# Chapter 5

## Compacting and Finishing

## *Part 2*

# Compaction Operations

- After selecting appropriate compaction equipment, a **compaction plan** must be developed.
- The major variables to be considered include:
  1. soil moisture content,
  2. lift thickness,
  3. number of passes used,
  4. ground contact pressure,
  5. compactor weight, and
  6. compactor speed.
- For vibratory compactors, it is also necessary to consider
  7. the frequency and amplitude of vibration to be employed.

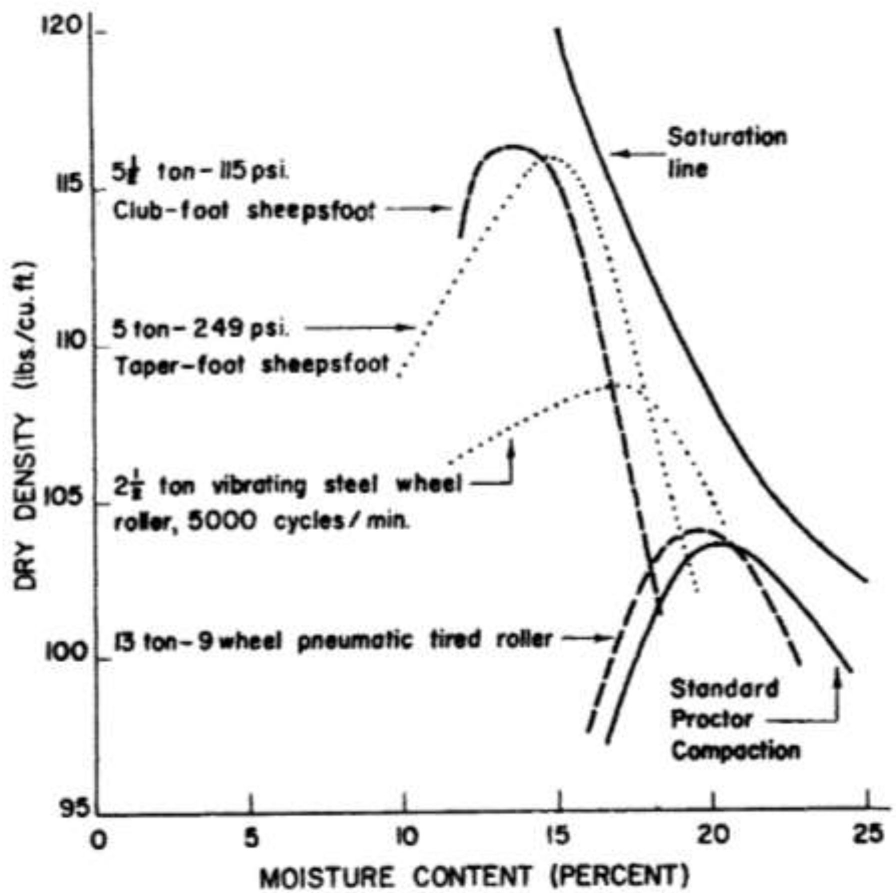
# Compaction Operations

- 1. soil moisture content
  - – the compactive effort delivered by a piece of compaction equipment will seldom be exactly the same as that of either the standard or modified compaction test.
  - – Thus, the field optimum moisture content for a particular soil/compactor combination will seldom be the same as the laboratory optimum.

# Compaction Operations

- This is illustrated by Figure 5-11, where only one of the four compactors has a field optimum moisture content close to the laboratory optimum.

**FIGURE 5-11**: Variation of optimum moisture content with roller type. (From reference 6)




THE EFFECT OF MOISTURE CONTENT ON THE DRY DENSITY OF A SILTY CLAY (CL) SOIL IN 9 in. LOOSE LAYERS WHEN FULLY COMPACTED BY UP TO 64 PASSES BY DIFFERENT TYPES OF COMPACTING EQUIPMENT.

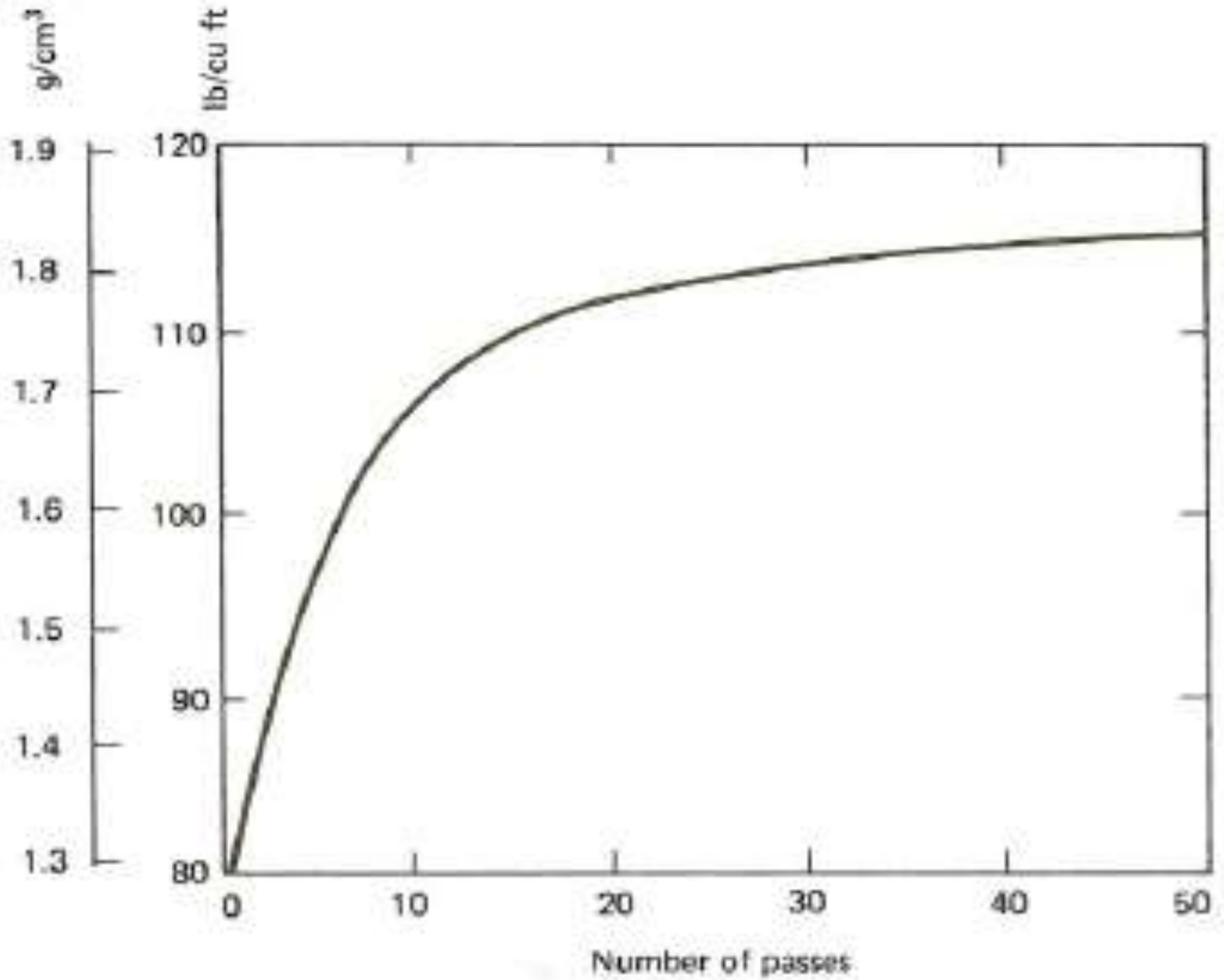
# Compaction Operations

- 2. Lifts thicknesses :
  - It should be kept thin for most effective compaction.
  - For all rollers, except vibratory rollers and heavy pneumatic rollers, a maximum of 5 to 8 in. (15 to 20 cm).
  - The maximum lift thickness depends on the static weight of the compactor.

# Compaction Operations

- 3. number of passes
- The compaction achieved by repeated passes:
  - The compaction achieved by repeated passes of a compactor depends on the soil/compactor combination utilized.
  - For some combinations (such as a tamping foot roller compacting a clayey gravel), significant increases in density may continue to occur beyond 50 passes.
  - As shown in Figure 5-12, the increase in density is relatively small after about 10 passes for most soil/compactor combinations.

# **FIGURE 5-12**: Typical effect of number of passes.



- 4. Effect of Ground contact pressure on Compaction:
  - for a tamping foot roller, Ground contact pressure may vary from:
    - 30 lb/sq in. (207 kPa) for a pneumatic roller to
    - 300 lb/sq in. (2070 kPa) or more for tamping foot rollers.
  - Within these ranges it has been found that:
    - total roller weight has a much more pronounced effect on the compaction achieved than does contact pressure.
  - The use of excessive ground contact pressure will result in shearing and displacement of the soil being compacted.

- 6. Effect of Travel time on Compaction:
  - Except for vibratory compactors, tests have shown little relationship between compactor travel speed and the compaction achieved.
  - For vibratory equipment,
    - travel speed (at a fixed operating frequency) determines the number of vibrations that each point on the ground surface will receive.
    - Therefore, when using vibratory equipment, tests should be performed to determine the compactor speed that results in the highest compactor productivity.
  - For conventional equipment the highest possible speed should be utilized that does not result in excessive surface displacement.

# Estimating Compactor Production

- Equation 5-1 may be used to calculate compactor production based on:
  - compactor speed,
  - lift thickness, and
  - effective width of compaction.
- The accuracy of the result obtained will depend on the accuracy in estimating <u>speed</u> and <u>lift thickness</u>.
- Trial operations will usually be necessary to obtain accurate estimates of these factors.
- Typical compactor operating speeds are given in Table 5-3.

**TABLE 5-3**: Typical operating speed of compaction equipment

| Compactor | Speed mi/h | Speed km/h |
|---|---|---|
| Tamping foot, crawler-towed | 3–5 | 5–8 |
| Tamping foot, wheel-tractor-towed | 5–10 | 8–16 |
| High-speed tamping foot | | |
| First two or three passes | 3–5 | 5–8 |
| Walking out | 8–12 | 13–19 |
| Final passes | 10–14 | 16–23 |
| Heavy pneumatic | 3–5 | 5–8 |
| Multitired pneumatic | 5–15 | 8–24 |
| Grid roller | | |
| Crawler-towed | 3–5 | 5–8 |
| Wheel-tractor-towed | 10–12 | 16–19 |
| Segmented pad | 5–15 | 8–24 |
| Smooth wheel | 2–4 | 3–6 |
| Vibratory | | |
| Plate | 0.6–1.2 | 1–2 |
| Roller | 1–2 | 2–3 |

# Estimating Compactor Production

Production (CCY/h)= $16.3 \times W \times S \times L \times E / P$ (5-lA)

Production (CCM/h) = $10 \times W \times S \times L \times E / P$ (5-lB)

Where

$P$ = number of passes required

$W$ = width compacted per pass (ft or m)

S = compactor speed (mi/h or km/h)

$L$ = compacted lift thickness (in. or cm)

$E$ = job efficiency

# Estimating Compactor Production

- The power required to tow rollers depends on the roller's total resistance (grade plus rolling resistance).
  - The rolling resistance of tamping foot rollers has been found to be approximately 450 to 500 lb/ton (225 to 250 kg/t).
  - The rolling resistance of pneumatic rollers and the maximum vehicle speed may be calculated by the methods of Chapter 4.

# Job Management

- trial operations are usually required to determine:
  - the exact values of soil moisture content,
  - lift thickness,
  - compactor weight, and
  - vibrator frequency and amplitude that yield maximum productivity while achieving the specified soil density.
- The use of a nuclear density device to measure the soil density actually being obtained during compaction is strongly recommended.

# Job Management

- Traffic planning and control is an important factor in compaction operations.
- Hauling equipment must be given the right-of-way without excessively interfering with compaction operations.

# 5-3 SOIL STABILIZATION

- *Soil stabilization* has been defined as:
  - the process of giving natural soils enough abrasive resistance and shear strength to accommodate traffic or loads.
- Soil stabilization methods include:
  - mechanical methods,
  - hydraulic methods,
  - reinforcement methods ,and
  - physiochemical methods.
- Some techniques falling under each of these categories are shown in Table 5-4.

# **TABLE 5-4**: Soil stabilization methods

| Mechanical | Hydraulic | Reinforcement | Physiochemical |
|---|---|---|---|
| Compaction | Drainage | Confinement | Admixtures |
| Deep compaction | Preloading | Inclusions | Freezing |
| Vibroflotation | Electroosmosis | Minipiles | Grouting |
| | | Soil nailing | Heating |
| | | Stone columns | |

- Deep compaction: dropping heavy weight ( 9-36 t) from a crane (15-30m) to increase the density of soil to a depth of up to 9 m.
- Vibroflotation: increasing density of cohesionless soil by inserting a vibratory probe into soli.
- Electroosmosis: employs electrical current to speed up the drainage of cohesive soils.

# 5-4 GRADING AND FINISHING

- *Grading* is the process of bringing earthwork to the desired shape and elevation (or grade).
- *Finish grading,* or simply *finishing,* involves:
  - smoothing slopes,
  - shaping ditches, and
  - bringing the earthwork to the elevation required by the plans and specification.
- Finishing usually follows closely behind excavation, compaction, and grading.
- Finishing, in turn, is usually followed closely by seeding or sodding (grass) to control soil erosion.

# 5-4 GRADING AND FINISHING

- The piece of equipment most widely used for grading and finishing is the motor grader (Figure 5-13).
- Grade trimmers and excavators are frequently used on large highway and airfield projects
  - because their operating speed is greater than that of the motor grader.

**FIGURE 5-13**: Modern motor grader.
(Courtesy of Fiatallis North America, Inc.)
https://www.youtube.com/watch?v=bFoN5LD0Q-w
https://www.youtube.com/watch?v=ZNWafIsqI_g

- In highway construction,
  - the process of cutting down high spots and filling in low spots of each roadway layer is called *balancing.*
  - *Trimming* is the process of bringing each roadway layer to its final grade.

- **Motor Grader**
- **Grade Excavators and Trimmers**
- **Estimating Grader Production**
- **Job Management**

# Motor Grader

- The *motor grader* is one of the most versatile items of earthmoving equipment.
- It can be used for:
  - light stripping,
  - grading,
  - finishing,
  - trimming,
  - bank sloping,
  - ditching,
  - backfilling, and
  - scarifying.

# Motor Grader

- It is also :
  - capable of mixing and spreading soil and asphaltic mixtures.
  - used on building construction projects as well as in heavy and highway construction.
  - It is frequently used for the maintenance of highways and haul roads.

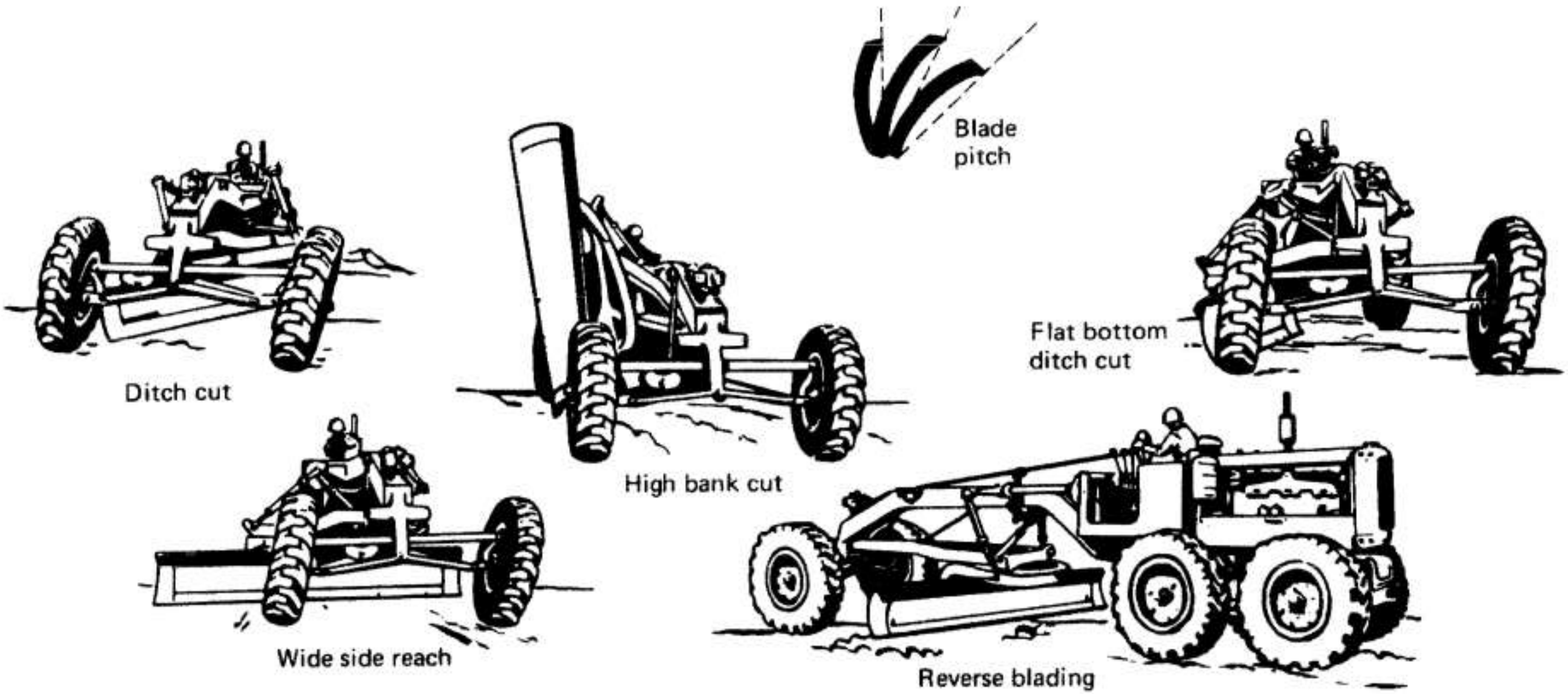
# Motor Grader

- The blade of a motor grader:
  - is referred to as a *moldboard* and is equipped with replaceable cutting edges and end pieces (end bits).
  - The wide range of possible blade positions is illustrated in Figure 5-15.

# **FIGURE 5-15:** Blade positions for the motor grader.

(U.S. Department of the Army)

https://www.youtube.com/watch?v=S1GSkljGjsg

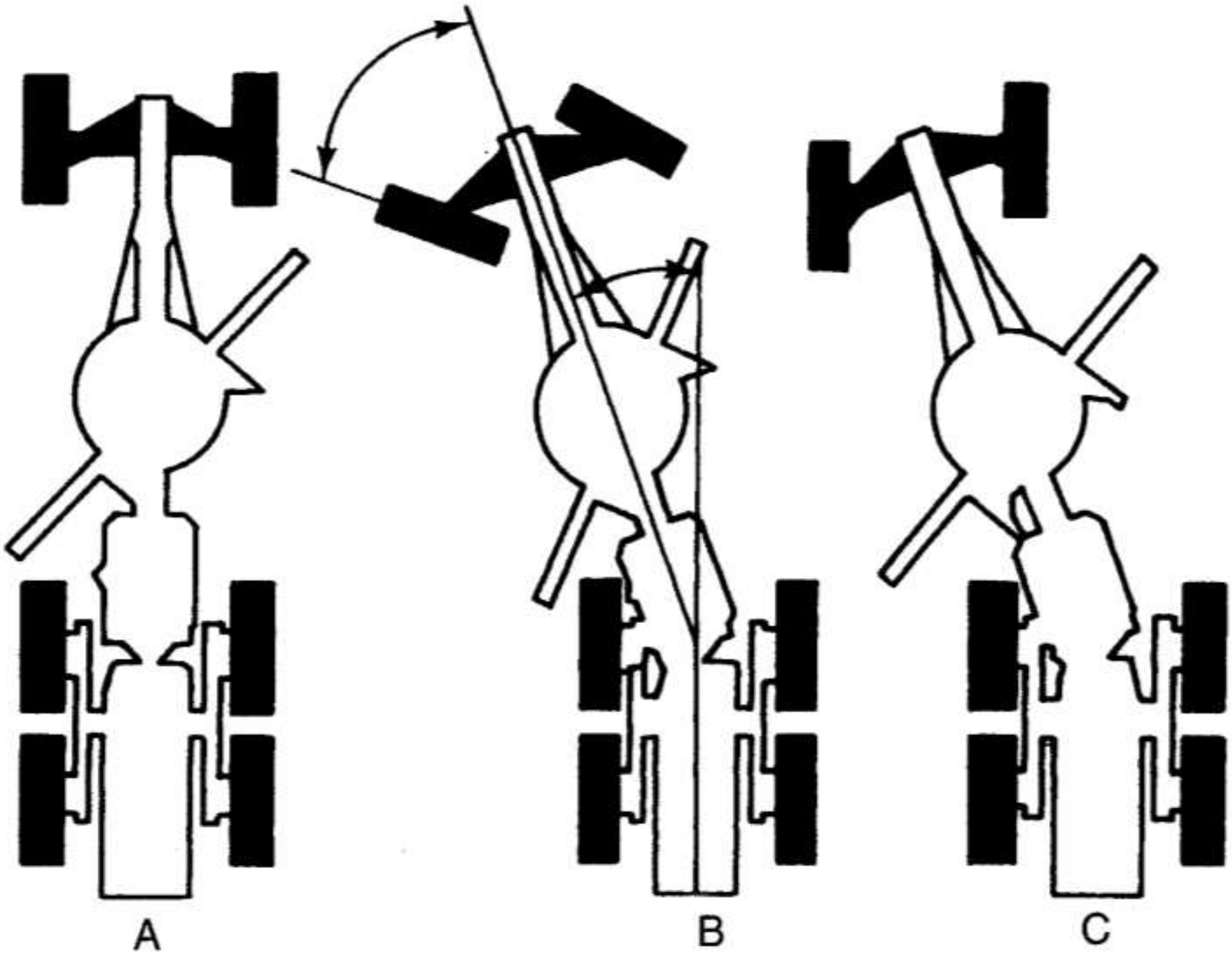


# Motor Grader

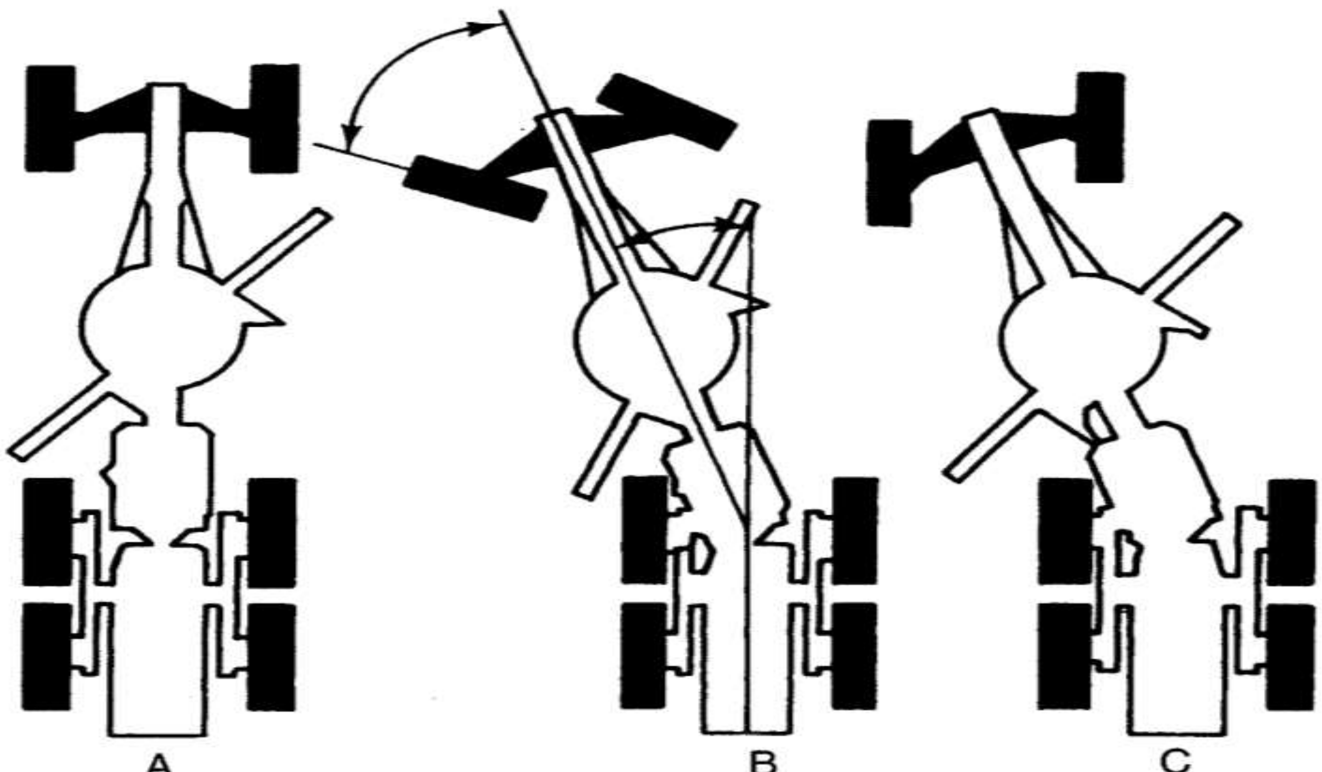
- Motor graders are available with articulated frames that increase grader maneuverability.
- The three possible modes of operation for an articulated grader are illustrated in Figure 5-16.

**FIGURE 5-16:** Articulated grader positions.

https://www.youtube.com/watch?v=JQXaW2svM7w



- The machine operation modes are:
  - **Conventional manner** when in the straight mode (Figure 5-16A).
  - **Articulated mode** (Figure 5-16B) to allow the machine to turn in a short radius.
  - **The crab mode** (Figure 5-16C) permits the rear driving wheels to be offset so that they remain on firm ground while the machine cuts banks, side slopes, or ditches.



# Motor Grader

- The front wheels of both conventional and articulated graders may be leaned from side to side.
- Wheels are leaned away from the cut to:
  - offset the side thrust produced by soil pressure against the angled blade.
  - assist in turning the grader.

# Motor Grader

- Graders are available with automatic blade control systems that:
  - permit precise grade control.
  - utilize a sensing system that follows an existing surface, string line, or laser beam to automatically raise or lower the blade as required to achieve the desired grade.

# Grade Excavators and Trimmers

- *Grade excavators* or *trimmers:*
  - they are machines that are capable of finishing roadway and airfield subgrades and bases faster and more accurately than can motor graders.
  - Many of these machines also act as reclaimers.
  - they are capable of scarifying and removing soil and old asphalt pavement.

**FIGURE 5-17:** Large grade trimmer/reclaimer/paver.
(Courtesy of CMI Corp.)

# Grade Excavators and Trimmers

- Grade trimmers:
  - They lack the versatility of motor graders.
  - They are very useful on large roadway and airfield projects.
    - Because of their accuracy and high speed.
  - Their large size often requires that they be partially disassembled and transported between job sites on heavy equipment trailers.

# Estimating Grader Production

- Grader production is usually calculated:
  - on a linear basis (miles or kilometers completed per hour) for roadway projects and
  - on an area basis (square yards or square meters per hour) for general construction projects.
- The time required to complete a roadway project may be estimated as follows:

$$\text{Time (h)} = \left[ \sum \frac{\text{Number of passes} \times \text{Section length (mi or km)}}{\text{Average speed for section (mi/h or km/h)}} \right] \times \frac{1}{\text{Efficiency}} \quad \textbf{(5–2)}$$

# Estimating Grader Production

- Average speed will depend on:
  - operator skill,
  - machine characteristics, and
  - job conditions.
- Typical grader speeds for various types of operations are given in Table 5-6.

# **TABLE 5-6**: Typical grader operating speed

| Operation | Speed | |
|---|---|---|
| | *mi/h* | *km/h* |
| Bank sloping | 2.5 | 4.0 |
| Ditching | 2.5–4.0 | 4.0–6.4 |
| Finishing | 4.0–9.0 | 6.5–14.5 |
| Grading and road maintenance | 4.2–6.0 | 6.4–9.7 |
| Mixing | 9.0–20.0 | 14.5–32.2 |
| Snow removal | 12.0–20.0 | 19.3–32.3 |
| Spreading | 6.0–9.0 | 9.7–14.5 |

# EXAMPLE 5-1

Fifteen miles (24.1 km) of gravel road require reshaping and leveling. You estimate that six passes of a motor grader will be required. Based on operator skill, machine characteristics, and job conditions, you estimate two passes at 4 mi/h (6.4 km/h), two passes at 5 mi/h (8.0 km/h), and two passes at 6 mi/h (9.7 km/h). If job efficiency is 0.80, how many grader hours will be required for this job?

**Solution**

$$\text{Time (h)} = \left(\frac{2 \times 15}{4.0} + \frac{2 \times 15}{5.0} + \frac{2 \times 15}{6.0}\right) \times \frac{1}{0.80} = 23.1\text{ h} \qquad \text{(Eq 5–2)}$$

$$\left[= \left(\frac{2 \times 24.1}{6.4} + \frac{2 \times 24.1}{8.9} + \frac{2 \times 24.1}{9.7}\right) \times \frac{1}{0.80} = 23.1\text{ h}\right]$$

# Job Management

- to maximize grader production efficiency, it is required:
  - Careful job planning,
  - the use of skilled operators, and
  - competent supervision.
- Use the minimum possible number of grader passes to accomplish the work.
- Eliminate as many turns as possible.