CONSTRUCTION OPERATIONS AND METHODS

**EQUIPMENT PRODUCTION**

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

- Dozers
- Graders
- Scrapers
- Loaders
- Excavators
- Cranes
- Compactors
- Dump Trucks

Cranes (will discuss another section)
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 x N) where Q = quantity of material to be moved
P = hourly production rate per dozer
N = Number of Dozers

Dozer Trick of Trade #3: To determine the number of dozers required to complete project
within specific time;
Total number of dozers = Q / (P x T) where Q = quantity of material to be moved
P = hourly production rate per dozer
T = maximum allowable duration in hours
- 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.
- Step 1b = find loaded vehicle weight (LVW) in tons. = EVW + weight of the load (WL)
  \[ WL = \text{scraper load volume (LCY)} \times \text{material unit weight (pounds per LCY) / 2000lb/ton} \]

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]) \times LVW
- RR Return = (40 + [30 x TP]) \times EVW
where - RR Haul = Rolling Resistance for the Haul Route
RR Return = Rolling Resistance for the Return Route
TP = Tire Penetration 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 \times \text{percent grade} \times \text{vehicle weight (tons)}
Therefore
- GR(+)Haul or GA(-)Haul = 20 \times \text{percent grade} \times \text{GVW (tons)}
- GR(+)Return or GA(-)Return = 20 \times \text{percent grade} \times \text{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.
**SCRAPPER PRODUCTION ESTIMATE SUMMARY**

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

\[-RPR = RR + GA(-) \text{ or } GR(+)\]

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.

→ 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.

→ 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.

→ The Travel speed could also be given in the question.

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

→ Total travel time is the sum of the time it takes the vehicle to complete one haul and one return. **Total TT** = **TT Haul** + **TT Return**, where TT = Travel Time

→ First figure out the Haul Travel Time,

\[-TT \text{ Haul} = \frac{\text{average haul distance (feet)}}{(88 \times \text{travel speed(mph)})}\]

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

→ Next figure out the return travel time (in minutes),

\[-TT \text{ Return} = \frac{\text{average return distance (feet)}}{(88 \times \text{travel speed(mph)})}\]

**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
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
GRADER
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.

\[ \text{Total time} = \frac{(P \times D)}{(S \times E)} \]

where—

- **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.
- 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.

\[
\text{Maximum production rate (LCY per hour)} = \text{heaped-bucket capacity} \times \text{bucket fill factor} \times 60 \text{ minutes} / \text{loader cycle time (min)}
\]

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.

\[
\text{Net production rate (LCY per hour)} = \text{maximum production rate (LCY per hour)} \times \text{efficiency factor}
\]

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.

\[
\text{Material weight (tons per LCY)} = \frac{\text{weight (pounds per LCY)}}{2,000 \text{ pounds per ton}}
\]

\[
\text{Net production rate (tons per hour)} = \text{net production rate (LCY per hour)} \times \text{material weight (tons per LCY)}
\]
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:

\[
q = \frac{(3600 \text{sec/hour} \times B \times E \times P)}{C} \times \text{Volume Correction}
\]

Volume Correction = for loose volume to bank volume = \(1/(1+\text{swell factor})\)

- \(q\) = 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
Compactor Trick of Trade #1: Use the following formula to determine compactor production in CCY per hour.

Production (CCY per hour) = \( \frac{16.3 \times W \times S \times L \times E}{N} \)

→ 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 = \( \frac{FD \times SCF}{CP} \)

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

\[
\text{Number of trucks required} = 1 + \frac{\text{truck cycle time (minutes)}}{\text{loader cycle time (minutes)}}
\]

• 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 3,000 LCY 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?
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
   \[ CF = \frac{2,300 \text{ lbs/LCY}}{2,500 \text{ lbs/LCY}} = .92 \]
b). Operator correction factor
   - use table provided = .75
c). Material – Type Correction Factor
   - use table provided = .8
d). Operating technique Correction Factor
   - use table provided = 1.2
e). Visibility Correction Factor
   - use table provided = 1.0
f). Efficiency Factor
   - 50 working minutes per hour / 60 minute working hour = .83
g). Machine transmission factor
   - use table provided = 1.0
h). Blade adjustment factor
   - use table provided = 1.0
i). Grade Correction Factor
   - use chart/graph provided = 1.15

Step 3: Determine total Correction Factor
\[ 1.15 \times .92 \times .75 \times .83 \times 1.2 \times x = .63 \]

Step 4: Determine Production
- Multiple Step 3 by Step 1 = 300LCY x .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) = \( \frac{Q}{(P \times N)} = \frac{3,000 \text{ LCY}}{(190 \text{ LCY} \times 1 \text{ dozer})} = 16 \text{ hours} \)

b. How many D7 dozers would be required to move 3000 LCY of clay in 7 hours?
   Total number of dozers = \( \frac{Q}{(P \times T)} = \frac{3,000 \text{ LCY}}{190 \text{ LCY per hour} \times 7 \text{ hours}} = 2.25 \text{ up 3} \)
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 an 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 operator's rest breaks and time required to turn around after each pass.

How many hours is required to grade the area?

Answer
A. 3 hours
B. 4 hours
C. 5 hours
D. 6 hours
GRADER

EXAMPLE ANSWER 1

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

\[ \text{Total time} = \frac{(P \times D)}{(S \times E)} \]

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.
  → This was given to be 2000 ft

Step 3: Figure out the Speed of the grader.
  → The speed was given as 4mph, which is 4mph \( \times \) 88 fpm/mph = 352 fpm

Step 4: Figure out the Efficiency factor.
  → This was also given to be .60

Step 5: Solve the equation
  → \( T = \frac{P \times D}{S \times E} = 30 \text{ pass} \times 2000\text{ft/pass} / (352 \text{ fpm}) \times .60 = 60,000 \text{ ft} / 211.2 \text{ fpm} = 284 \text{ mins} = 4.7 \text{ hrs} \) round up to 5 hours
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 having 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
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

\[
\text{Excavator Production} = \frac{3600s/\text{hr} \times 3\text{cy} \times .85}{20s/cycle} \times \frac{50\text{min}}{60\text{min}} \times \frac{1}{(1+.35)} = 283.3\text{bcy/hr}
\]