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Comparative Analysis of the Characteristics of Backhoe Excavators and Loader Excavators

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Abstract: *The topic of hydraulic excavators is briefly elaborated, including their classification, main components, and operating principles, as machines commonly used for earthmoving operations. Emphasis is placed on the most common types of hydraulic excavators—backhoe excavators and loader excavators—their technical specifications, components, modes of operation, and specific features related to performing earthmoving tasks. Through the provided description of their components, working principles, and technical characteristics, the paper enables a better selection of the appropriate type of excavator for efficiently carrying out specific tasks such as excavation, transport, loading, or other operations involving earth materials.*

***Keywords**: Excavator; backhloe excavator; loader excavator; backhoe bucket; front bucket;.*

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I. INTRODUCTION

Excavators are among the most commonly used heavy machines. They are extremely versatile and find applications across various industrial sectors, particularly in construction and mining. Most often, they are used for digging large-profile trenches, but also for foundation excavation, demolition of structures, lifting and placing heavy materials, river dredging, landscaping, and even forestry operations.

In general, every excavator consists of a boom, arm, bucket, and a cab mounted on a rotating platform. The cab is positioned on top of the undercarriage, which may be equipped with either tracks or wheels. An example of a tracked excavator is shown in Fig. 1.

Fig. 1. 1. Undercarriage with drive system, 2. Upper structure with cabin, 3. Cabin, 4. Hydraulic cylinders, 5. Arm, 6. Bucket, 7. Boom.

There are also universal excavators which, in addition to digging, are used for various other tasks. The main components of an excavator are: 1. Undercarriage with tracks or wheels and 2. Upper structure with cabin. Mounted on these bases is the equipment that forms the excavator's arm (the boom, the arm, and the working tool). The undercarriage can also be equipped with rubber wheels, in cases where the excavator is used for smaller-scale tasks and where easier maneuverability on flat terrain is required.

The undercarriage consists of a robust frame structure that supports the entire machine along with the tracks or wheels. Large excavators are equipped with specialized tracks over 1 meter wide. Track-equipped excavators offer better maneuverability on wet and sloped terrains. On the excavator's undercarriage, a horizontal sprocket wheel is mounted, toothed either on the inner or outer side. This meshes with the drive gear on the upper structure, allowing the cab to rotate 360 degrees. The undercarriage houses the drive mechanism, power transmission, couplings, and brakes. The upper structure contains the cab, which houses the engine and the working tool, i.e., the excavator arm. The main components of the excavator arm are the boom, arm, and bucket. Excavators are used for digging earth materials and loading. They are most commonly classified into: 1.. Excavators with front (loading) buckets—loaders—used for digging above the excavator's base level, and 2. Excavators with backhoe (deep digging) buckets—backhoes—used for digging below the excavator's base level [1],[2].

1.1 Excavator classification

Excavators can be divided into backhoe excavators and loaders, or a combination of both in the form of a backhoe-loader, as shown in Fig. 2.

Fig. 2. a). Backhoe excavator, b). Loader excavator, c). Backhoe-loader excavator

Excavators are divided in two groups: with cyclic operation and with continuous operation.

Further classification of cyclic excavators is based on the system used to move the excavator arm. They are divided into mechanical excavators, which use cables and pulleys to move the arm, and hydraulic excavators, which use a hydraulic system for arm movement. Mechanical excavators are categorized as; front shovel excavators, rotary shovel excavators, dragline excavators, grapple excavators. Hydraulic excavators are categorized as; backhoe loaders (HBOL) – trenching machines, front shovel loaders,(HBČK) – loading machines, telescopic excavators, grapple excavators. The general classification of excavators according to their operating principle is shown in Fig. 3.

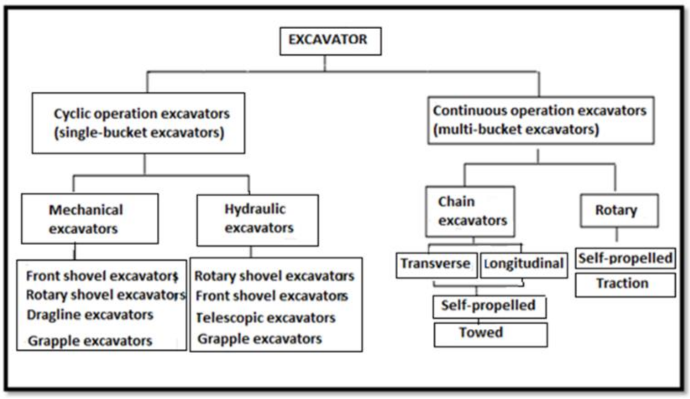

Fig. 3. The basic excavator classification

Continuous operation excavators are equipped with multiple buckets that move sequentially in a continuous loop. Based on the method of movement and bucket transportation, they are classified into chain-type and rotary-type excavators.

In chain-type excavators, the buckets are attached to a chain mechanism. These are further divided based on the orientation of the buckets relative to the machine into; transverse chain excavators, longitudinal chain excavators. Each of these can be either; self-propelled and towed.

In contrast, rotary excavators have buckets mounted on a rotating wheel, which continuously fills and empties the buckets. These, too, are classified as; self-propelled rotary excavators and towed rotary excavators.

1.2 Main components of the hydraulic system of the excavator

The hydraulic system of excavators enables them to perform their numerous functions and is an essential part of excavators and other heavy equipment. The hydraulic circuit provides control of power and movement of the excavator.

The components of the excavator's hydraulic circuit are the cylinders, hydraulic motors, oil reservoir, hydraulic pump, excavator engine, pressure relief valve, main control valve, filters, hydraulic fluid, hydraulic hoses, and the intercooler (Fig.4) [1].

Hydraulic cylinders are devices that enable linear motion in the hydraulic system.

Hydraulic motors are devices that enable rotational motion in the hydraulic system.

The oil reservoir is a part of the hydraulic circuit that stores the hydraulic fluid used to power the excavator. The hydraulic fluid is pumped from the reservoir to other components of the hydraulic system and then returns back to the reservoir after being used.

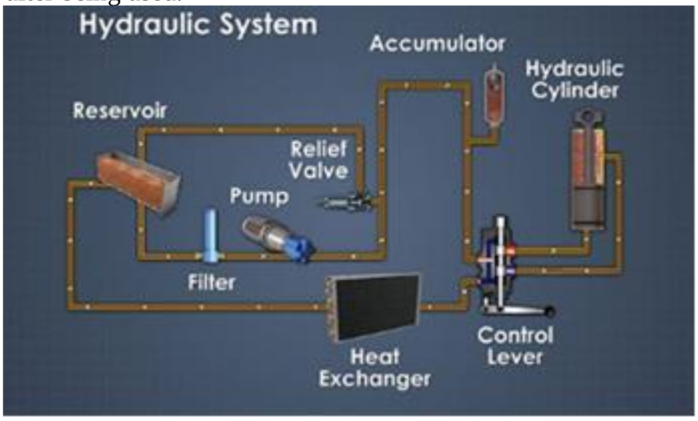

Fig. 4. The components of the excavator's hydraulic circuit

The hydraulic pump is a device that pumps hydraulic fluid from the oil reservoir to the rest of the hydraulic system. The two most common types of hydraulic pumps used in excavators are gear pumps and piston pumps. Piston pumps are generally a better option. They are more efficient than gear pumps and can handle higher pressures and speeds, allowing them to move more fluid to other components.

The excavator engine is responsible for powering the hydraulic pump and the alternator, which supplies the electrical system of the excavator. Most excavators are equipped with diesel engines.

The pressure relief valve is a device used to release excess pressure generated in the hydraulic system. This pressure can be caused by various factors, such as a faulty component or accumulation of debris in the system. The pressure relief valve helps ensure that the system pressure is maintained at a safe level and that excess pressure is released before it can cause any damage.

The main control valve is a part of the hydraulic circuit that allows the operator to control the flow of hydraulic fluid and distribute it between different parts of the hydraulic system, such as linear actuators (cylinders) and rotary actuators (motors). Using the main control valve, the excavator operator controls the movement of the excavator.

Filters are used to ensure that the hydraulic fluid is clean and free from any debris or contaminants. Without filters, the hydraulic system can become clogged with dirt or contaminated, which can lead to system failure or breakdown. Contaminated hydraulic fluid is the number one cause of

hydraulic system component failure. Therefore, hydraulic fluid filters are installed at multiple locations throughout the hydraulic system.

Hydraulic fluid is a type of incompressible liquid used to transmit energy in the hydraulic system. Additionally, hydraulic fluid helps keep the excavator’s components and hoses lubricated, preventing corrosion and wear. Without hydraulic fluid, the excavator would not be able to move.

Hydraulic hoses on excavators are parts that must be durable and capable of withstanding high pressure. The pressure rating for the hose should exceed the normal operating pressure of the system and take into account expected pressure spikes.

The oil cooler can be considered the second most common source of hydraulic system failure due to excess heat. During excavator operation, hydraulic fluid heats up because of the energy released as heat. Excessive heat significantly reduces the lifespan of excavator hoses and seals due to the increased rate of chemical reaction of these components with the hydraulic fluid. Also, excess heat affects the viscosity of the hydraulic fluid, leading to poor lubrication of moving parts in the excavator’s hydraulic system.

1.3 Technical and operational characteristics of excavators as mechanized machines

Theoretical capacity

This is a performance indicator of each excavator individually.

For machines with cyclic operation

$$Qthcikl = n \cdot Q_1 \text{ [m}^3\text{/h]}$$

where, n is number of cycles per hour, Q_1 is amount of production performed during one cycle.

This most often represents the volume of the working tool, although in many cases it can be expressed in other ways.

For machines with continuous operation

$$Qthcont = A \cdot v \; [m^3 /h]$$

where $A \; [m^2]$ is cross-sectional area of the material flow (for example, in cases like cutting a layer dozers, graders, or laying an asphalt layer, etc.), $v \; [m/h]$ is velocity of the material flow movement.

Technical capacity represents another important characteristic of a machine's performance. The technical capacity takes into account the filling coefficients and the digging coefficient.

$$Q_{teh} = Q_{th} \cdot \frac{K_p}{K_r}$$

where $Q_{th}$is theoretical capacity, $K_p$is filling coefficient of the working tool, $K_r$is looseness (diggability) of the soil.

Operational capacity

Operational capacity takes into account the time utilization of a machine, as well as the method of machine control (manual, servo, automated, etc.) and the working conditions (ergonomics).

$$Q_e = Q_{teh} \cdot kn \cdot kv \; [m^3 /h]$$

where $Q_{teh}$is technical capacity, $kn = 0.82 - 0{,}92$ is control coefficient (manual), $kn = 0.96 - 0.98$ is control coefficient (servo) and $kv = 0{,}75 - 0.85$ is time utilization coefficient. This coefficient directly depends on the organization of production and management.

Besides capacities, other indicators for a mechanization machine are:

- Energy engagement index: $Ie = E/Q_{teh}$
- Embedded mass index: $Im = m/Q_{teh})$
- Fuel consumption index: $Ig = q/Q_{teh}$
- Cost price per unit of production:

$$C_k = k \cdot \frac{\sum T}{Q_{teh}}$$

where, $Q_{teh}$is technical capacity, k is profit coefficient and T is total costs (depreciation, maintenance, etc.). The service life of a construction and mining machine, according to literature sources, ranges from 8,000 to 30,000 operating hours. These are rough approximate values.

II. CHARACTERISTICS OF A HYDRAULIC BACKHOE EXCAVATOR-TRENCH DIGGER

Excavators – backhoes (Fig.5) are relatively large and heavy machines. Their main components are: lower part – undercarriage with tracks or wheels, a cabin mounted on a rotating platform which is located above the lower part, and an excavator arm. The excavator arm consists of a boom, stick, and bucket. Generally, the same components can be found on every excavator, but differences exist only in the dimensions and the angles of the parts' placement. The control is easy, with servo devices (joysticks), and the cabins are ergonomically designed. A hydrostatic transmission is used (pumps, hydraulic cylinders, hydraulic motors for rotating the turret and moving the tracks) [3],[4].

Fig. 5. 1. Cabin, 2. Engine, 3. Boom, 4. Stick, 5. Bucket

The movements that such an excavator (backhoe loader) can perform are:

– rotation – movement of the boom,
– movement – rotation of the stick,
– movement – rotation of the bucket,
– rotation of the swivel base (cab),

– movement of the entire machine (maneuvering)

The excavator arm with the bucket attachment allows digging through soil or other materials and lifting the excavated material. The cabin can rotate 360 degrees. These excavators most often use tracks to provide traction and stability, enabling them to move on steep slopes or uneven terrain without slipping downhill and to climb hills with less risk, making them suitable for work in hilly areas and leveling uneven grounds. Although tracked machines are slower, the tracks provide greater balance, flexibility, and overall stability.

They also have the capability to be equipped with other attachments (e.g., soil compactor, hammer, grapple arm, etc.). Different bucket sizes can be used to better suit the work tasks at the site, such as moving debris or materials, demolition, trench digging, hauling, and more.

The capacity of excavators during operation is:

$$Up = U\text{т} \times Kv \times Kr \times Kp \times Kvr \; [\text{m}^3/\text{h}]$$

where U_t is theoretical output (m³/h), K_v is coefficient of utilization of working time, K_p is bucket filling coefficient, K_r is soil looseness coefficient, K_{vr} is coefficient of rotation of the excavator cabin

For excavators, as well as for all other machines, the value of U_t is calculated or taken from literature, while the values of the other coefficients are read from tables in the literature depending on the specific working conditions or are calculated.

2.1 Basic parts of the arm of a hydraulic backhoe excavator

The arm of the backhoe excavator is shown in Figure 6 and primarily consists of the boom, stick, bucket/attachment, and cylinders. The hydraulic cylinders enable the movement of the parts. The components are connected to each other by pins forming a joint that allows the parts to rotate in order to perform actions. The hydraulic system, with the help of hydraulic cylinders and hydraulic lines running through the boom and stick, enables the movement of the bucket [5], [6].

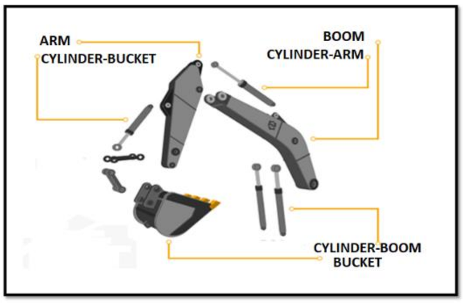

Fig. 6. Components of a hydraulic excavator with a backhoe bucket

The boom of the excavator is the largest component of the excavator arm. It is attached directly to the cabin and rotates together with the cabin. This rotation and lifting action allow the arm to raise and lower relative to the digging surface and to extend or retract the reach of the arm while rotating.

The stick (or dipper arm) is located between the boom and the attachment/bucket and rotates around the joint it forms with one end of the boom. This rotation further allows the arm to position the attachment/bucket farther from or closer to the machine, and to control the height of the bucket relative to the digging surface. By changing the angle of the stick, the operator can position the bucket deeper than the machine's digging level or at a point higher than the ground to load a truck or pile up materials.

The attachment/bucket is located at the very end of the arm. There is a wide range of attachments used on excavators, from tools for clearing soil to attachments for breaking and smashing large rocks. The most common attachment is the bucket, but even buckets for excavators can vary in size, the materials they are made of, teeth, and side cutters for digging, as well as thumbs for grasping materials.

The boom cylinders are usually two, one on each side of the boom, with one end attached to the cabin and the other end to the boom. Extending and retracting these cylinders raises and lowers the boom and, consequently, the entire arm.

The stick cylinder is mounted at the top of the boom and rotates the stick around its joint with the boom.

The bucket cylinder is connected to the bucket via linkages. Extending the bucket cylinder controls the filling and emptying of the bucket.

With a skilled excavator operator behind the controls, precise movements of the excavator arm can be executed. Usually, by operating multiple cylinders simultaneously, complex and precise movements of the excavator arm are enabled.

2.2. Operating Characteristics of an Excavator During Earthworks

Excavators with a backhoe bucket can dig deep below the level at which the machine is positioned. The area covered by the reach of the boom and the arm of the excavator is called the digging envelope. The depth to which the tip of the bucket teeth can reach below the machine's level in order to extract a bucket of material is known as the digging depth. The deeper the excavation, the longer the reach needs to be, which in turn increases the pressure on the boom and the digging arm or stick of the machine.

Generally, the deeper the excavation, the larger the machine required (unless the soil is a non-cohesive material like sand). Figure 7 shows a typical side view of the working reach of a backhoe loader. The image illustrates the depth and height that the boom and the arm can achieve. When selecting an excavator, the lengths of the boom and the arm must be taken into consideration. The optimal digging depth for a boom and arm is around 60 to 70% of the machine's class reach. Therefore, to excavate a trench 10 meters deep, the excavator should have a nominal digging depth of approximately 18 meters [3],[4].

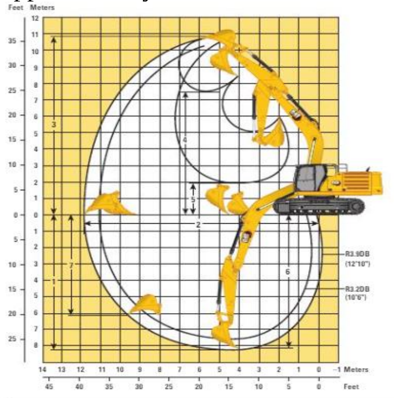

Fig. 7. Working envelope of a backhoe excavator

The horizontal angle in degrees (in plan view) between the position of the bucket when it is in the digging position and its position when dumping the load is called the swing angle. If the swing angle increases, the time required for the digging and dumping cycle also increases, which leads to reduced productivity and increased costs. Optimal productivity is achieved when the swing angle is equal to 90 degrees.

2.3 Hydraulic excavator - backhoe model CAT323F LN

The hydraulic excavator-backhoe from the manufacturer Caterpillar, model CAT 323F LN (Fig. 8), belongs to the best fuel efficiency in its class. The excavator is equipped with a C4.4 ACERT engine and features a state-of-the-art hydraulic system and Cat Grade Control system (2D bucket tip guidance displayed in the cabin) to enable the most precise movements during earth digging, load lifting, and all other operations.

The CAT 323F LN consumes less fuel because the automatic control allows the engine to run continuously at a lower speed but at optimal power for maximum efficiency. The automatic engine speed control also reduces RPMs when the machine does not require full power. The automatic engine shutdown feature turns off the engine when it has been idle for a preset time, which can be easily adjusted via the monitor. There is a choice of three power modes — high power, standard power, and eco mode. By switching between these modes, the machine meets different operational needs. All these benefits result in reduced fuel consumption, lower repair and maintenance costs, and an extended engine lifespan.

Fig. 8. Hydraulic excavator-backhoe from the manufacturer Caterpillar, model CAT 323F LN

Basic technical specifications of this backhoe excavator model CAT 323F LN are[3]:
Engine: model CAT C4.4 ACERT, power 122 [kW], engine speed 1,800 rpm
Engine oil capacity: 25 liters
Fuel tank: 310 liters, average consumption about 13 l/h
Coolant capacity: 30 liters
Hydraulic system: hydraulic oil capacity – 260 liters, hydraulic oil pressure – 35,000–38,000 kPa, oil flow through hydraulic system – 428 l/min
Weight and ground pressure: 22,300 kg, 55.7 kPa
Bucket: capacity – 1.3 m³, bucket digging force – 140 kN

Movement: travel speed – 5.6 [km/h], drawbar pull – 205 kN
Excavator dimensions (Fig. 9) with boom type R 2.9.

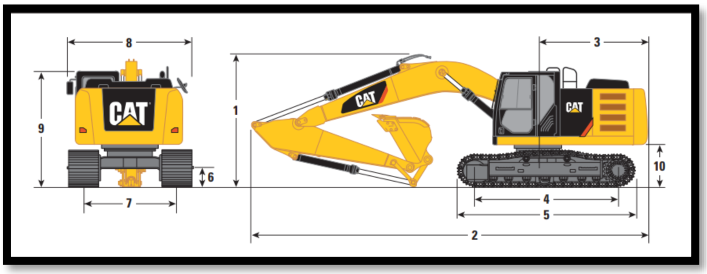

Fig. 9. Dimensional characteristics

1 – Transport height: 3020 mm
2 – Transport length: 9560 mm
3 – Length of the tail (engine and counterweight): 2830 mm
4 – Length between track roller centers: 3650 mm
5 – Track length on ground: 4450 mm
6 – Ground clearance: 450 mm
7 – Width between track centers: 2000 mm
8 – Overall width (with 500 mm wide tracks): 2550 mm
9 – Cab height: 3010 mm
10 – Counterweight height: 1020 mm

Working reach of the bucket:
Maximum digging depth: 6710 mm
Maximum reach parallel to ground level: 9850 mm
Maximum digging height: 9450 mm
Maximum loading height: 6500 mm
Minimum loading height: 2180 mm

III. CHARACTERISTICS OF A HYDRAULIC EXCAVATOR WITH FRONT BUCKET-LOADER

The backhoe loader (Fig.10) is a machine whose main components are the engine, cabin, two-part boom, bucket, and chassis, usually mounted on wheels but sometimes on tracks. It has a wide bucket positioned at the front, connected to the cabin via a two-part boom.

The loader is a machine used to move or load materials such as soil, rocks, sand, demolition debris, and so on.

Fig. 10. 1. Engine, 2. Cabin, 3. Two-part boom, 4. Bucket

There are many types of loaders depending on the design, application, and equipment. The bucket capacity of a loader can range from 0.5 to 36 cubic meters, depending on the machine size and its use. The bucket capacity of a loader is generally much larger than that of a backhoe loader. Loaders can be wheeled or tracked, especially where rubber tires might be damaged by construction debris or where the ground is soft and muddy. Wheels provide better mobility and speed and do not damage paved roads or tracks, but they offer less traction.

To enable multiple functions, manufacturers equip loaders with quick-attach equipment that expands the range of tasks the loader can perform.

Control is always via servo devices and joysticks, and cabins are ergonomically designed and protected against rockfalls. Hydrostatic transmissions are used (pumps, hydraulic cylinders, hydraulic motors for turret rotation and track movement). Automated designs also exist. Diesel engines are most commonly used as power sources, but some versions may have gasoline or electric motors [1],[5].

The calculation of loader performance can be done using the formula:

$$Up = Ut \times Kv \times Kp \times Kr \ (\mathrm{m^3/h})$$

where U_t is theoretical performance, K_v is coefficient of working time utilization, K_p – bucket fill factor
K_r is soil looseness coefficient
For loaders, as well as for all other machines, the value of U_t is calculated or taken from literature, while the coefficient values are read from tables in the literature depending on the specific working conditions or are calculated.

3.1. Basic parts of the arm of an excavator with front bucket

The basic parts of the excavator arm with front bucket loader are shown in Figure 11.

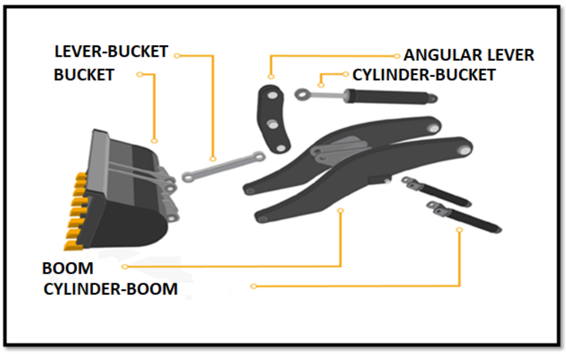

Fig. 11. Basic parts of the excavator arm with front bucket loader

The bucket is the main working element. All parts of the arm are designed to work together to enable the operator to control the bucket's action while pushing, carrying, digging, lifting, and dumping material. Loader buckets are designed in a wide range of configurations, with bucket models selected to suit activities ranging from loading heavy rocks to digging large pits, loading trucks, and even pushing snow.

The bucket cylinder, depending on the connection design, may have one or two cylinders responsible for tilting the bucket to scoop or dump materials. These bucket cylinders must be strong enough to handle heavy materials and a heavy bucket during routine loading and unloading.

The loader boom consists of two large and heavy interconnected arms that rotate at the machine connection. The boom length determines the height to which the material can be lifted, so the machine (and its boom length) must match the work it is intended to perform.

The boom cylinder performs the lifting and lowering of the boom, which in turn moves the loader arm, allowing the operator to load, pile materials, and perform other tasks. To facilitate these lifting operations, two boom cylinders work in unison to raise and lower the boom because the combined weight of the load, boom, and bucket can be significant. These cylinders must be designed to match the work the machine is intended to perform.

The linkage lever is present in a loader with a Z-type connection. It is connected to the bucket cylinder on one side and to the bucket on the other side, while in the center it is pivotally connected to the boom at its midpoint. The linkage lever is the foundation that allows the operator to control the bucket.

The bucket lever is often called the "dog bone" due to its shape. The connections between the bucket and lever, as well as between the lever and linkage lever, are connected by multiple pins. Although the design of the bucket linkage is not very complicated, the constant forces they endure and the friction of the moving parts can cause them to weaken and bend without proper maintenance [6],[7].

The movement of the loader arm with a front bucket is achieved by hydraulic cylinders extending and retracting.

One of the most notable differences in loaders is the design of the loader arm. The most common arm designs in terms of operation are the Z-linkage system and the parallel linkage system.

The Z-linkage design connects the bucket to the machine in a specific way. The bucket cylinder is connected to a lever located in the center of the loader arm, which is pivotally connected in the middle to allow angular rotation. The other end of the lever is connected to the bucket by a straight link. The formation of these parts in a "Z" shape gives the design its name. This is the traditional and original linkage design for loaders.

Advantages of the Z-linkage connection include fewer joints and a simpler design for maintenance. Generally, it provides greater digging power.

Disadvantages of the Z-linkage connection are that the lever and the bucket cylinder can obstruct the operator's view, and the bucket rotates as the arm is raised and lowered, making it harder to maintain load balance between the bucket and the ground.

The parallel linkage system divides the bucket cylinder's work between two cylinders mounted on each arm of the loader. The bucket connections also involve more linkages, often connected in specific ways to improve the rotation of parts.

Advantages of the parallel linkage system include better visibility of the bucket, maintaining the bucket level while raising and lowering the arm, and being ideal for loading specific materials with forks or other attachments.

Disadvantages of the parallel linkage system are a more complex design with more linkages and parts, and less power for tasks that require high force.

When operating the loader, the operator activates commands through the controls inside the cabin, which send signals to extend or retract the cylinders. Activating the arm cylinders raises or lowers the loader arm, while activating the bucket cylinders rotates the bucket on the loader arm.

Extending the bucket cylinder rotates the upper part of the lever forward, causing the lower part to rotate toward the machine. Due to the way the cylinder is connected to the bucket, this action pulls the upper part of the bucket toward the machine, forcing the bucket to rotate upward. When the cylinder moves in the opposite direction, the bucket rotates the lever toward the operator, initiating the bucket emptying action. For rotation in the horizontal plane, movement of the entire machine is required.

3.2 Operating Characteristics of a Backhoe Loader during Earth Excavation

Backhoe loaders are typically maneuverable machines suitable for longer distances but have limited mobility in small and confined spaces. They are primarily used for loading and moving materials. They are ideal for gathering and hauling materials into piles for temporary storage or for loading onto trucks, but they can also perform earth excavation [3].

They are designed to dig above the excavation face level, not for deep earth digging. The size of the bucket used during operation can vary, mainly depending on the machine's capacity.

The work cycle usually involves filling the bucket, lifting the bucket, retracting or repositioning, and dumping the material onto a pile or into a truck.

A general side view of the working reach or digging envelope is shown in Figure 12, where it is observed that the digging depth and height are less than those of a trenching machine.

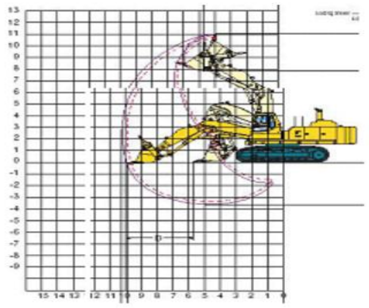

Fig. 12: Working envelope of a backhoe excavator

3.3 Hydraulic Front Bucket Loader – CAT966 GC

The CAT 966 GC (Fig.13) is a medium-class wheeled loader from Caterpillar, known for its ease of operation and handling. It offers low fuel consumption, load-sensing hydraulics, intuitive controls, and a variety of buckets to meet different job requirements. The excellent machine performance combined with low maintenance and operating costs makes the CAT 966 GC one of the best loaders in its class[3].

Fig. 13. Hydraulic Front Bucket Loader – CAT966 GC

The engine management system at idle, automatic engine shutdown at idle, variable-speed fan, and load-sensing hydraulics contribute to the machine's low fuel consumption.

The proven geometry of the Cat Z-linkage combined with high-performance buckets provides excellent material penetration and high breakout forces. This results in low fuel consumption and exceptional productivity.

The electronically controlled automatic planetary transmission with fast and smooth shifting features gear-shift protection and single-clutch shifting for efficiency, durability, and seamless gear changes.

An optional drive control system enhances rough terrain maneuverability, increasing operator confidence and efficiency by providing excellent material retention. This control assist activates automatically without operator intervention.

The spacious cab features easily accessible controls and excellent visibility, providing a comfortable working environment for efficient and effortless operation.

A wide, flat, distortion-free front windshield with a windshield protector guards against impacts. The glass extends down to the cab floor, offering outstanding visibility of the bucket and front tires.

Other advantages of the backhoe loader include:

Practical access to the left, right, and rear sides of the engine compartment provides excellent serviceability.

The rear grille that swings upward allows easy access for cleaning the cooling cores.

Hinged wheel guards are easily removed and reinstalled, providing wide access to all maintenance points and the engine compartment.

The optional Cat Autolube system offers full monitoring of the lubrication system and signals any required action with audible and visual alerts.

Basic technical characteristics of this type of backhoe loader are (Fig.14) [3]:

Engine – model CAT C9.3B, power 239 kW,
Rotations per minute 1600 rpm
Amount of engine oil – 26 liters
Fuel tank – 320 liters, average consumption about 19 l/h
Cooling fluid amount – 53 liters
Hydraulic system – amount of hydraulic oil – 101liters,
Hydraulic oil pressure – 22,900 - 27,780 kPa,
Oil flow through the hydraulic system – 327 l/min
Weight and carrying capacity – 21,780 kg, 13,640 kg
Bucket capacity – 3.2 – 7.1 m³,
Bucket breakout force 164 kN
Movement – forward speed up to 34.8 km/h,
Reverse speed up to 36.9 km/h

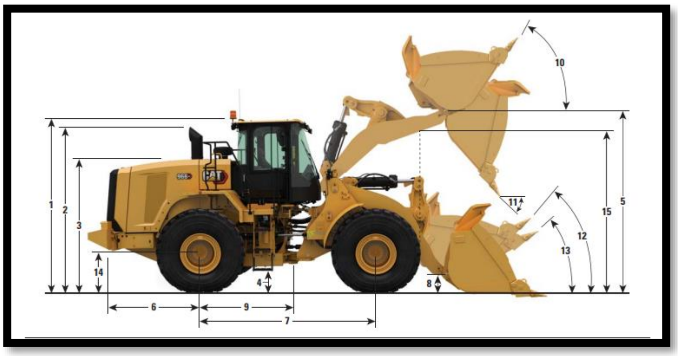

Fig. 14. Dimensional characteristics of the backhoe

1 - Height to the top of the cab: 3582 mm
2 - Height to the top of the exhaust system: 3539 mm
3 - Height to the engine hood: 2804 mm
4 - Ground clearance: 455 mm
5 - Height to the bucket attachment in raised position: 4256 mm
6 - Length from the centre of the rear axle to the end of the counterweight: 2453 mm
7 - Wheelbase: 3550 mm
8 - Height of the bucket attachment when carrying: 614 mm
9 - Distance from the center of the rear axle to the assembly: 1775 mm
10 - Maximum lift angle backward: 62 degree
11 - Dump angle at maximum lift: 44 degree
12 - Backward arc during carrying: 50 degree

13 - Arc during normal carrying relative to the ground: 42 degree
14 - Height to the axle: 819 mm
15 - Maximum dumping height: 3705 mm
Working range of the bucket:
• Width: 3220 mm
• Material dumping distance at maximum bucket lift: 3059 mm
• Total height with bucket at maximum lift: 5823 mm
• Digging depth: 105 mm

IV. GENERAL CHARACTERISTICS OF EARTHWORKS USING MACHINERY

During the process of digging or moving earth material using machines designed for that purpose, contact and action occur between the working attachment, usually the bucket of the machine, and the ground itself where various forces and stresses arise during the work execution. There are certain specifics that are important for the process.

The maximum cutting depth is the nominal depth that the blade or bucket can cut into the soil in a single pass. It can be considered as a single pass through the cycle to fill the bucket. An efficient operator will position the bucket or blade deep enough so that the cycle is completed in one movement and the bucket or blade is filled to its nominal capacity.

The deeper the cut, the more effort is required for the equipment to push the blade edge or the bucket teeth into and through the material to be excavated. With deeper penetration, the blade or bucket will fill faster. This shortens the distance or reduces the extension of the excavator boom, reducing the cycle time and thus increasing production. Otherwise, higher operational costs are incurred (more fuel, oil, more expensive maintenance) because the machine has to work harder to dig deeper. Optimal engine efficiency (most economical operation) is achieved when the equipment excavates at the optimal cutting depth for that engine size, blade or bucket, and soil type.

Penetration force is the operational force needed to push the blade edge or bucket teeth directly into the material.

Breakout force is the operational force required to break the material apart after the teeth or blade edge have been positioned.

The breakout force develops by bending the bucket downward "toward the machine" as with a standard excavator or upward "toward the machine" as with a loader excavator. More force is required to dig solid material compared to loose sandy material. This usually means greater power and larger and more durable mechanical components on the machines.

V. DIFFERENCES IN PERFORMING EARTHWORKS WITH AN EXCAVATOR AND A LOADER EXCAVATOR

Backhoe loaders and excavators have similar but also quite different functions in their use. The excavator is designed primarily for digging, while the wheeled loader moves material more easily. The key difference between these two machines lies in their primary purpose.

First, there is the bucket capacity. Wheeled loaders are much more efficient at moving materials than excavators. The bucket on a wheeled loader has a larger capacity and can also be used for digging, but its main purpose is to transfer large amounts of material with less effort.

The excavator is excellent for digging but cannot carry as much material. To compensate for this weakness, these two machines often work together. The relationship between the wheeled loader and the excavator is like a partnership. One machine handles the digging, while the other moves around the piles of excavated material to remove excess material from the site.

Flexibility and reach differ between the types of machines. Loaders are great at pushing and pulling loads but cannot match the diverse capabilities of the excavator. The 360-degree operational flexibility of an excavator offers more possibilities than a machine that works only in a straight line or at a right angle — especially when access to difficult locations is required, where other equipment cannot reach due to risks associated with entering hard-to-reach areas.

When deciding which machine is more suitable for a job, several questions should be asked to better determine the best option:

The choice really depends on the type of work being done and the specific needs of the site. The main function at the worksite influences whether to use an excavator, a wheeled loader, or both. For example, if the primary task is to dig material to create a pool, the excavator will be the best option, especially if digging produces only relatively small amounts of material to be removed.

However, the loader will be a better choice if the work is likely to result in large quantities of material needing removal from the site, such as excavation for an underground parking garage. In reality, for maximum efficiency, most larger construction projects benefit from having both machines available.

The height of the excavation is another factor that can influence the decision. Backhoe excavators have a much greater reach height, which means they can move materials more freely. Of course, operators have a clear view of where they unload materials from the excavator, so accuracy is improved in that respect. Wheeled loaders have a lower dump point, which can make handling more difficult.

The technical characteristics of these two types of machines also show that wheeled loaders generally consume more fuel per hour because they have more powerful engines and larger quantities of consumable fluids during regular maintenance, compared to excavators of similar size.

If working with a limited budget and only one type of machine can be chosen, ongoing operating costs should be considered. Both machines are built tough to withstand heavy work. However, higher maintenance costs can be expected for wheel replacements and wear-and-tear on wheeled loaders. Backhoe excavators mostly have tracks, which experience less wear. Both machines have moving parts. The operation of a wheeled loader is simpler than that of an excavator, so it is assumed that wheeled loaders may require fewer repairs compared to backhoe excavators.

The working space is very important to determine which machine to use. Although excavators are often larger machines, they can actually work in tight spaces due to their 360-degree movement capability. This offers much greater flexibility because once positioned, they do not need to be relocated as often.

For efficient operation, wheeled loaders require more space. They operate only by moving forward, which means they can only be used in areas where the vehicle can approach directly ahead. Then, space is needed to turn easily, which takes up much more room than the turning radius of an excavator. Generally, the excavator is the better choice for smaller or confined spaces.

VI. CONCLUSION

Excavators and loaders are the most common and essential tools for earthmoving tasks. Both serve the functions of digging, transporting, and loading materials

They allow easy movement of large quantities of materials, making them incredibly useful in construction or cleanup work in areas where other vehicles cannot access due to size or weight limitations.

There is no strict answer as to which machine should be used when high digging power and heavy lifting capacity are needed. However, it is best to choose the machine that fits the specific needs based on differences in size, rotation range, and adaptability.

Therefore, if the budget does not limit you to just one machine, the backhoe excavator is probably the smart choice. It can dig in both small and large scales and can also be used for material transport, although not very efficiently. On the other hand, wheeled loaders are capable of digging, but due to the bucket width, they cannot handle digging smaller tasks like trenches.

In general, backhoe excavators offer slightly more flexibility, but ideally, having a wheeled loader available as well would be the best option.

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