Construction Equipment
Earthwork & Soil Compaction

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Cable-operated excavators

Features:
- complicated driving system
- many moving elements → manifold potential failures
- low working performance
- extensive maintenance requirements

Front shovel
1. bogie undercarriage
2. slewing upper machinery (drive, operator’s canopy, counter-weight)
3. turn mechanism
4. boom
5. arm
6. bucket
7. cable-lines

Backacter
1. bogie undercarriage
2. slewing upper machinery (drive, operator’s canopy, counter-weight)
3. turn mechanism
4. boom
5. arm
6. bucket
7. cable-lines
Cable-operated excavators

1. bogie undercarriage
2. slewing upper machinery (drive, operator’s canopy, counter-weight)
3. turn mechanism
4. boom
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6. cable-lines

Features:
- complicated driving system
- many moving elements → manifold potential failures
- low working performance
- extensive maintenance requirements

Dragline

Clamshell
Cable-operated excavators

- Intermittent (cyclic) operation
- Attachments: shovel, hook, dragline, clamshell, boring equipment
Hydraulic excavators
(slewing excavators)

1. wheel-bogie
2. turn mechanism
3. slewing upper machinery
4. boom
5. arm
6. backacter
7. boom cylinders
8. arm cylinder
9. bucket cylinder
10. bucket moving rods
11. auxiliary attachment
12. outrigger

Wheel-mounted backacter slewing excavator
Hydraulic excavators
(slewing excavators)

1. bogie undercarriage
2. turn mechanism
3. slewing upper machinery
4. boom
5. arm
6. backacter
7. boom cylinders
8. arm cylinder
9. bucket cylinder
10. Bucket moving rods

Track-mounted backacter slewing excavator
Hydraulic excavators
(slewing excavators)

1. bogie undercarriage
2. turn mechanism
3. slewing upper machinery
4. boom
5. arm
6. front shovel
7. boom cylinders
8. arm cylinder
9. shovel moving cylinders

Track-mounted front shovel slewing excavator
Hydraulic excavators
(slewing excavators)

1. frame (carriage)
2. slewing upper machinery (engine, operator’s canopy, counter-weight)
3. hoe (shovel or bucket)
4. arm
5. boom (monoblock or articulated)
6. hoe rods
7. boom lifting cylinder
8. arm moving cylinder
9. hoe moving cylinder
10. outrigger (strut, jack)
11. auxiliary attachment (blade)

Backacter, wheel-mounted

Front shovel, track-mounted

Excavator (in action)
Attachments

Clamshell bucket (for granular material)

Breakers, Jaws
(for concrete, reinforced concrete and steel)

Screening adapter (for recycled material)

Others: loader bucket; drill; trunk-grip; cutter; trencher; fingered grips (for fibers or bars); crusher; vibro-plate; etc.
Attachments

Sheet-wall piling equipment

Boring (auger) equipment

Fingered grip

Crusher adapter
Hydraulic excavator attachments

- Backactor bucket
- Clamshell

Earthwork attachments

- Auger
- Ripper

Others: loading attachment; surface vibrator; roller compactor; bucket-lined or rotary trencher; profile buckets; sheet-wall driver; etc.
Hydraulic excavator attachments

Earthwork attachments

Special bucket-typed attachments

a. drainer; b. ripper; c. canal maintainer; d. ripper-cleaner; e. profile bucket; f. extended cutter; g. ripper-profiler; h. ejector; i. tamper
Demolisher and Recycler attachments

Hydraulic excavator attachments

Screen drum

Bucket-wheel

Crusher (mill)

Breaker

Snapper (cutter/jaw)
Hydraulic excavator attachments

Grabs, grips and loaders

Grabbing and loading attachments
a. clamshell; b. boring; c. fingered; d. bale grip; e. barrel/pipe grip; f. logger
Estimating performance (output) of intermittent excavators

Technical output:
Theoretical technical output \( (Q_t) \) assuming ideal circumstances
(soft soil, less than 90° slewing angle, skilled operator, etc.)

\[
Q_t = \frac{3600 \cdot q}{t_c} \quad m^3/h
\]

Where
• \( q \) = volume (capacity) of bucket [m³]
• \( t_c \) = \( t_e + t_{sl1} + t_d + t_{sl2} \) cycle-time (single period) [s]
• \( t_e \) = extraction (charging/excavating/loading) time [s]
• \( t_{sl1} \) = (lifting and) slewing time (from) [s]
• \( t_d \) = discharging (unloading) time [s]
• \( t_{sl2} \) = slewing (and lowering) time (to) [s]
Adjusted technical output:

Corrected (adjusted) technical output ($Q_a$) considering construction of the excavator and behaviour of the soil

$$Q_a = Q_t \cdot \frac{k_f}{k_l} \quad \text{m}^3 / \text{h}$$

Where

- $k_f$ = bucket fill factor (0.6 – 0.89)
- $k_l$ = soil loosening factor (1.1 – 1.65)

Bucket fill factor is the ratio of volume of soil in the bucket and of technical volume (capacity) of the bucket.

Soil loosening factor is the ratio of volume of excavated loose soil in the bucket and that of compacted (natural) soil before extraction (excavation).
Effective (estimated) output:

Corrected adjusted output ($Q_e$) considering expected (experienced) time-efficiency of application (operation/site management)

$$Q_e = Q_a \cdot k_t \quad m^3 / h$$

Where

• $k_t =$ time efficiency factor (0.45 – 0.83)

Time efficiency factor is the estimated ratio of effective (factual) and of „calendar” (scheduled) operation time of the equipment on site. It depends on lot of factors and circumstances such as: maintenance demand, skill of operator, idle (waiting) times, manoeuvre (relocating) times, etc.. Experienced values for hydraulic excavators are between 0.45 and 0.83.
1. wheel tractor
2. backacter
3. arm
4. slewing boom
5. boom cylinder
6. arm cylinder
7. bucket cylinder
8. slewing mechanism
9. suspension (base) plate
10. outrigger
11. front attachment (loader)
Backhoe excavators

Features:

- multifunctional (universal excavator)
- base (frame): wheel or track mounted
- attachment slewing ability: ± 90°
- auxiliary attachment: front bucket or blade
Backhoe excavators

Features:
- Multifunctional front shovel
- Draw beam (telescopic arm)
- Transversely slidable boom
A. with rigid frame

1. track (caterpillar)
2. engine
3. blade
4. main frame
5. lifting cylinder
6. tilting cylinder
7. bolt
8. ball-joint
9. swivel cylinders

Bulldozers (dozers)

Adjustability of blade:
- Cutting depth
- Cutting angle (tilt, adjusted to soil type)
- Slope angle ($\alpha$)
- Heading angle ($\beta$)

{ Ball-jointed main frame only }

Landscaping (levelling) by dozer

10...20 m
10...20 m

~ 1 m

B. with ball-jointed frame

1. track (caterpillar)
2. engine
3. blade
4. main frame
5. lifting cylinder
6. tilting cylinder
7. bolt
8. ball-joint
9. swivel cylinders
Advantages of delta drive:
- due to elevated engine and drive risk of getting dust (mud) in is less
- longer operation (life) time
- increased bulk clearance

Disadvantages of delta drive:
- higher costs of manufacturing
- more components, longer crawler belt
Bulldozers (dozers)

- Up-to-date controls
- Laser control
- Satellite control

Bulldozer equipped with ripper attachment
Scrapers

1. single-axle tractor  
2. articulation  
3. bowl  
4. apron  
5. ejector  
6. apron cylinder  
7. bowl cylinder  
8. ejector cylinder

Hauling excavated soil  
Discharging bowl, spreading soil
Scrapers
Phases of a cycle (turn)

Excavating (charging): apron up (open), bowl down (penetrating into the soil)

Hauling (and compacting): apron down (close), bowl up

Discharging (spreading and compacting): apron up (open), bowl up, ejector forward
Scrapers

1. tractor
2. gooseneck
3. scraper bowl
4. steering cylinder
5. bowl cylinder
6. ejector
7. apron
8. apron cylinder
9. apron rods
10. rear engine
   (rear wheel drive)

All-Wheel-Drive Scraper
(Charging and penetration provided by towing power of tractor)

11. cutting edge
12. discharge slide
13. elevator
14. hydro-engine
   (of elevator)

Elevator-scraper
1. tractor (engine)
2. articulated carriage
3. blade
4. tilting frame
5. main frame
6. swivel ring
7. ball-joint
8. lifting cylinder (jack)
9. tilting cylinder
10. swivel cylinder

(d) cutting depth
(δ) cutting angle
(β) slope angle
(α) heading angle
(s) sliding
Graders

**Typical application:** refinery earthworks, levelling, topsoil excavation, spreading

a. grader: $H_2 < h$

Effect of uneven surface ($h$) on position of blade ($H$)

b. dozer: $H_1 > h$

Laser controlled (C) grader equipped with ripper (A) and front blade (B) attachment
Compactors

Rollers
- Drive
  - Roller wheel
    - Steel runner
      - Bareface steel drum
      - Cammed wheels
    - Rubber wheel
      - Static weight
      - +Vibration
  - Compaction by
    - Towed
      - Self-propelled
        - Directed excitation
        - Circular excitation
    - Self-propelled
      - Poker vibrator

Vibrators
- Surface vibrator
  - Towed
    - Diesel engine
  - Self-propelled
    - Directed excitation
    - Circular excitation
    - Beater-piston

Tampers
- Electric
- Dropping weight
- Beater-piston
Basic types:

- Rubber-wheel roller
- Barefaced steel-drum
- Tamping (spiked/cammed) roller (for clay and adherent soil)

Features:

- Main application is soil compaction
- Towed individually or in groups
- Static load transferred to the soil can be controlled by weights mounted

Towed group of static rollers
Self-propelled rollers

Typical configurations

a. bareface steel roller

b. rubber-wheel roller

Soil compression (stress) under roller wheels

Rubber-wheel configuration
Principle of vibratory compaction:

Grains of soil are affected by periodically alternating inertial forces. These forces make grain particles ‘floating’, so ordering is progressed without friction.

At vibratory compaction low amplitude high frequency excitation is used for loose soil or for deep layers. High amplitude low frequency excitation is used for cohesive soils in thin layers. Frequency of excitation should be close to characteristic frequency of the soil.

Ways of excitation:

- circular excitation: simple construction, single exciter unit, eccentric should always rotate in direction of advancing
- directed excitation: double exciter unit, generates both compressing and sharing forces in the soil simultaneously
- oscillation: the two exciter masses generate moment at the surface of the drum creating compressing and sharing forces in the soil, so grains are ordered horizontally. Vertical force is provided by the weight of the drum
Vibratory roller drives

Roller Compactor: low working speed (v = 5 ... 20 km/h)
Mechanic drive: gear-down unit (cogwheel gear, chain drive)
Hydraulic drive: low r/min hydro-motor, high driving torque

Excentric axle: high r/min value is needed for excitation and for efficient compaction (n = 2400 ... 4500 r/min)

Double engine drive (both roller wheels are driven)

1. vibrating roller
2. excentric axle
3. carriage (frame)
4. rubber spring
5. V-belt drive
6. chain drive
7. engine
8. gear-down unit
9. clutch
10. exciting motor
11. cogwheel gear
Vibratory roller remote control

1. vibro roller
2. exciter unit
3. controlling unit
4. monitor
5. acceleration sensor
6. radio receiver-transmitter
   (database + controlling-monitoring system)
7. satellite
8. adjusting direction angle

**Controlling parameters:**
dynamic elastic modulus of material to be compacted
(via measuring acceleration)

**Controlled parameters:**
vertical excitation force ($F_{ve}$)
frequency of vibration
working direction of the unit

$F_{ve} = \text{MAX}$

$F_{ve}$

$F_{ve} = 0$
Circular excitation  
( changing direction of rotation )

Directed excitation  
( changing angle of direction )

Exciter unit drive
1. engine
2. V-belt drive
3. exciting mass
4. rubber spring
5. compactor plate
6. cogwheel
7. exciter unit
8. layshaft
Tampers can be used for to compact nearly all types of soil. Thickness (depth) of layer can be compacted effectively is about 40 cm. Compaction frequency is between 2 and 15 Hz.
Applicable (effective) compaction method to be used at different types of soil

1. Single-grain soil structures → vibratory compaction
2. Well distributed grain-size → low frequency vibratory compaction
3. Air and water removal → static cammed steel drum or rubber wheel compactors
4. Sand and gravel → vibratory rollers
5. Clay and silt → cammed steel drum, sometimes rubber wheel compactors
Soil stabilization

**Job:** stabilizing (solidifying) loose soil structure

**Methods:** in-situ stabilization, pre-mixed stabilization

**Steps** (in-situ):
- ripping the soil by rippers (1)
- crushing (breaking) soil by bucket-wheels (2)
- improving soil structure by adding missing soil-fragments, or cement (3) and water (4), or lime, or asphalt, and spreading it
- mixing additives and on-site soil by bucket-wheels (5)
- compacting solidified layer by surface vibrators (6) and roller compactors (7)
Soil stabilizing and resurfacing train

Train units:

- resurfacing unit
- water or slurry tank
- asphalt emulsion tank
- vibratory steel- and rubber-wheel rollers