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, face 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 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.
In closed slurry shield jacking, separation wall is placed behind the cutter head of 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 face to outside the shaft as waste slurry. Waste slurry is recycled after treatment at a separation plant.

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 face, excavation and jacking are operated.
High Concentration Slurry

In closed shield jacking with high concentration slurry, separation wall is placed behind the cutter head of boring machine. Between separation wall and excavation face, highly concentrated slurry is injected to stabilize the face while keeping excavation smooth. In this method, excavated soil is removed from the 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 for progress, material and equipment, work, safety and pollution.

Progress Control
Based on the construction plan, each work of jacking project needs to complete by deadline after making sure of 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 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 educated 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 neighbors 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 force from friction and excavation.
Press-in
In press-in method, a leading head and a pilot tube are pressed in against the 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 for excavation and spoil removal to the drive shaft. Remote control for direction is available.

![Figure 9 Auger for Small Diameters with High Strength Pipe Slurry](image)

**Figure 9 Auger for Small Diameters with High Strength Pipe Slurry**

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

**Figure 10 One Step Slurry for Small Diameters with High Strength Pipe**
In two step method, firstly, pilot tube is connected behind leading cutter head and jacked to the reception shaft. Then pilot tube is replaced by jacking pipes.

1st Step: Jacking of pilot Tube

2nd Step: Jacking of RC Pipe

Earth Pressure Balance

In earth pressure balance method, one step is the norm with leading cutter head attached to the top of jacking pipes. 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 11 Two Step Slurry for Small Diameters with High Strength Pipe

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

Low strength pipe jacking uses PVC pipe. Leading head gets part of jacking force for its driving 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, leading head and pilot tube are jacked in as a first step. Then, enlargement head attached to the front end of pilot tube rotates and excavates tunnel with diameter of the pipe. The spoil is conveyed by screw to the drive shaft. Driving force at the face is transmitted through either casing or screw conveyor from the jack. Jacking pipes receive only friction force with surrounding soil from the jack.

![Figure 15 Two Step Press in for Small Diameters with Low Strength Pipe](image)

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

![Figure 16 One Step Auger for Small Diameters with Low Strength Pipe](image)
**Slurry**

In slurry jacking, a casing pipe with a slurry pipe for injection and removal inside is connected to the tail end of leading head. Pressurized slurry is injected to the face for its support while cutter head rotates for excavation. Excavated soil is mixed with slurry and removed from the face to the soil separation plant on the ground. Driving force at the face is transmitted through the casing pipe from the jack. Jacking pipes accepts force only for friction with surrounding from the jack.

![Figure 17 One Step Slurry for Small Diameters with Low Strength Pipe](image1)

**Earth Pressure Balance**

In earth pressure balance jacking, plasticizer injection and pinch valve control enable face support. Cutter head rotates and excavates soil. Screw conveyor removes the spoil as much volume as the driving length while stabilizing face pressure. Casing rod is used to transmit jacking force to cope with 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](image2)
Steel Casing Pipe

In steel casing pipe jacking, the casing pipe is used to transmit jacking force to make tunnel. Inside the casing, PVC pipe is inserted and 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, 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, auger head and screw conveyor are installed in the leading head attached to the front end of steel casing pipe. They rotate for excavation and spoil removal to the drive shaft.

![Figure 20 One Step Auger for Small Diameters with Steel Casing Pipe](image)
**Rotational Casing**

In rotational casing method, single and double casing methods are available. In single casing, drill bit is attached to the front end of casing pipes and drive device rotates and jacks the casing pipe.

![Figure 21 Rotational Casing for Small Diameters with Single Steel Casing Pipe](image)

In double casing, inside the outer casing without rotation is rotational inner casing. The front end of inner casing has drill bit cutter. Inner casing is removed to the drive shaft after the casings reach the reception shaft.

![Figure 22 Rotational Casing for Small Diameters with Double Steel Casing Pipe](image)
**Slurry**

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

![Slurry Plant Diagram](image)

**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 for medium to large diameter, controls for progress, material and equipment, work, safety and pollution are highlighted for QA and QC for jacking for small diameters. Specific problems of small diameter jacking include impossible jacking, zigzag line, pipe break, surface settling, groundwater inflow, damage to other utility lines. Man-entry is not possible for small diameters. So excavation face cannot be seen directly by eyes. Furthermore, even in emergency, human operation is impossible in the tunnel. For this reason, it is costly to control the emerging situation. Therefore, QA and QC need to have maximum attention.

**Lateral Jacking**

When open cut is not feasible for lateral installation, such as when sewer main is deep, lateral jacking is taken. In lateral jacking, a steel casing pipe is jacked from the surface to the sewer main. After the soil in the casing is removed, 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.
Reference