade L)] \* Blade Length
      * Where blade angle from normal condition (perpendicular to movement)
    - Lo- width of overlap (often 0.6m)
      * This overlap accounts for the need to keep the tires out of the windrow on the return pass
  + Of- Operating Factor = Job efficiency
  + N-Number of returns required to arrive at level and cover road width
* Total time required to finish work:

= D\*N/(V\*E)

Where

V- Speed of grader

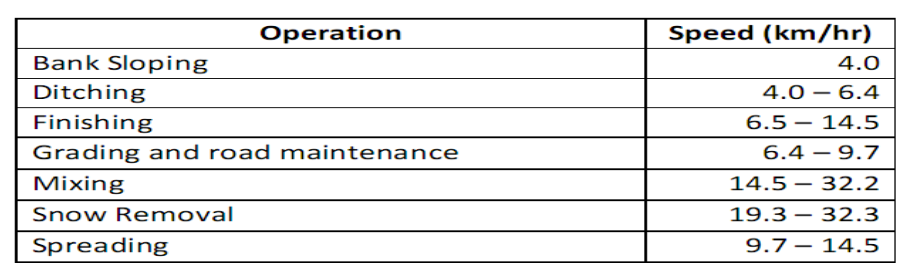
D- Distance travelled in each pass

E- Efficiency Factor

N-Number of returns required to arrive at level and cover road width

Average speed depends on the operator skill, machine characteristics, and jobcondition. Typical grader speeds for various types of operations are given in Table

Typical grader operating speed

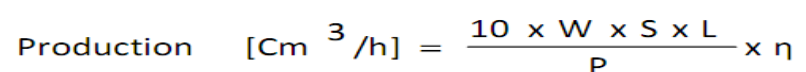


EXERCISE

A maintenance of 7.5km roadway requires cleaning the ditches and leveling and reshaping the roadway. Cleaning the ditches requires one passes in first gear (5km/hr) while leveling the road requires two passes in second gear (7.5km/hr) and reshaping requires three passes in third gear (10km/hr). Calculate the time requires to finish the job by using a 60% efficiency cat grader.

Compactor ProductivityEquation below may be used to calculate compactor production based on compactor  
speed, lift thickness, and effective width of compaction. The accuracy of the result will

depend on the accuracy in estimating speed and lift thickness. Trail operations willusually be necessary to obtain accurate estimates of these factors.

Where P = number of passes requiredW = width compacted per pass (m)S = Compactor Speed (km/hr)L = compacted lift thickness (cm)

**Productivity of Haulers**since hauling units involve travel of excavated materials; computing the travel timeis the most important step in computing the productivity of the hauler.The choice of the type and size of haulers is based on the consideration that thenumber of haulers selected must be capable of disposing of the excavated materialsexpeditiously. Factors which affect this selection include:The cycle capacity **C** of a piece of equipment is defined as the number of output unitsper cycle of operation under standard work conditions.

The productivity of a hauler unit can be computed using



however since hauling unit involve travel of excavated material; computing the travel time is the most important step in computing the productivity of the hauler