Pipe Jacking

Japan Sewage Works Association

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Pipe jacking is a trenchless method of new pipe installation. Factory-made pipe sections are jacked or pushed behind the tunnel boring machine or other tunnel excavation methods. Jacking force is transmitted from thrust wall installed in the drive shaft. Pipe jacking is used for the following cases.

1. Heavy traffic roads and crossings of railways, rivers, and massive structures
2. Sensitive environment & neighborhoods
3. Deep Installation

The followings need to be considered when jacking is adopted.
1. High water table and difficult soil condition may require special work.
2. Jacked pipe may subside in soft ground.
3. Handling unexpected subsurface obstacles may face difficulties while jacking.
4. Experienced operators and well organized construction work are necessary.
5. Location of shafts is important. Drive shaft may affect surrounding grounds.

Classification of Pipe Jacking

Classification can be made by several aspects such as methods of excavation, tunnelface support, jacking force transmission, spoil removal and so on. The nominal diameter of jacking pipe is also used for classification of pipe installation. In Japan, the diameters from 800 to 3000mm are defined as medium to large. The diameters correspond to man-entry size. The diameters from 150 to 700mm are defined as small. An example of classification is shown in Figure 1.
Selection of Jacking Method
Selection of jacking method needs to consider the following conditions: traffic, drive length, soil & groundwater conditions, sewer line route, diameter, traffic and neighborhoods at shafts, spoil removal and carry-in of pipes at shafts, subsurface obstacles and utilities, aerial power cable. Among them, the most important point is soil and groundwater conditions. The soil and groundwater conditions may require additional ground improvement works such as a chemical grouting. It is difficult to change jacking methods due to inoperable situation once a project begins. Therefore, the right method has to be chosen.

Jacking Method for Medium to Large Diameters
The nominal diameters of this category are 800 to 3000mm with worker entry.

Open Hand Shield
Open hand shield method is mainly used when excavation face is stable with small influence of groundwater. Its system is quite simple. As excavation face is open, obstacles are removed easily. The open hand shield method is often used for short drive length.
Figure 2 Open Hand Shield for Medium to Large Diameters

**Slurry**

In closed slurry shield jacking, the separation wall is placed behind the cutter head of the boring machine. Between separation wall and excavation face, slurry is injected to stabilize the face while keeping excavation smooth. Excavated material is transported from the tunnel face to outside of the shaft as waste slurry. Waste slurry is recycled after treatment at a separation plant.

Figure 3 Slurry for Medium to Large Diameters

**Earth Pressure Balance**

In closed earth pressure balance shield jacking, separation wall is placed behind the cutter head of boring machine. Excavated soil with or without plasticizer is filled between separation wall and excavation face to stabilize the face. By controlling the amount of excavated soil removed from the tunnel face, excavation and jacking are operated.
High Concentration Slurry

In closed shield jacking with high concentration slurry, the separation wall is placed behind the cutter head of the boring machine. Between the separation wall and the excavation face, highly concentrated slurry is injected to stabilize the tunnel face while keeping excavation smooth. In this method, excavated soil is removed from the tunnel face intermittently behind the excavator by the valve operation. Then it is sucked out of the shaft. High concentration slurry method is in the same category of closed face as the slurry method. It is also similar to the open hand shield method as both methods release the face pressure in the tunnel.
Quality Assurance and Quality Control for Jacking for Medium to Large Diameters

The quality assurance (QA) and quality control (QC) include controls on progress, material and equipment, work, safety and pollution.

Progress Control
Based on the construction plan, each jacking project needs to be completed for the deadline after checking work content and commencement time. Jacking is more likely to face uncertain incidents related to soil conditions and groundwater compared with ordinary civil engineering works. In order to minimize the uncertain incidents, a pre-installation survey needs to be done thoroughly.

Materials and Equipments Control
The materials and equipments used in jacking need to be tested to whether or not they conform to the specification on their dimensions, strengths and materials. Fragile material products need special care for their handling.

Work Control
During the works, soil conditions, groundwater, line of pipes, breaks and deformation of pipes need to be monitored constantly.

Safety Control
In many cases, jacking is conducted under groundwater table with poor soil condition in a confined tunnel. Since this working environment is harmful and dangerous, rules and regulations on safety need to be observed tightly. In addition, necessary equipment needs to be installed for the health of workers. Workers need to be trained to be aware of the safety and their health should be well monitored.

Pollution Control
In many cases sewer jacking takes place in downtown. Damage to the neighbors area needs to be prevented. To this end, environment, soil conditions, surface and subsurface structures close to jacking route, and wells need to be inspected beforehand. Adequate measures such as soil improvement need to be taken.
Jacking Method for Small Diameters

The nominal diameters of this category are 700mm or below without a worker entry. Jacking is operated by remote control from a drive shaft. Special consideration should be paid to avoid the situation where excavators or heads get stuck on the way.

An example of classification is shown in Figure 6. It is based on pipe material, excavation and spoil removal methods, and pipe installation methods.

![Figure 6 Classification of Small Diameter Jacking]

**High Strength Pipe**

High strength pipes include RC, ductile iron, resin concrete, and so on. With the use of high strength pipes, jacking force is transmitted through the pipe to resist the friction and excavation force.
**Press-in**

In press-in method, a leading head and a pilot tube are pressed in the tunnel face as the first step. In the second step, a screw conveyor is inserted into the pilot tube and an enlargement cutter head and pipes are placed behind the tube. The enlargement cutter head moves forward and spoil is discharged to the reception shaft while pipes are being jacked.

**Figure 7 Press-In for Small Diameters with High Strength Pipe**

**Figure 8 Press-In for Small Diameters with High Strength Pipe**
Auger

In the Auger method, Auger and screw conveyor are installed in leading head. Auger and screw conveyor rotates in order to excavate and the spoil is removed to the drive shaft. Remote control for direction is available.

Figure 9 Auger for Small Diameters with High Strength Pipe Slurry

In slurry method, the leading cutter head is ahead of the jacking pipes or the pilot tube. Slurry is injected to stabilize the face while excavating with the rotation of cutter head. The spoil is mixed with slurry and transported to the soil separation plant above the ground. One and two steps systems are available. Either of them can use remote direction control.

In one step slurry method, the system is a miniature of the slurry jacking for medium to large diameters. Jacking pipes are directly connected to leading cutter head.
Figure 10 One Step Slurry for Small Diameters with High Strength Pipe

In two step method, firstly, the pilot tube is connected behind the leading cutter head and is jacked to the reception shaft. Then the pilot tube is replaced by jacking pipes.

1st Step: Jacking of pilot Tube

2nd Step: Jacking of RC Pipe

Figure 11 Two Step Slurry for Small Diameters with High Strength Pipe

Earth Pressure Balance

In earth pressure balance, one step method with leading cutter head attached to the top of jacking pipes is the norm. In case of sandy soil, plasticizer is injected to the head. By controlling the amount of spoil removed from excavation face, face support is achieved. Spoil removal methods include screw conveyor, pressure, and vacuum.

Figure 12 One Step Earth Pressure Balance for Small Diameters with High Strength
Pipe, Screw Conveyor for Spoil Removal

Figure 13 One Step Earth Pressure Balance for Small Diameters with High Strength Pipe, Pressure for Spoil Removal

Figure 14 One Step Earth Pressure Balance for Small Diameters with High Strength Pipe, Vacuum for Spoil Removal

Low Strength Pipe
Low strength pipe jacking uses PVC pipe. The leading head gets part of jacking force to drive into the face while pipes receive the rest of jacking force to cope with friction. Low
strength pipe jacking includes press-in, auger, slurry, and earth pressure balance.

**Press-in**
In press-in, the leading head and the pilot tube are jacked in as a first step. Then, the enlargement head attached to the front end of the pilot tube rotates and excavates tunnel with diameter of the pipe. The spoil is conveyed by screw to the drive shaft. The driving force at the face is transmitted through either casing or screw conveyor from the jack. The jacking pipes receives only friction force with the surrounding soil of the jack.

![Diagram of Press-in Jacking Process](image)

**Figure 15 Two Step Press in for Small Diameters with Low Strength Pipe**

**Auger**
In Auger jacking, the Auger head and the screw conveyor are in the leading head. They rotate to excavate the soil and to remove the spoil while taking the drive force from the jack. The jacking pipes accept force only for friction with surrounding of the jack.

![Diagram of Auger Jacking Process](image)
**Figure 16 One Step Auger for Small Diameters with Low Strength Pipe**

**Slurry**

In slurry jacking, a casing pipe (with a slurry pipe for injection and one for removal) is connected to the tail of the leading head. Pressurized slurry is injected to the face for support while the cutter head rotates for excavation. The excavated soil is mixed with slurry and removed from the face to the soil separation plant on the ground. The driving force is transmitted through the casing pipe from the jack. The jacking pipes undergo force only from the friction with the surrounding from the jack.

**Figure 17 One Step Slurry for Small Diameters with Low strength Pipe**

**Earth Pressure Balance**

In earth pressure balance jacking, plasticizer injection and pinch valve control allow the face support. The cutter head rotates and excavates the soil. The screw conveyor removes as much spoil volume as the driving length while stabilizing the face pressure. A Casing rod is used to transmit jacking force to cope with the resistance force at the face. Soil friction force is taken by jacking pipes.

**Figure 18 One Step Earth Pressure Balance for Small Diameters**
with Low Strength Pipe

Steel Casing Pipe
In steel casing pipe jacking, the casing pipe is used to transmit the jacking force to create the tunnel. Inside the casing, a PVC pipe is inserted and an annular space is grouted. Steel casing pipe jacking methods are classified as press-in, auger, rotational casing, and slurry by transmission of jacking force, excavation and spoil removal, and pipe installation.

Press-In
In press-in method, a pneumatic ram is used to drive a casing pipe in to the soil.

![Figure 19 One Step Press-In for Small Diameters with Steel Casing Pipe](image)

Auger
In auger method, the Auger head and the screw conveyor are installed in the leading head which is attached to the front end of the steel casing pipe. They rotate in order to excavate the soil who are removed to the drive shaft.
Rotational Casing
In rotational casing method, single and double casing methods are available. In single casing, the drill bit is attached to the front end of the casing pipes. The drive device rotates in order to jack the casing pipe.

Figure 21 Rotational Casing for Small Diameters with Single Steel Casing Pipe
The double casing is composed of two part, one outer casing that does not rotate and one inner casing that does. The front end of the inner casing have a drill bit cutter. The inner casing is removed from the drive shaft after the casings reach the reception shaft.
**Figure 22 Rotational Casing for Small Diameters with Double Steel Casing Pipe**

**Slurry**

In slurry method, the leading head is attached to the front end of the jacking pipes or the pilot tubes. The pressurized slurry is injected to the cutting face to support it. The cutter head rotates and excavates the soil. The spoil is mixed with slurry and transported to a soil separation plant on the ground.

**Figure 23 Slurry for Small Diameters with Steel Casing Pipe**

**QA and QC for Jacking for Small Diameters**

In the same way as the jacking method for medium to large diameter, controls for progress, material and equipment, work, safety and pollution are highlighted for QA and QC for small diameters jacking. Small diameter jacking have some specific problems such as: impossible jacking, zigzag line, pipe break, surface settling, groundwater inflow, damage to other utility lines. Man-entry is not possible for small diameters. So the excavation face cannot be checked directly visually. Furthermore, even in case of emergency, human operation is impossible in the tunnel. For this reason, it is expensive to control the emerging situation. Therefore, QA and QC requires special attention.

**Lateral Jacking**

When open cut is not feasible for lateral installation, because the sewer main is too deep, lateral jacking is taken. In lateral jacking, a steel casing pipe is jacked from the surface to the sewer main. After the soil removing in the casing, a bore is drilled on the sewer
main. Then a PVC pipe with special saddle is connected to the sewer main. The nominal diameters for lateral jacking are from 100 to 250mm.

Figure 24 Lateral Jacking