

Chapter 3

Excavating and Lifting

Part 1

3-1 INTRODUCTION

- **Excavating and Lifting Equipment**
- **Excavators and Crane-Shovels**
- **Excavator Production**

Excavating and Lifting Equipment

- An *excavator* is defined as a power-driven digging machine.
- The major types of excavators used in earthmoving operations include
 - 1. Hydraulic excavators
 - 2. Members of the cable-operated crane-shovel family (shovels, draglines, hoes, and clamshells).
 - 3. Dozers, loaders, and scrapers can also serve as excavators.



FIGURE 3-1 Hydraulic excavator-backhoe. (Courtesy of Caterpillar Inc.)

2. Members of the cable-operated crane-shovel family (shovels, draglines, hoes, and clamshells).



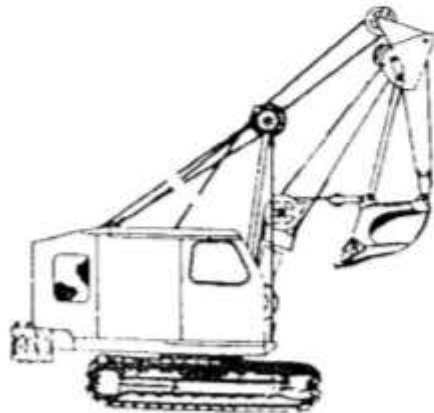
CRANE (HOOK)



CLAMSHELL



DRAGLINE



BACK HOE



SHOVEL



PILEDRIVER

Figure 3-2 Members of the cable-operated crane-shovel family. (U.S. Department of the Army)

3. Dozers, loaders, and scrapers



Excavating and Lifting Equipment

- In this chapter we focus on
 - hydraulic excavators and
 - the members of the crane-shovel family used for excavating and lifting operations.

- Members of this family include:
 - the shovel, backhoe, dragline, clamshell, mobile crane, and pile driver.



CRANE (HOOK)



CLAMSHELL



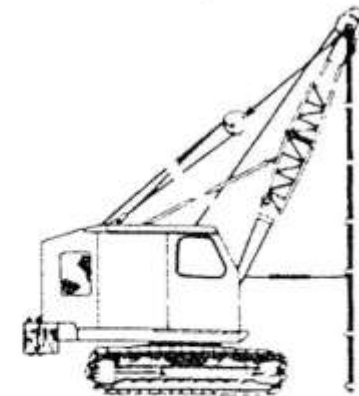
DRAGLINE



BACK HOE



SHOVEL



PILEDRIVER

Figure 3-2 Members of the cable-operated crane-shovel family. (U.S. Department of the Army)

- *hydraulic excavators* have largely replaced the cable-operated crane-shovel family.
- functionally similar hydraulic machines are available including the **front shovel** and **backhoe**.
- Attachments available for the hydraulic excavator include *clamshells, augers, compactors, and hammers*.



- The advantages of hydraulic excavators over cable-operated machines are:
 - faster cycle time,
 - higher bucket penetrating force,
 - more precise digging, and
 - easier operator control.

- Excavators and crane-shovels consist of three major assemblies:
 - A. a carrier or mounting (crawler, truck, and wheel mountings)
 - B. a revolving superstructure containing the power and control units (also called the revolving deck or turntable)
 - C. a front-end assembly.

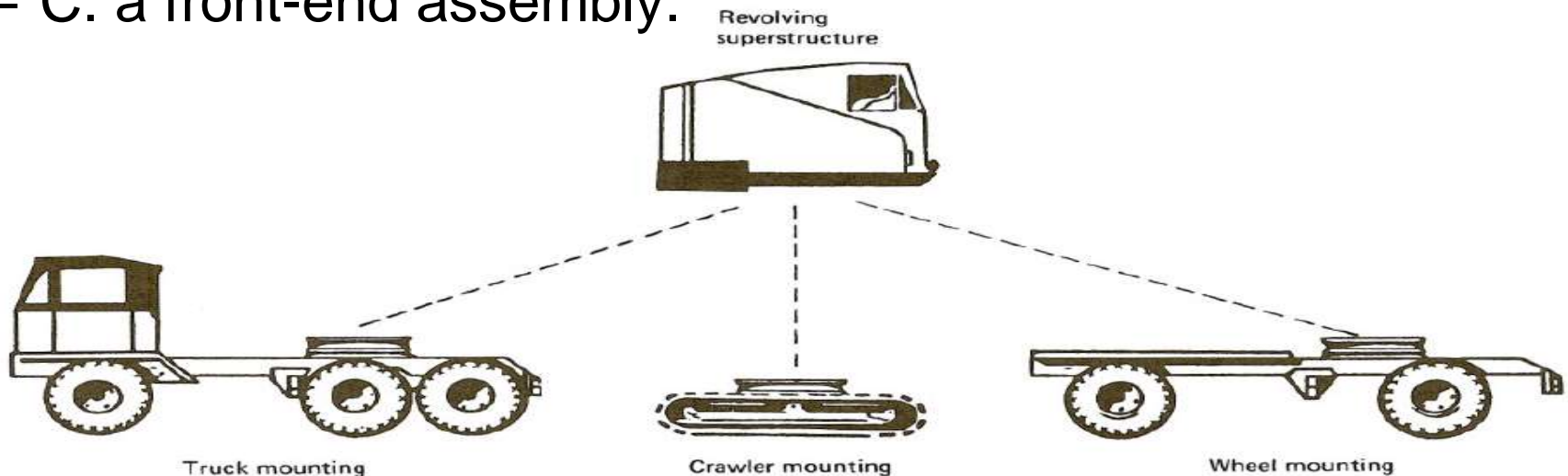


FIGURE 3-2 Crane-shovel mountings and revolving superstructure. (U.S. Department of the Army)

- The crawler mounting
 - provides excellent on-site mobility and its low ground pressure enables it to operate in areas of low trafficability.
 - widely used for drainage and trenching work as well as for rock excavation.

- Truck and wheel mountings
 - They provide greater mobility between job sites
 - but are less stable than crawler mountings and require better surfaces over which to operate.
 - Truck mountings use a modified truck chassis as a carrier and thus have separate stations for operating the carrier and the revolving superstructure.

- Wheel mountings use a single operator's station to control both the carrier and the excavating mechanism.
- Truck mountings are capable of highway travel of 50 mile/hr (80 km/hr) or more, whereas wheel mountings are usually limited to 30 mile/hr (48 km/hr) or less.

Comparison summary between the 3 mounting types

Mounting	On-site Mobility	Mobility between job site	Number of Station	Speed limit
Crawler	Excellent	low	1	Low speed
Truck	Good	Great	2	50 mile/hr [80 km/hr]
Wheel	Good	Great	1	30 mile/hr [48 km/hr]

Excavating and Lifting Equipment

- Issues will be discussed:
 - the principles of operation,
 - methods of employment, and
 - techniques for estimating the production of
 - shovels, backhoes, clamshells, and draglines.
 - Cranes and their employment are also discussed.

Excavator Production

- To utilize Equation 2-1 for estimating the production of an excavator, it is necessary to know the volume of material actually contained in one bucket load.

Production =

$$\text{Volume per cycle} \times \text{Cycles per hour (2-1)}$$

- The methods by which excavator bucket and dozer blade capacity are rated are given in Table 3-1.

TABLE 3-1
Bucket-capacity rating methods

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

Excavator Production

- *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.

Excavator Production

- *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.

Excavator Production

- **Note:** 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.**

Excavator Production

- 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*.

TABLE 3-2**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

EXAMPLE 3-1

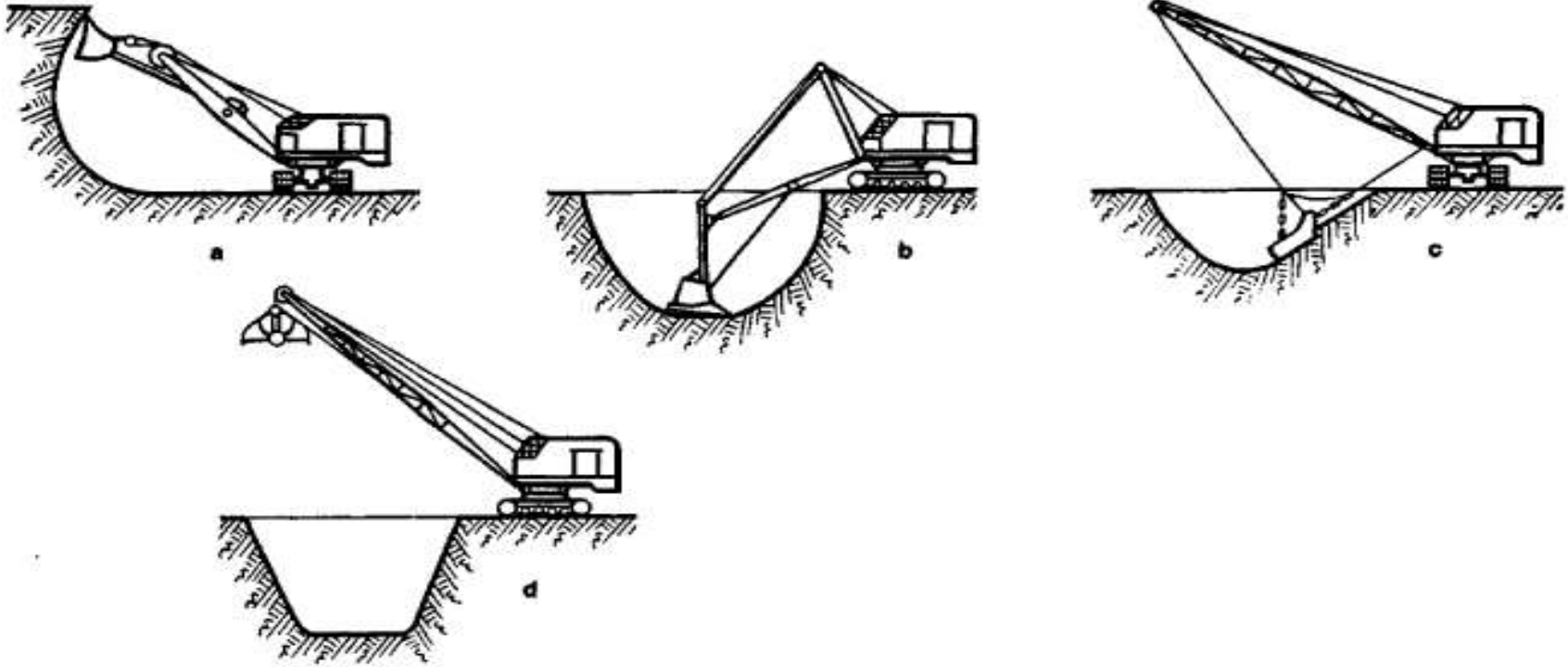
Estimate the actual bucket load in bank cubic meter for a loader bucket whose heaped capacity is 3.82 m^3 . The soil's bucket fill factor is 0.90 and its load factor is 0.80.

Solution

$$\text{Bucket load} = 3.82 \times 0.90 = 3.44 \text{ LCM} \times 0.80 = 2.75 \text{ BCM}$$

3-2 HYDRAULIC EXCAVATORS

- Operation and Employment
- Production Estimating
- Job Management

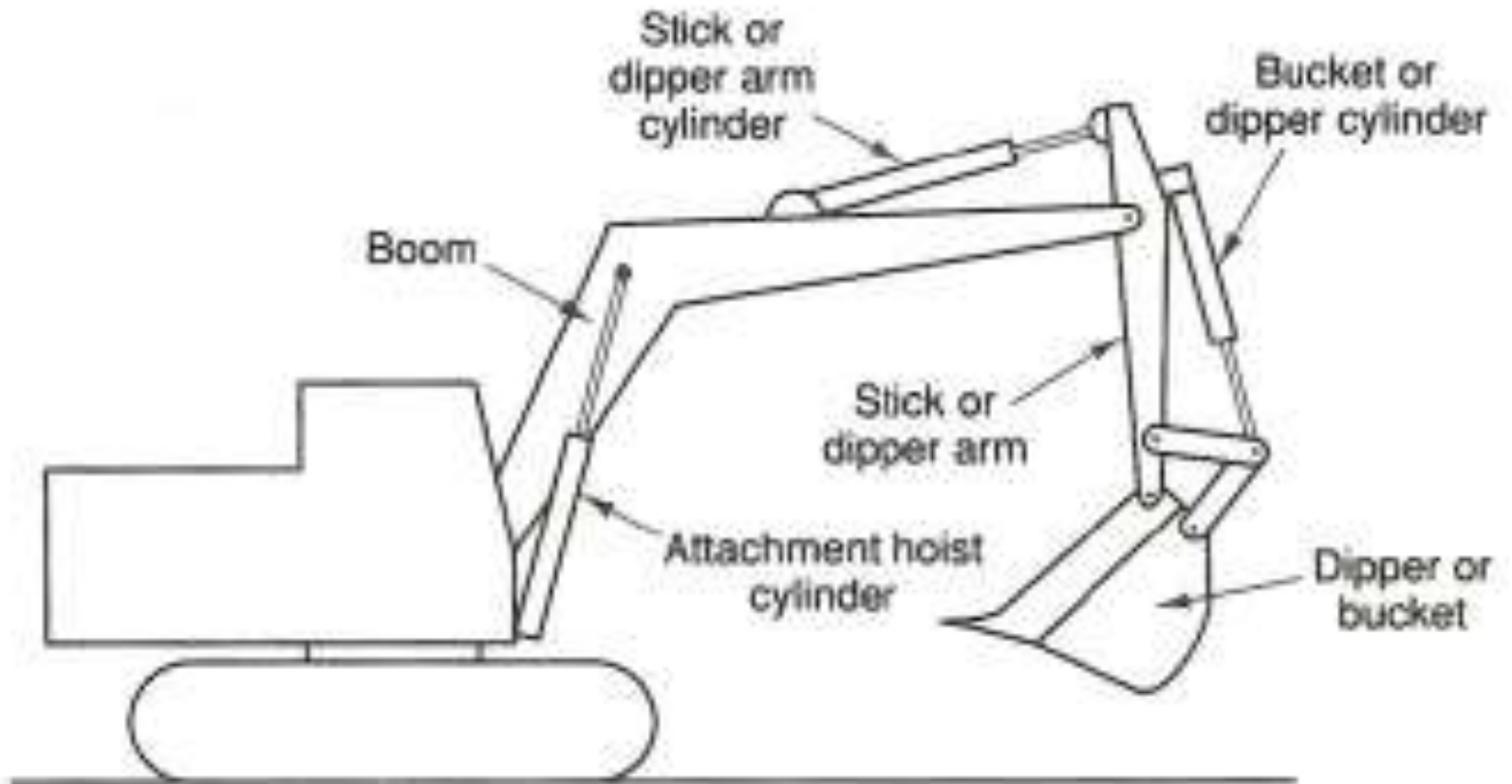


BACKHOE

- A *backhoe* (or simply *hoe*) is an excavator designed primarily for excavation below grade.
- The backhoe is widely utilized for trenching work.



FIGURE 3-3: Components of a hydraulic excavator-backhoe



Operation and Employment

- In trench excavation the best measure of production is the **length of trench excavated per unit of time**.
 - Therefore, a dipper width should be chosen which matches the required trench width as closely as possible.

Operation and Employment

- When equipped with dozer blade, they may also be employed in:
 - leveling,
 - grading,
 - backfilling, and
 - general job cleanup.

Production Estimating

$$\text{Production (LCY/h)} = C \times S \times V \times B \times E \quad (3-1)$$

Where C = cycles/h (Table 3-3)

S = swing-depth factor (Table 3-4)

V = heaped bucket volume (LCY or LCM)

B = bucket fill factor (Table 3-2)

E = job efficiency

Table 3-3 Standard cycles per hour for hydraulic excavators

Type of Material	Machine Size			
	Wheel Tractor	Small Excavator: 1 yd (0.76 m ³) or Less	Medium Excavator: 1¼–2¼ yd (0.94–1.72 m ³)	Large Excavator: Over 2½ yd (1.72 m ³)
Soft (sand, gravel, loam)	170	250	200	150
Average (common earth, soft clay)	135	200	160	120
Hard (tough clay, rock)	110	160	130	100

Table 3-4 Swing-depth factor for backhoes

Depth of Cut (% of Maximum)	Angle of Swing (deg)					
	45	60	75	90	120	180
30	1.33	1.26	1.21	1.15	1.08	0.95
50	1.28	1.21	1.16	1.10	1.03	0.91
70	1.16	1.10	1.05	1.00	0.94	0.83
90	1.04	1.00	0.95	0.90	0.85	0.75

- In trenching 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 the trench from the trench walls.
- Normal excavator production should be multiplied by the appropriate value from Table 3-5 to obtain the effective trench production.

Table 3–5 Adjustment factor for trench production

Type of Material	Adjustment Factor
Loose (sand, gravel, loam)	0.60–0.70
Average (common earth)	0.90–0.95
Firm (firm plastic soils)	0.95–1.00

EXAMPLE 3-2

- Find the expected production in loose cubic meter (LCM) per hour of a small hydraulic excavator.
 - Heaped bucket capacity is 0.57 m^3 .
 - The material is sand and gravel with a bucket fill factor of 0.95.
 - Job efficiency is 50 min/h.
 - Average depth of cut is 4.3 m.
 - Maximum depth of cut is 6.1m and
 - average swing is 90° .

EXAMPLE 3-2

Solution

Cycle output = 250 cycles/60 min (Table 3-3)

Depth of cut (% of maximum) = $(4.3 / 6.1) \times 100 = 70\%$

Swing-depth factor = 1.00 (Table 3-4)

Bucket volume = 0.57 LCM

Bucket fill factor = 0.95

Job efficiency = $50/60 = 0.833$

Production = $250 \times 1.00 \times 0.57 \times 0.95 \times 0.833 = 113 \text{ LCM/h}$

Job Management

- In selecting the proper backhoe for a project, consideration must be given to the :
 - maximum depth,
 - working radius, and
 - dumping height required.
- Check also for adequate clearance for the carrier, superstructure, and boom during operation.

Job Management

- Although the backhoe will excavate fairly hard material, do not use the bucket as a sledge in attempting to fracture rock.
- Light blasting, ripping, or use of a power hammer may be necessary to loosen rock sufficiently for excavation.
- When lifting pipe into place do not exceed load given in the manufacturer's safe capacity chart for the situation.

3-3 SHOVELS

- **Operation and Employment**
- **Production Estimating**
- **Job Management**



FIGURE 3-6: Hydraulic shovel.
(Courtesy of Kobelco American, Inc.)

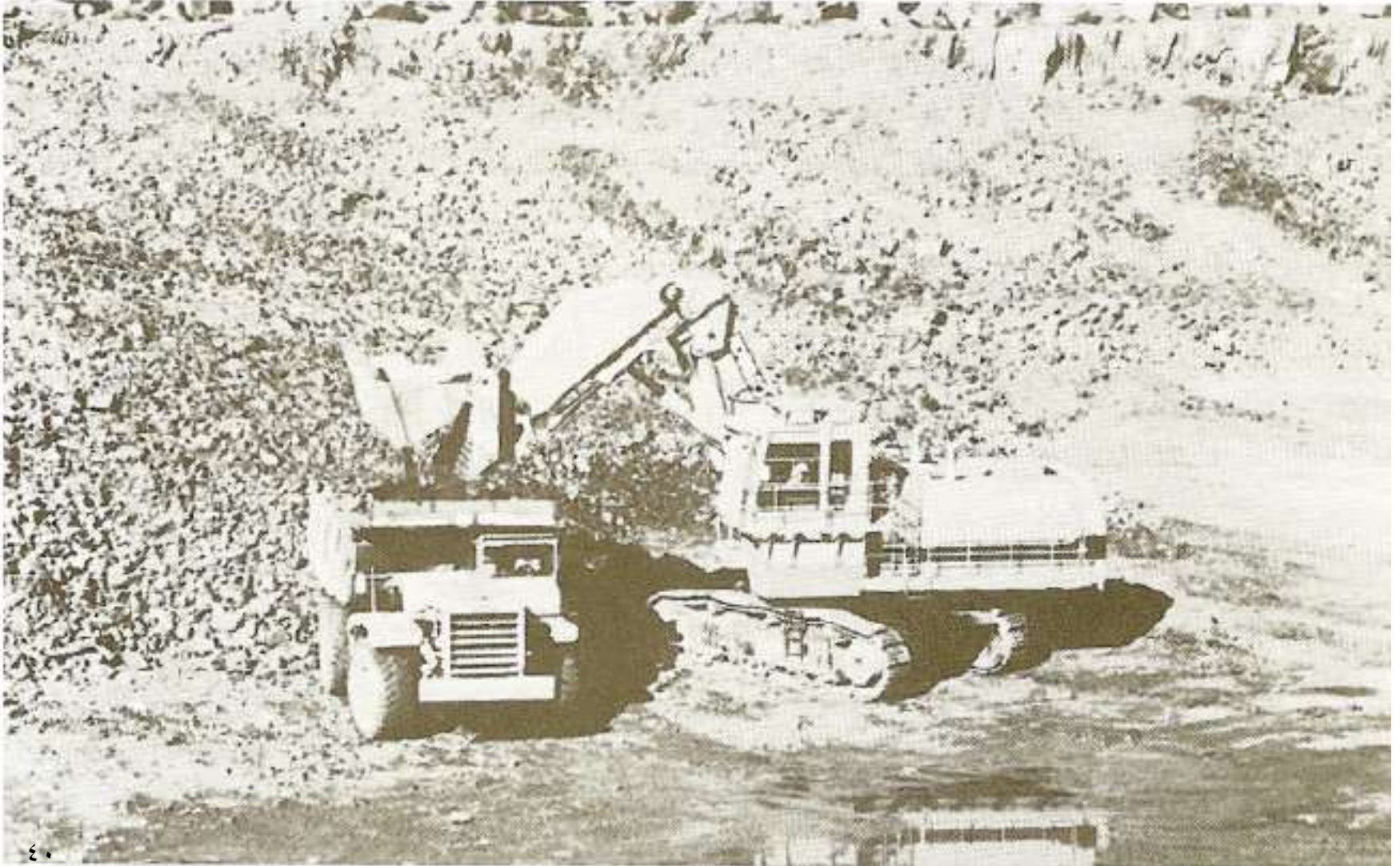
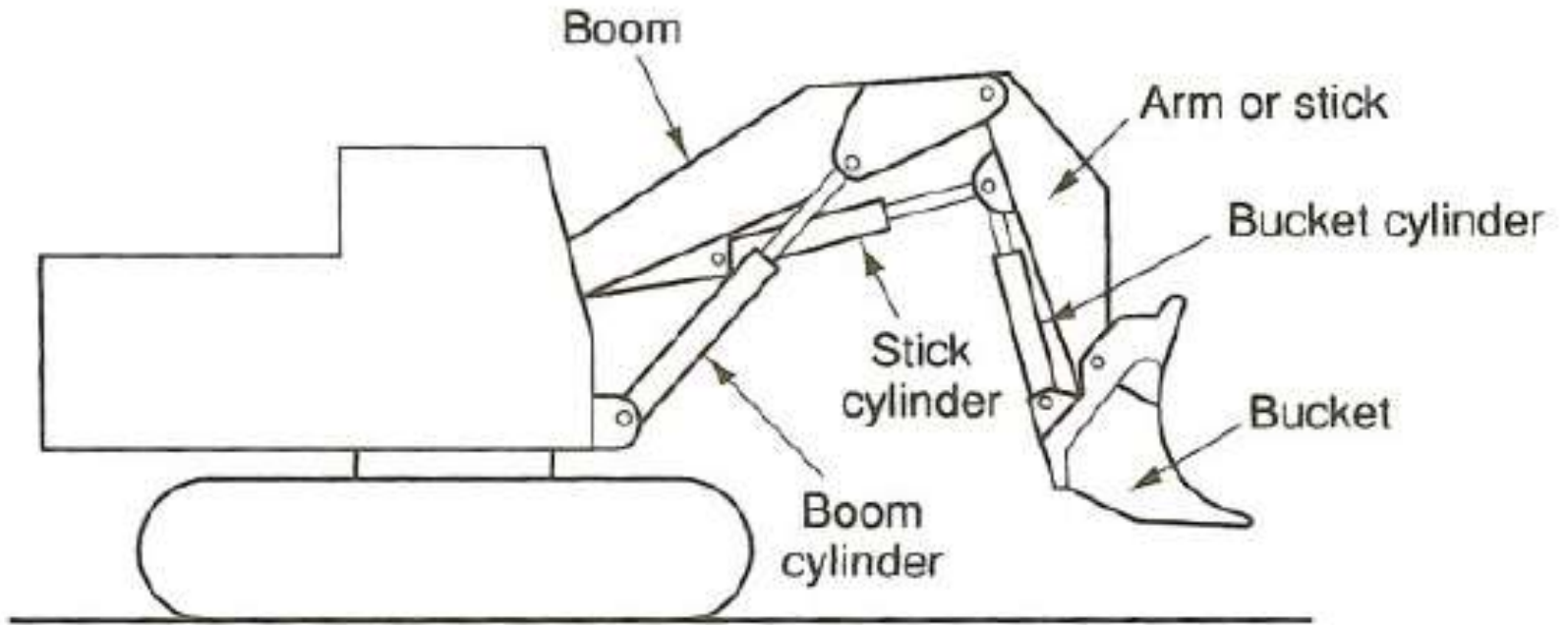


FIGURE 3-7: Components of a hydraulic shovel



<https://www.youtube.com/watch?v=H4Kx84DO4KU>

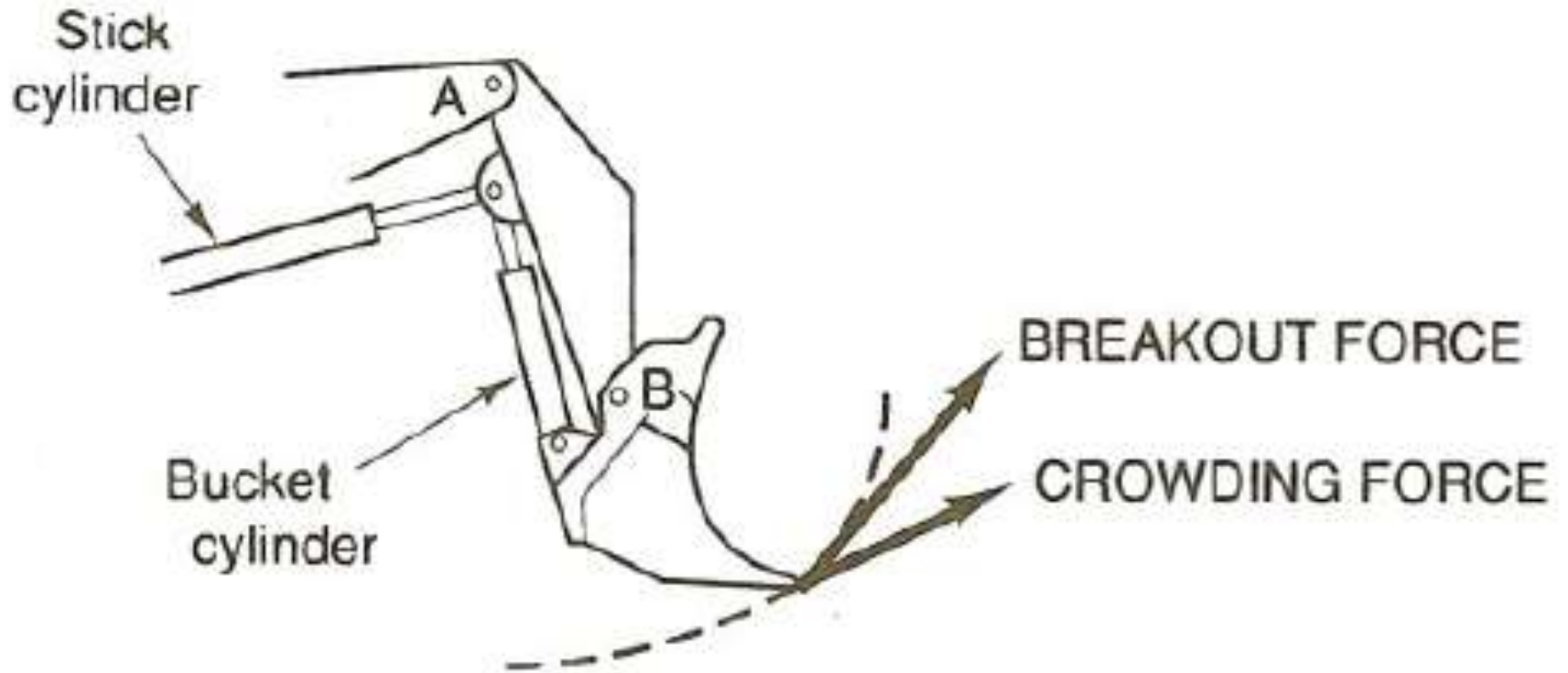
Operation and Employment

- The *hydraulic shovel* illustrated in Figure 3-6
- It is also called a :
 - *front shovel* or
 - *hydraulic excavator-front shovel.*

Operation and Employment

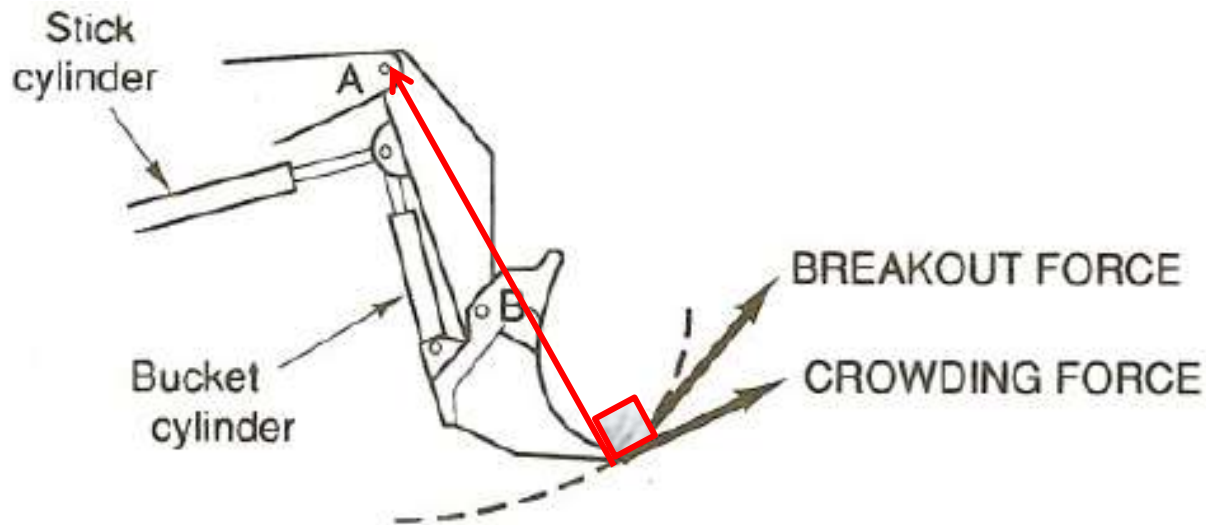
- The hydraulic shovel digs with a combination of:
 1. crowding force and
 2. breakout (or prying) force.
- illustrated in Figure 3-8.

FIGURE 3-8: Digging action of a hydraulic shovel



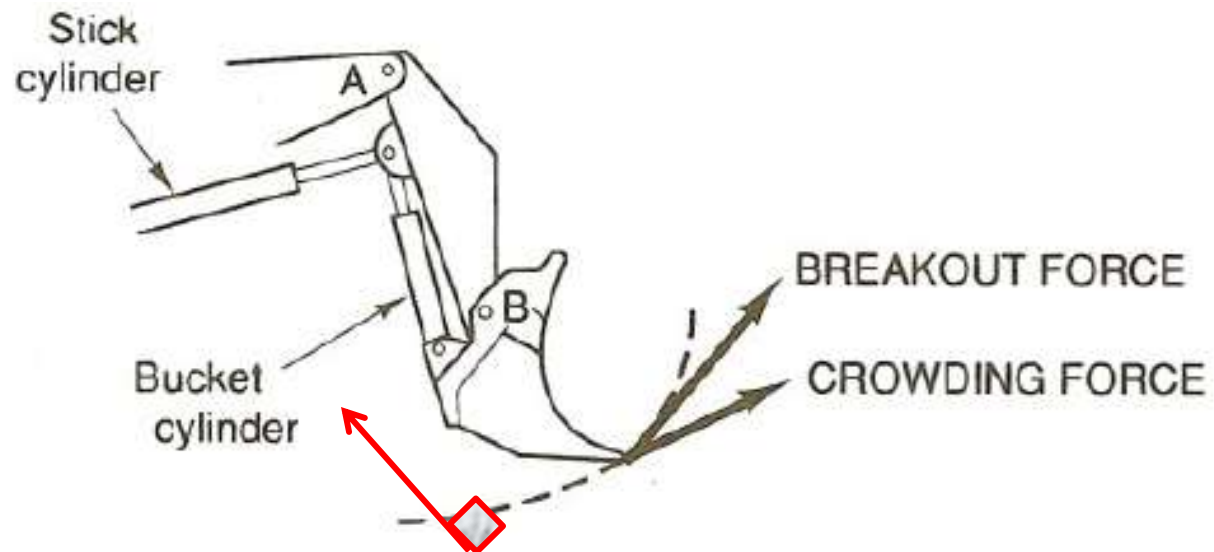
Operation and Employment

1. Crowding force: is generated by the stick cylinder and acts at the bucket edge on a tangent to the arc of the radius from point A.



Operation and Employment

2. Breakout force: is generated by the bucket cylinder and acts at the bucket edge on a tangent to the arc of the radius through point *B*.



- For hydraulic shovels, there are 2 types of Bucket available:
 - front-dump buckets and
 - bottom-dump buckets.



Operation and Employment

- Bottom-dump buckets are:
 - more versatile,
 - provide greater reach and dump clearance, and
 - produce less spillage.
 - Bottom-dump buckets are heavier than front-dump buckets of equal capacity, resulting in a lower bucket capacity for equal bucket weight.
- Front-dump buckets:
 - cost less and
 - require less maintenance.

Operation and Employment

- Shovel has a limited ability to dig below track level.
 - It is most efficient when digging **above** track level.
- For most effective digging, the shovel should have a vertical face to dig against.
 - This surface, known as *digging face*,
 - It is easily formed when excavating a bank of hillside.

Production Estimating

- Production for hydraulic shovels may be estimated using Equation 3-2 together with Table 3-6, which has been prepared from manufacturers' data.

$$\text{Production (LCY/h or LCM/h)} = C \times S \times V \times B \times E \quad (3-2)$$

where

C = cycles/h (Table 3-6)

S = swing factor (Table 3-6)

V = heaped bucket volume (LCY or LCM)

B = bucket fill factor (Table 3-2)

E = job efficiency

Table 3-6 Standard cycles per hour for hydraulic shovels

Material	Machine Size					
	<i>Small</i> <i>Under 5 yd (3.8 m³)</i>		<i>Medium</i> <i>5–10 yd (3.8–7.6 m³)</i>		<i>Large</i> <i>Over 10 yd (7.6 m³)</i>	
	Bottom Dump	Front Dump	Bottom Dump	Front Dump	Bottom Dump	Front Dump
Soft (sand, gravel, coal)	190	170	180	160	150	135
Average (common earth, soft clay, well-blasted rock)	170	150	160	145	145	130
Hard (tough clay, poorly blasted rock)	150	135	140	130	135	125

	Adjustment for Swing Angle					
	<i>Angle of Swing (deg)</i>					
	45	60	75	90	120	180
Adjustment factor	1.16	1.10	1.05	1.00	0.94	0.83

EXAMPLE 3-3

- Find the expected production in loose cubic meter (LCM) per hour of:
 - a 2.3-m³ hydraulic shovel equipped with a front-dump bucket.
 - The material is common earth with a bucket fill factor of 1.0.
 - The average angle of swing is 75° and
 - job efficiency is 0.80.

EXAMPLE 3-3

Solution

Standard cycles = 150/60 min (Table 3-3)

Swing factor = 1.05 (Table 3-3)

Bucket volume = 2.3 LCM

Bucket fill factor = 1.0

Job efficiency = 0.80

Production = $150 \times 1.05 \times 2.3 \times 1.0 \times 0.80$
= 290 LCM/h

Job Management

- The two major factors controlling shovel production are:
 - the swing angle and
 - lost time during the production cycle.