Methods, Mechanisms of Digging

The maximum depth of cut is the rated depth that the blade or the bucket can cut into the soil in one pass. A pass can be considered one time through the cycle to fill the bucket or the blade. An efficient operator will set the bucket or the blade just deep enough so that when one motion or cycle is complete, the bucket or the blade will be filled to its rated capacity. Whether a blade or a bucket, the deeper the cut, the more effort required for the equipment to push the blade edge or the bucket teeth into and through the material to be excavated. The deeper the penetration, the faster the blade or the bucket will fill. This shortens the push distance or reduces the extension of the excavator's boom, reducing the cycle time and increasing the production. The trade-off is higher operation costs (more fuel, lubricant, higher maintenance) because the machine must work harder to dig deeper. Optimum motor efficiency (most economical operation) is achieved when the equipment excavates at the optimum depth of cut for that size of motor, blade or bucket, and soil type.

Crowding force is the operational force required to push the edge or the bucket teeth into the material face. It can be done mechanically, like an excavator or front shovel or by driving into the material face like a loader. Breakout force is the operational force necessary to break material apart once the bucket teeth or edge is set. Breakout force is developed by curling the bucket downward ‘‘to the machine’’ like the excavator, or upward ‘‘away from the machine’’ like the front shovel. Greater force is required to break hard-packed material vs. loose sandy material. Typically this means greater power and larger and more durable mechanical components.

EXCAVATING EQUIPMENT SELECTION

Excavating equipment included:

. Excavators

. Backhoes

. Front shovels

EXCAVATORS

The excavator combines digging and lifting abilities. Excavators come in a wide range of sizes. Bucket size, boom length, and operating speed are primary considerations for choosing the 94 Construction Equipment for Engineers, Estimators, and Owners proper excavator. Typically, the faster the operating speed, the faster the machine can load, swing, dump, return, and dig (the normal excavator production cycle). Excavators are ideal for digging and dumping into a dump truck or a pile. Excavators are ideal for underground utility construction. For trenching, the operator fills the bucket and dumps to the side above grade. With the excavator in the same path, the operator can also use the bucket side and bottom to scrape the dirt back into the trench and compact it after the work is done. Another reason that the excavator is ideal for underground utility construction is its lifting ability. Most buckets have an ‘‘eye’’ for securing rigging. Pipe can be easily rigged and placed in the trench. If necessary, the load can be picked up and ‘‘walked’’ to the placement point. Obviously, the excavator should be rated for the load.

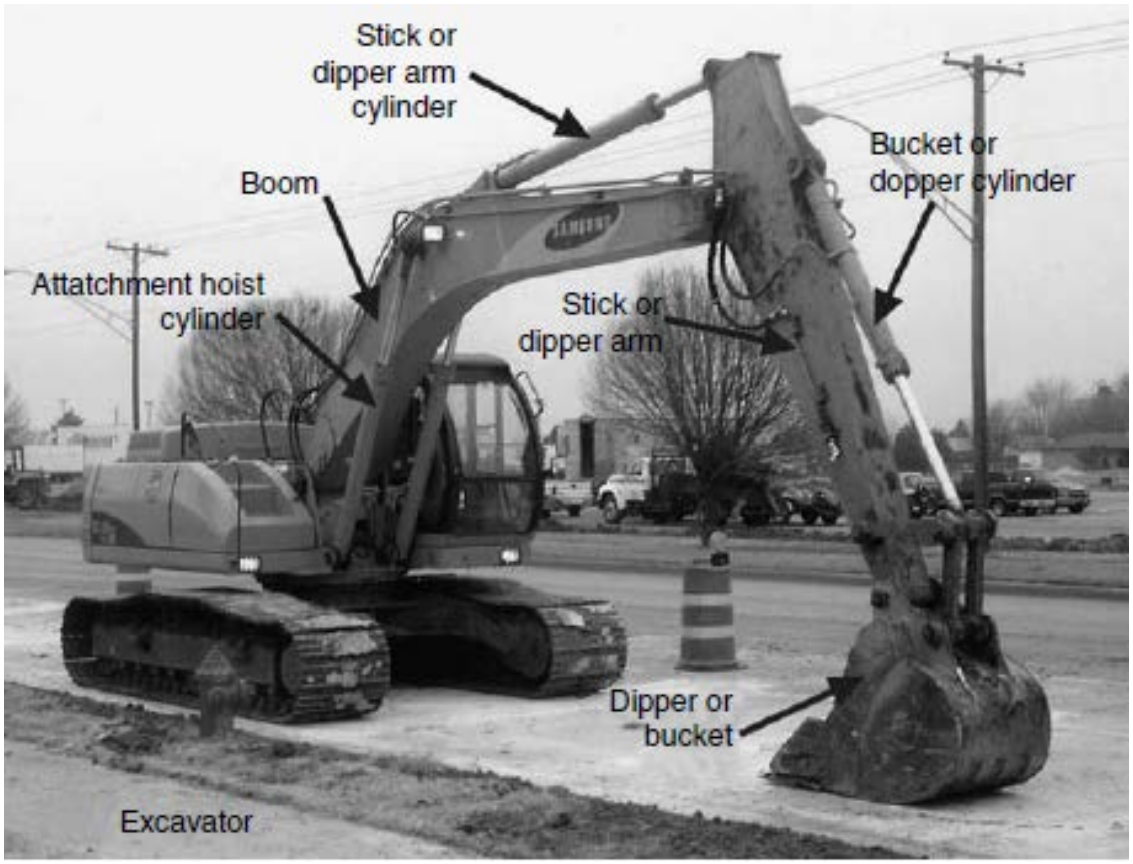
Excavators can accommodate numerous attachments such as pinchers for lifting logs or pipes, a jackhammer for busting up concrete or compacted soil, or a magnet for metal material moving. Excavator attachments are similar to backhoe attachments and are run by hydraulics. Along with the many attachments, excavators can be equipped with long reach booms, demolition arrangements, different shoe selections, and

different quick coupler systems. Bottom dump buckets permit more accurate loading of narrow trucks and reduce spillage.

Figure below 1 shows an excavator working on a surface below grade called a ‘‘bench.’’ The figure also shows how a flat surface is created next to the hole where a concrete drainage culvert is built. If the soil is really unstable, benching the edges of the hole may be required instead of sloping. It is like stair-stepping the excavation. The bench can also serve another purpose. In this case, the bench provides a surface for equipment to move and work. By working on this lower surface, the excavator’s digging depth can be increased. Note the backhoe and bulldozer in the background. Several excavators could be placed on ascending benches to accommodate the depth of the dig. The bottom excavator is actually performing the excavation.

Excavator on a bench.

As it digs, it swings and dumps the spoil on the next bench up. Other excavators placed on the benched areas pass the soil up out of the hole to be stored, spread, or hauled away.



Excavator parts.

The Output of Power Excavator:

The output is affected by numerous factors such as the following:

1. Class of material.
2. Depth of cut.
3. Angle of swing.
4. Job condition.
5. Management condition.

The output of an excavator should be expressed in cubic meters per hour (m^3/hr). (The capacity of a dipper is based on its struck volume. In excavating some classes of materials, it is possible for a dipper to pick up an amount which may exceed the struck volume.

BACKHOES

Backhoes are probably the most common piece of construction equipment found on commercial construction projects. They come in many sizes and are ideal for light excavation, trenching, material moving, and loading. Backhoes can be used as a hoe or a loader and can accommodate many different accessories and attachments for different operations. One of the backhoe's greatest strengths is that many attachments can be used to increase its versatility on a job site. Simple efficient systems are designed for easy connection of most attachments. If the contractor does not need the attachment all of the time, it can be rented as needed. Figure shows the hoe part is located on the back of the machine (backhoe). The operator drives and operates the loader bucket from the front seat and operates the hoe from the rear seat. Backhoes are designed to operate using outriggers for stability. Outriggers are spread on the digging end (excavator).

The scooping bucket supports the front end. All four wheels are off the ground when digging. The backhoe is ideal for light underground utility construction. The hoe can be used for trenching and lifting like the excavator. The bucket can be used for hauling material and backfill. If a loader bucket is used to move material, production is figured like a front-end loader. If the excavator bucket is used, production is figured like an excavator. Cycle components are the same. Times may be slightly less because of the manoeuvrability and size difference of the backhoe compared to a larger loader or excavator. Backhoes are made for lighter

work than typical loaders or excavators. They are purchased for many times their multiuse capacity. They need a fairly level and stable work surface and enough area for proper outrigger placement.

Backhoe.

FRONT SHOVELS

Front shovels operate very similarly to front-end loaders; they are designed to dig above grade into the face of the excavation, not to scoop at ground level. These shovels typically operate on tracks for better traction when pushing the bucket into the face to be excavated. The work typically entails filling the bucket, backtracking or positioning and dumping the bucket contents into a pile or a truck. Front shovels are typically not very mobile and travel distance minimized. Some shovels are equipped with bottom dump buckets to reduce wear on the machine and provide greater dumping and loading accuracy.

Front shovels excavate above grade or into a material face or pile above the operating surface. Their production cycle is similar to an excavator: dig, backtrack, dump, reposition, and start over. Shovels

digging into dense material typically operate on tracks. Shovels used for material rehandling where digging is not required might operate on tires. Front-end loaders operate similarly to front shovels, but are made for scooping at ground level, not excavating. They are classified similarly by their upward scooping motion. For optimum depth of cut, the bucket should be filled when it reaches the top of the face in one pass. This depends on the type of material and the size of the bucket. Optimum digging height for most shovels is between 40 and 50% of the rated maximum digging height. Breakout force is developed by crowding the material away from the shovel by pushing the bucket teeth into the material face and curling the bucket upward and toward the machine.

Equipment packages will vary based on the volume of work, desired productivity, equipment availability, and specific work conditions and needs. The excavator is used for:

- digging operations
- levelling operations
- pushing operations
- load and carry operations
- handling loads similar to crane
- mounting other equipment and acting as a tool carrier
- preparing and levelling stock storage pads
- towing loads and other equipment similar to a tractor
- General clean up of work areas.

TABLE: Earthmoving and Excavating Work Activities and Equipment Packages.

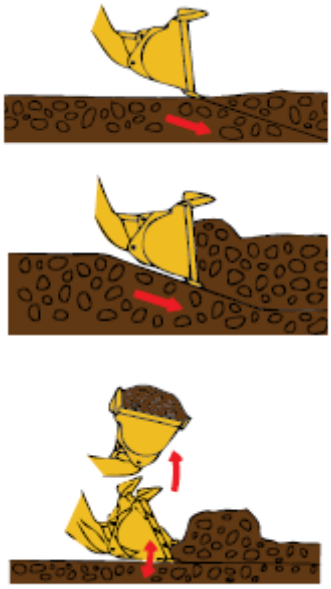
Activity	Dozer	Loader	Grader	Scraper	Dump Truck	Backhoe	Excavator	Front Shovel
Excavating above grade								×
Excavating below grade	×			×		×	×	
Grubbing	×						×	
Heavy ripping	×							
Light ripping			×					
Tree stump removal	×						×	
Topsoil removal/storage	×		×	×				
Rough cutting	×			×			×	
Rough filling	×	×		×	×			
Finish grading			×					
Foundation excavation						×	×	
Foundation backfilling		×				×	×	
Footing excavation						×	×	
Road base construction	×	×	×		×			
Temporary road construction	×	×	×		×			
Haul road maintenance			×					
Culvert placement	×		×		×	×	×	
Earth berm/ dam construction	×		×		×			
Drainage ditch maintenance						×	×	
Haul less than 500′	×	×						
Haul 500′ to 2 miles				×				
Haul over 2 miles					×			
Soil windrowing	×		×					
Soil spreading	×	×	×	×	×			
Excess loose soil removal		×			×			
Deep trench excavation							×	
Shallow trench excavation						×		
Trench backfilling	×	×				×	×	
Utility pipe placing — small						×	×	
Utility pipe placing — large							×	
Trench box placement/ movement						×	×	
Debris/trash removal		×			×		×	
Rock removal	×	×			×		×	
Asphalt paving removal	×	×			×		×	
Concrete removal	×	×			×		×	
Structure demo	×	×			×		×	
Assisting scrapers	×			×				
Towing other equipment	×	×						
Concrete placement — bucket							×	
Crane pad construction	×		×		×			
Detention pond excavation	×			×			×	
Benching	×		×				×	
Side sloping	×							

The digging operation should be carried with:

1- Set the edge of the bucket facing slightly down.

2- Drive the excavator forward and operate the lift arm control lever forward to cut a thin layer of the surface each time when excavating the soil.

3- Operate the lift arm control lever slightly up and down to reduce the resistance when driving the excavator forward. When digging with the bucket, avoid imposing the digging force onto only one side of the bucket.



Rough site excavation or site levelling is done in the following sequence:

1. A surveyor stakes the area outlining the perimeter of the work and details the depth of the cuts or fills.

2. A motor grader or bulldozer strips the surface of vegetation and debris.

3. A bulldozer with a ripper makes a pass over the area to be cut. It is advisable to rip a couple of inches deeper than the actual cut to be made. The loosened soil provides better traction for the bulldozer than a hard denser undisturbed surface.

4. A bulldozer removes the topsoil layer, pushing it into an out of the way stockpile to be spread when final grading and landscaping are done.

5. The bulldozer pushes dirt into piles to be moved to areas of the site needing fill or to be stockpiled at a remote location.

6. Several scrapers assisted by a bulldozer are used for mass surface excavation and to haul the excavated dirt to another location on site.

7. A motor grader spreads the dumped dirt at the new location.

8. Excavators dig rough detention areas.

9. Excavated soil is loaded into dump trucks by front-end loaders to be hauled off site.

10. A bulldozer and motor grader are used to finish the rough leveling of the site and detention areas.

Trench excavation for underground utilities is done in the following sequence:

1. A surveyor stakes the route of the trench and details the depth of cut.

2. A bulldozer and motor grader are used to grub, clear, and stabilize the surface.

3. An excavator or backhoe is used to scoop the dirt from the trench and pile it parallel to the trench. (Dense soils might require use of a trencher).

4. A forklift is used to unload, move, and hold the pipe while it is prepared for installation.

5. The excavator lifts and places the pipe in the trench.

6. A front-end loader is used to backfill the trench when the installation is complete.

Mechanism of opening hole

The size of a power excavator is indicated by the size of the dipper, expressed in cubic meters. In measuring the size of the dipper the earth is struck within the contour of the dipper, this is referred to as the struck volume, as distinguished from the heaped volume which the dipper may pick up in loose soil.

With an excavator in the correct position (near the face of the earth to be excavated), the dipper is lowered to the floor of the pit, with the teeth pointing into the face.

A crowding force is applied through the shaft and at the same time tension is applied to the hoisting line to pull the dipper up the face of the pit. If the depth of the face, referred to as the depth of cut, is right the dipper will be filled as it reaches the top of the face. If the depth of the cut is too shallow, it will not be possible to fill the dipper completely without excessive crowding and hoisting tension. This subjects the equipment to excessive strain and reduces the output of the unit.

If the depth of the cut is greater than is required to fill the dipper, it will be necessary to reduce the depth of penetration of the dipper into the face if the full face is to be excavated or to start the excavation above the floor of the pit. The material left near the floor of the pit will be excavated after the upper portion of the face is removed.

Optimum Depth of Cut

The optimum depth of a cut is the depth which produces the greatest output and at which the dipper comes up with a full load without undue-crowding. The optimum depth of cut varies with class of material (soil) and the size of dipper.

Types of holes

The Effect of the Depth of Cut on the Output of an excavator:

1) If the depth of the face is too shallow:-

a) It will be difficult to fill the dipper in one pass up the face.

b) So the time per cycle will increase. When the operator makes more than one pass to fill the dipper, the output of the excavator will be reduced.

2) If the depth of the face is greater than the minimum required to fill the dipper.

a) He may reduce the depth of penetration of the dipper into the face in order to fill the dipper in one full stroke.

b) He may be digging above the base of the face and then remove the lower portion later.

c) He may run the dipper up the full to the face and let the excess earth spill down to the bottom of the face, to be picked up later.

Any of the above procedures, will result in some lost time, based on the time required to fill the dipper when it is digging at optimum depth.

The percent of optimum depth of cut is obtained by dividing the actual depth of cut by the optimum depth for the given material and dipper, then multiplying the result by (100).

$$\%\ \ of\ optimum\ \ cut = \frac{Actual\ \ Depth}{Optimum\ \ Depth} \times 100$$

The Effect of the Angle of Swing on the Output of an excavator:

The angle of swing is horizontal, expressed in degree, between the position of dipper when it is excavating and the position when it is discharging the load. In another word, the horizontal angle in degrees (plan view) between the position of the bucket when it is digging and its position when it discharges its load is the angle of swing. If the angle of swing is increased, the digging and dumping cycle time is increased, thus

reducing production and increasing cost. Ideal production is achieved when the angle of swing equals 90^o. For maximum efficiency when setting up an excavator to dig a trench and load dump trucks with the excavated dirt, the loading path or spot of the trucks should be perpendicular to the direction of the excavator's tracks at 90^o or less.

The total time in a cycle includes digging, swinging to the dumping position, dumping and returning to the digging position. If the angle of swing is increased the time for cycle will be increased and the output of the equipment will be decreased.

The Effect of the Job Conditions on the Output of an excavator:

Every owner of an excavator knows that no two excavation jobs are alike. There are certain conditions at every job over which the owner of the shovel has no control. Job conditions may be classified as excellent, good, fair and poor. There is no uniform standard which may be used as a guide in classifying a job. Each job planner must use his own judgment and experience, in deciding which condition best represents his job.

The Effect of the Management Conditions on the Output of an excavator:

The attitude of the owner of an excavator in establishing the conditions under which an excavator is operated will affect the output of the excavator. While the owner may not be able to improve job conditions, he may take several steps to improve management conditions. Management conditions may be classified as excellent, good, fair and poor.