## **CONSTRUCTION OPERATIONS AND METHODS**



## \*\*EQUIPMENT PRODUCTION\*\*

The Equipment that will be covered on the exam and in this section are;



Graders



Loaders



Excavators



Compactors



Cranes(will discuss another section)



**Dump Trucks** 





## <u>DOZERS</u> <u>PRODUCTION ESTIMATE SUMMARY</u>



Dozer Trick of Trade #1: To figure out production rate(LCY/hr) of a dozer follow these easy steps.

Step 1: Find the Ideal maximum dozer production rate.

- Using production charts based on the particular dozer model and type of blade. Step 2: Find the different correction factors for less than ideal conditions.

a). Material – weight Correction Factor

CF = 2,300lb/LCY(ideal)/actual lb/LCY

- b). Operator correction factor
  - use table provided
- c). Material Type Correction Factor
  - use table provided
- d). Operating technique Correction Factor
  - use table provided
- e). Visibility Correction Factor
  - use table provided
- f). Efficiency Factor
  - use table provided or assume number operating per hour
- g). Machine transmission factor
  - use table provided
- h). Blade adjustment factor
  - use table provided
- i). Grade Correction Factor
- use chart/graph provided

Step 3: Determine total Correction Factor

- multiple all correction factors
- Step 4: Determine Production
  - Multiple Step 3 by Step 1

Step 5: Make sure it is in the right units of production

ex. BCY, CCY, LCY per hour.

- use the shrinkage or swell factor given to calculate or use tables.

Dozer Trick of Trade #2: To determine how much time is need to complete the job

Total time (hours) =  $Q / (P \times N)$  where Q = quantity of material to be moved

P = hourly production rate per dozer

N = Number of Dozers

<u>Dozer Trick of Trade #3:</u> To determine the number of dozers required to complete project within specific time:

Total number of dozers =  $Q / (P \times T)$  where Q = quantity of material to be moved

P = hourly production rate per dozer

T = maximum allowable duration in hours



## <u>SCRAPER</u> <u>PRODUCTION ESTIMATE SUMMARY</u>



- The optimum haul distance for the small- and medium-size scrapers is 300 to 3,000 feet. There are larger scrapers that are effective up to 5,000 feet.

- The production cycle for a scraper consists of six operations—loading, haul travel, dumping and spreading, turning at the dump site, return travel, and turning and positioning to load

Scraper Trick of Trade #1: For the PE exam, the question could be any one of these following steps or a combination of a few.

Step 1: Determine the vehicle weight, empty and loaded.

- Step 1a = find Empty vehicle weight (EVW), in tons.  $\rightarrow$  find in a table that will be given
- Step 1b = find loaded vehicle weight(LVW) in tons. = EVW + weight of the load(WL)
   WL = scraper load volume (LCY) x material unit weight (pounds per LCY) / 2000lb/ton

Step 2. Determine the average grade (in percent) and the distance (in feet) for both the haul and return routes.

- Uphill grades are positive (+) and downhill grades are negative (-).
- This information will be given or you can obtain from a mass diagram or a haul route profile.

Step 3. Determine the rolling resistance (in pounds) for both haul and return.

#### - RR Haul = (40 + [30 x TP]) x LVW

#### - RR Return = $(40 + [30 \times TP]) \times EVW$

where - RR Haul = Rolling Resistance for the Haul Route

- RR Return = Rolling Resistance for the Return Route
- TP = Tire Pentration in inch ( note may be different for the haul and return route)
- 40 = constant that represents the flexing of the driving mechanism, in pounds per ton
- 30 = constant that represents the force required to climb out of the rut, in pounds per ton per inch

Step 4. Determine the grade resistance or the grade assistance.

- GR(+) or GA(-) = 20 x percent grade x vehicle weight (tons) Therefore

- GR(+)Haul or GA(-)Haul = 20 x percent grade x GVW (tons)

- GR(+)Return or GA(-)Return = 20 x percent grade x EVW (tons)

where---

GR(+) = grade resistance, in pounds

GA(-) = grade assistance, in pounds

20 = constant that represents 20 pounds per ton of vehicle weight per degree of slope

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## <u>SCRAPER</u> <u>PRODUCTION ESTIMATE SUMMARY</u>



<u>Step 5. Determine the rimpull required</u>. Rimpull is the additional force acting against the vehicle – which is the rolling resistance plus or minus the grade resistance/assistance.

-RPR = RR + GA(-) or GR(+) where— RPR = rimpull required, in pounds RR = rolling resistance, in pounds GA(-) = grade assistance, in pounds GR(+) = grade resistance, in pounds

#### Step 6. Determine the travel speed.

 $\rightarrow$ The travel speed of a piece of equipment is the maximum speed at which the vehicle can develop the rimpull required to overcome the opposing forces of grade and rolling resistance. The manufacturer normally provides this information in tables or charts

 $\rightarrow$  To determine the travel speed, locate the rimpull required for either the haul or return on the left side of the chart. Read to the right until intersecting the line representing the highest gear which can achieve that amount of rimpull. Read down from the gear intersect to determine the maximum travel speed.

 $\rightarrow$  The Travel speed could also be given in the question.

#### Step 7. Determine the total travel time.

 $\rightarrow$  Total travel time is the sum of the time it takes the vehicle to complete one haul and one return. Total TT = TTHaul + TTReturn, where TT = Travel Time

 $\rightarrow$  First figure out the Haul Travel Time,

#### -TT Haul = average haul distance (feet) / (88 x travel speed(mph))

-Where TT = travel time, in minutes, 88 = conversion factor used to convert mph into feet per minute (fpm)

 $\rightarrow$ Next figure out the return travel time (in minutes).,

#### - TT Return = average return distance (feet) / (88 x travel speed(mph))

#### Step 8. Determine the cycle time.

→CT = total TT + TD + LT
-Where;
CT = total scraper cycle time, in minutes
TT = travel time
TD = total turn and dump time
LT = load time



#### <u>SCRAPER</u> PRODUCTION ESTIMATE SUMMARY



Step 9. Determine the trips per hour.

TPH = working minutes per hour / CT

where— TPH = trips per hour CT = total scraper cycle time, in minutes

Step 10. Determine the hourly production rate.

#### P = TPH x average LCY per load

where— P = hourly production rate, in LCY per hour TPH = trips per hour

Step 11. Determine the total time in hours required to complete the project/task.

Total time (hours) = Q / P x N

where—

**Q** = total volume to move, in BCY

- P = hourly production rate, in BCY per hour
- N = number of scrapers

Step 12. Determine the number of push tractors required.

N = CT / PT

where—

N = number of push tractors required CT = total scraper cycle time, in minutes PT = total pusher cycle time, in minutes



## <u>GRADER</u> PRODUCTION ESTIMATE SUMMARY



- Graders are multipurpose machines used for grading, shaping, bank sloping, and ditching. They are used for mixing, spreading, side casting, leveling and crowning, general construction, and road and runway maintenance. Graders cannot perform dozer work because of the structural strength and location of its blade. However, they can move small amounts of material. They are capable of working on slopes as steep as 3:1. Graders are capable of progressively cutting ditches to a depth of 3 feet.

- The components of the grader that do the work are the blade and the scarifier. The blade's position and pitch are adjustable and are determined by the type of operation being performed.

Grader Trick of Trade #1: Use the following formula to prepare estimates of the total time (in hours or minutes) required to complete a grader operation.

#### Total time = $(P \times D) / (S \times E)$

where----

P = number of passes required

D = distance traveled in each pass, in miles or feet

S = speed of grader, in mph or fpm (multiply mph by 88 to convert to fpm)

E = efficiency factor

• **Number of passes.** Estimate the number of passes (based on the project requirements) before construction begins.

• **Distance traveled.** Determine the required travel distance per pass before construction begins.

• **Speed of the grader.** Speed is the most difficult factor in the formula to estimate accurately. As work progresses, conditions may require that speed estimates be increased or decreased. Compute the work output for each rate of speed used in an operation. The speed depends largely on the skill of the operator and the material type.

• Efficiency factor. For grader operations the efficiency factor is usually no better than 60 percent.



## <u>LOADER</u> PRODUCTION ESTIMATE SUMMARY



- Loaders are used extensively in construction operations to handle and transport material, to load haul units, to excavate, and to charge aggregate bins at both asphalt and concrete plants. The loader is a versatile piece of equipment designed to excavate at or above wheel or track level.

- Many factors affect loader production: operator skill, extent of prior loosening of the material, slope of the operating area, height of the material, climate, and haul-unit positioning.

Loader Trick of Trade #1: CUBIC-YARD ESTIMATES

Step 1. Determine the material type and the rated heaped-bucket capacity of the loader.

Step 2. Select the bucket fill factor from Table or given, based on the material type.

Step 3. Determine the average cycle time from Table or given based on the size of wheel loader.

Step 4. Determine the maximum production rate using the following formula.

#### Maximum production rate (LCY per hour) = heaped-bucket capacity x bucket fill factor x 60 minutes / loader cycle time (min)

*Step 5.* Determine an efficiency factor. Efficiency depends on both the job conditions and management. A good, average loader efficiency is 50 minutes of work per hour.

*Step 6.* Determine the net production rate in LCY per hour. Multiply the maximum production rate (LCY per hour) by the efficiency factor.

#### Net production rate (LCY per hour) = maximum production rate (LCY per hour) x efficiency factor

#### Trick of the Trade #2: TONNAGE ESTIMATES

Determine the net production rate in tons per hour. Multiply the net production rate (LCY per hour) by the material weight (tons per LCY). Divide the material weight by 2,000 to convert pounds per LCY to tons per LCY.

#### Material weight (tons per LCY) = weight (pounds per LCY) / 2,000 pounds per ton

Net production rate (tons per hour) = net production rate (LCY per hour) x material weight (tons per LCY)



## <u>EXCAVATOR</u> PRODUCTION ESTIMATE SUMMARY



- $\rightarrow$  Factors that affect hoe production are the ;
  - Width of the excavation , Depth of the cut, Material type, Working radius for digging and dumping, Required bucket dumping height.

#### Excavator Trick of the Trade # 1:

**Step 1.** Determine the bucket fill factor based on the material type

- Using a chart or it will be given, Lacking any other information, use an average of 85 percent.

**Step 2.** Use a hoe cycle time based on past performance data if available or use the average cycle time given

Step 3. Determine the ideal production rate (LCY per hour).

Step 4. Determine the production rate (LCY per hour) by adjusting for efficiency.

Step 5. Convert the production rate from LCY per hour to BCY per hour.

**Excavator Trick of the Trade # 2:** The production rate can also be found by the following equation;

#### q = ((3600sec/hour x B x E x P) / C) x Volume Correction

Volume Correction = for loose volume to bank volume = 1/(1+swell factor)

q = Volume of soil excavated and dumped in a truck by the excavator (CY/hr)

- **B** = Bucket struck capacity (CY)
- E = Bucket efficiency factor (from a table or given)
- P = Productivity factor (from a table or given)
- C = Cycle time for 90 degree angle and optimum depth



## <u>COMPACTOR</u> PRODUCTION ESTIMATE SUMMARY



**Compactor Trick of Trade #1:** Use the following formula to determine compactor production in CCY per hour.

Production (CCY per hour) = (16.3 x W x S x L x E) / N

 $\rightarrow$  Where—

16.3 = constant for converting the factors in feet, mph, and inches to CCY W = compacted width per pass, in feet

S = compactor speed, in mph

L = compacted lift thickness, in inches

**E** = efficiency - The efficiency of a daytime compaction effort is typically 50 minutes per hour. Reduce the efficiency to 45 minutes per hour for nighttime compaction. **N** = number of passes required

**Compactor Trick of Trade #2:** Determine the total number of compactors required on the project, using the following formula.

Compactors required = FD x SCF / CP

→Where –
 FD = amount of fill delivered (LCY per hour)
 SCF = soil conversion factor (LCY:BCY)
 CP = compactor production (CCY per hour)



## <u>DUMP TRUCK</u> PRODUCTION ESTIMATE SUMMARY



The production capacity of the loading equipment is normally the hauling operation's controlling factor. Never keep loading equipment waiting. If there are not enough trucks, there will be a loss in production.

#### Dump Truck Trick of Trade #1: Number of Trucks Required

Use the following formula to estimate the number of trucks required to keep loading equipment operating at maximum capacity:

## Number of trucks required = 1 + truck cycle time (minutes)/ loader cycle time (minutes)

• The number 1 in the formula is a safety factor against the necessity for closing down loading equipment due to lack of hauling equipment. If all operations are on schedule, one truck will always be standing by at the loader, ready for spotting.

• The truck cycle time is the time required for a truck to complete one cycle of operation. One complete cycle is the time a loaded truck takes to travel to the dump site, unload, return to the loading unit, and be reloaded.

• The loader cycle time is the time it takes the loading equipment to load the truck, plus any time lost by the loading equipment while waiting for the truck to be spotted.



# PRODUCTION ESTIMATE QUESTION 1



Given the following dozer production charts, what is the average hourly production(LCY/hr) of a straight-blade D7(with tilt cylinder) moving hard-packed clay an average distance of 200 feet, down a 10 percent grade, using slot dozing. The estimated material weight is 2,500 lbs per LCY. The operator is of average ability and will work during daylight hours. Expected efficiency is 50 minutes per hours.

a. How much time will it take to move 3,000LCY of hard packed clay, using one D7 dozer using the production rate figured out above?

b. How many D7 dozers would be required to move 3000 LCY of clay in 7 hours?



Table 2-4. Material-Type Correction Factors

Material State	Factor for Crawler Tractors
Loose, stockpile	1.2
Hard to cut; frozen, with tilt cylinder Hard to cut; frozen, without tilt cylinder	0.8 0.7
Hard to drift; dead (dry, noncohesive) material or very sticky material	0.8
Rock (ripped or blasted)	0.6 to 0.8

Table 2-5. Operating-Technique Correction Factors

Operating Technique	Factor for Crawler Tractors
Slot dozing	1.2
Side-by-side dozing	1.15 to 1.25



## PRODUCTION ESTIMATE ANSWER 1



Given the following dozer production charts, what is the average hourly production(LCY/hr) of a straight-blade D7(with tilt cylinder) moving hard-packed clay an average distance of 200 feet, down a 10 percent grade, using slot dozing. The estimated material weight is 2,500 lbs per LCY. The operator is of average ability and will work during daylight hours. Expected efficiency is 50 minutes per hours.

Step 1: Find the Ideal maximum dozer production rate.

- Using production charts = 300 LCY Step 2: Find the different correction factors for less than ideal conditions. a). Material – weight Correction Factor CF = 2,300 lbs/LCY / 2,500 lbs/LCY = .92b). Operator correction factor - use table provided = .75c). Material – Type Correction Factor - use table provided = .8d). Operating technique Correction Factor - use table provided = 1.2e). Visibility Correction Factor - use table provided = 1.0f). Efficiency Factor - 50 working minutes per hour / 60 minute working hour = .83g). Machine transmission factor - use table provided = 1.0h). Blade adjustment factor - use table provided = 1.0i). Grade Correction Factor - use chart/graph provided = 1.15Step 3: Determine total Correction Factor  $-1.15 \times .92 \times .8 \times .75 \times .83 \times 1.2 \times = .63$ **Step 4: Determine Production** - Multiple Step 3 by Step  $1 = 300LCY \times .63 = 190 LCY$ 

 a. How much time will it take to move 3,000LCY of hard packed clay, using one D7 dozer using the production rate figured out above? Total time (hours) = Q / (P x N) = 3,000 LCY/ (190 LCY x 1 dozer) = 16 hours

b. How many D7 dozers would be required to move 3000 LCY of clay in 7 hours? Total number of dozers =  $Q / (P \times T) = 3,000$  LCY/ 190 LCY per hour x 7 hours = 2.25 up 3







A 2000 ft x 150 ft plot of land needs to be graded, it is estimated that the grader will need to make two passes to get each pass to grade. The grader blade is 10 ft wide, with a average speed of 4 mph. The operator is very experienced, The efficiency of the operation is estimated to be 60%. The efficiency percentage takes into account the operators rest breaks and time required to turn around after each pass.

How many hours is required to grade the Area?









Using the given formula for graders production rate the questions is straight forward;

#### Total time = $(P \times D) / (S \times E)$

where----

- P = number of passes required
- D = distance traveled in each pass, in miles or feet
- S = speed of grader, in mph or fpm (multiply mph by 88 to convert to fpm) E = efficiency factor

• Step 1: Figure out the Number of passes required.

→ You know that the width of the blade is 10 ft and the width of the area to be graded is 150. So 150ft divided by 10 ft per pass = 15 passes. Also it was given that the grader will need to conduct two passes in order to grade the ground properly so  $15 \times 2 = 30$  pass required.

Step 2: Figure out the required Distance traveled.

 $\rightarrow$  This was given to be 2000 ft

#### Step 3: Figure out the Speed of the grader.

 $\rightarrow$  The speed was given as 4mph, which is 4mph x 88 fpm/mph = 352 fpm

#### Step 4: Figure out the **Efficiency factor.**

 $\rightarrow$  This was also given to be .60

#### Step 5: Solve the equation

 $\rightarrow$  T = P x D / (S x E) = 30 pass x 2000 ft/pass / (352 fpm) x .60 = 60,000 ft / 211.2 fpm =

$$= 284 \text{ mins}$$
 4.7 hrs round up to 5 hours



## <u>EXCAVATOR</u> EXAMPLE QUESTION 1



A excavator have a 3cy bucket is being considered for use on a project to *excavate very* hard clay with a swell factor of 35% from a borrow pit. The clay will be loaded into trucks *hav*ing a loading height of 10 ft. The average cycle time for the excavator to load bucket, swing, dump, return is 20 second., The efficiency factor is equal to a 50-min hour?

What is the estimated production of the excavator in cubic yards bank measure?

Answer		
A.	284 bcy/hr	
B.	245 bcy/hr	
C.	185 bcy/hr	
D. 352 bcy/hr		

Material	Fill Factor (Percent)
Moist loam or sandy clay	100 to 110
Sand and gravel	95 to 110
Rock (poorly blasted)	40 to 50
Rock (well blasted)	60 to 75
Hard, tough clay	80 to 90



## <u>EXCAVATOR</u> EXAMPLE ANSWER I



Step 1. Size of bucket, 3cy

Step 2: Bucket fill factor (Table 9.4), hard clay 80 to 90%; use *average* 85%

Step 3. Typical cycle element times: 20 sec

Step 4: Efficiency Factor: 50 min/hour

Step 5: Class of Material, hard clay, swell 35%

Step 6: Excavator Production

 $=\frac{3600s/hr \times 3cy \times .85}{20s/cycle}x\frac{50\min}{60\min}x\frac{1}{(1+.35)}=283.3bcy/hr$