IMPROVEMENT OF SOIL DEPOSITS BY CURVED GROUTING

HIROSHI YOSHIDA[1], **KUNIO SAITO**[2,a] and **KENJI ISHIHARA**[2,b]

[1]*Chemical Grouting Co. Ltd., 2-2-5, Toranomon, Minato-ku, Tokyo, 105-0001, Japan.*
E-mail: h-yosida@chemicalgrout.co.jp

[2]*Research and Development Initiative, Chuo University, 1-13-27-31225 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan. E-mail: [a]saitoh@civil.chuo-u.ac.jp; [b]ke-ishi@po.iijnet.or.jp*

Abstract: A brief description is given of the in-situ technique of drilling a long curved hole under the ground. As an example of utilizing this method, a conduct of in-situ pilot test in Japan is introduced in which jet-grouted column were installed in the horizontal direction in a saturated sand deposit. This example indicated viability and applicability of the technique for improving soil deposits in curved alignments.

Keywords: Jet grouting; curved; pilot test.

1. INTRODUCTION

The permeation grouting has often been used in Japan for stabilizing sand-rich deposits against liquefaction during earthquakes. Also, of frequent use is the jet grouting which is effective for any type of soil materials. The grouting technique has been implemented by first drilling a vertical hole and then lifting the jet monitor gradually from the bottom of the drilled hole while ejecting cement slurry. Over a period of the last decades, there has been a growing demand to reinforce soil deposits underneath existing structures such as oil tanks, buildings and underground viaducts. In response to such needs, techniques for drilling curved holes have been developed and the advances in this technique made it possible to implement a horizontal array of the jet grouting. In this paper, the method to drill a curved hole will be briefly described first and an example of its installation will be given for jet grouting by making use of the curved boring.

2. METHOD OF DRILLING A CURVED HOLE

The drilling is performed by advancing a cylindrical steel tube 65 to 90 mm in diameter which is equipped with a brim-shaped cutting edge as shown in Fig. 1. More detailed setting of the cutting blade with the drill rod is illustrated in Fig. 2. If the drill rod is rotated continuously using drilling mud, a hole is guided to advance straightforward as illustrated in Fig. 2(a). If the hole is to be curved, the brim should be first rotated statically to a targeted direction through remote control from the entrance of the hole on the ground surface. Then the operator pushes forwards the drilling rod. When the rod does not advance, it is moved back and forth while ejecting the drill mud from the end of the drill rod. For the soft deposits with a SPT N-value less than about 30, this operation can be done without difficulty. Even for stiffer soil deposits, the same operation can be worked out without much difficulty. The angle of curvature is controlled manually by the operator by adjusting the force of pushing the drill rod. If the hole is to be curved sharply, i.e., at a large angle, the pushing force should be stronger and via versa. The location of the bored hole is checked,

Ground Improvement Technologies and Case Histories
Edited by C. F. Leung, J. Chu and R. F. Shen. *Published by* Research Publishing Services.

ISBN: 978-981-08-3124-0
doi:10.3850/GI178

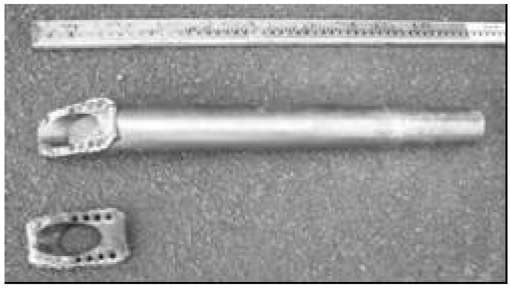

Figure 1. Brim-shaped cutting bit for curved drilling.

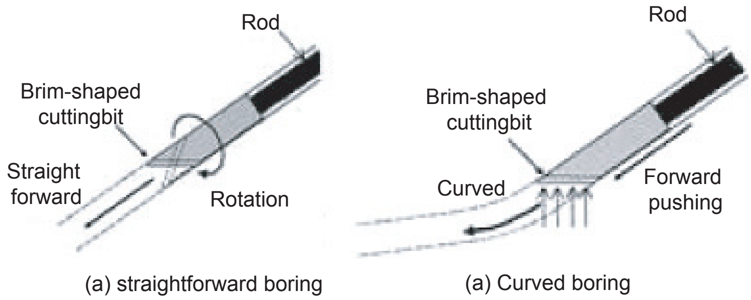

Figure 2. Illustration for straight-forward and curved boring.

as necessary, by once taking out the dill rod and by inserting a gyroscope-equipped flexible rod into the drill rod. When pulling out the gyroscope-rod, the continuous records are obtained on the angle of the already-drilled curved hole at many points at some intervals. Using these data, a complete trace of a curved bored hole can be established in the three-dimensional manner. After the curved portion has been advanced through a targeted distance, the phase of continuous rotation may be resumed, if the hole is to be guided straightforward. In case the hole is to be curved again, the direction of the brim is changed again by the remote control, and the phase of static pushing is implemented.

By combining the two phases of operation as above, that is, continuous rotation and static pushing with shifted direction of the brim, curved drilling towards any direction and distance can be executed. To demonstrate how the rotation of a long curved rod could be worked out within the curved narrow hole, a curved rod was placed on several supports on the ground as shown in Fig. 3 and then it was rotated. The rotation could be performed without any difficulty. It may be difficult to understand, by intuition, how continuous rotation of a long curved rod can be managed by an operator at one end on the ground surface, but it can indeed be feasible even in the long hole. The machine in operation for the inclined drilling is shown in Fig. 4. The curved boreholes can be utilized for multiple purposes. Examples of using the curved hole for jet grouting will be described in the following.

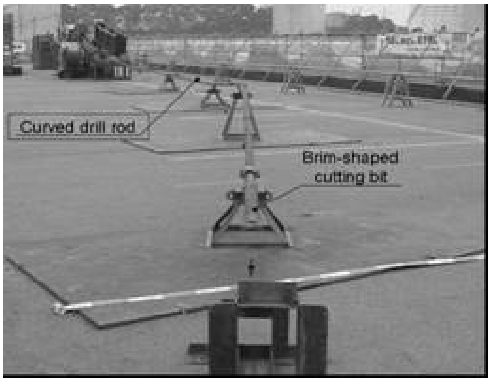

Figure 3. A long curved rod to drill a hole in the ground.

Figure 4. Inclined drilling in operation.

3. CURVED JET GROUTING

In the normal practice of jet grouting, a vertical hole is first drilled and then the monitor rod is lowered to a targeted depth. Then, jet grouting operation is conducted upwards. It is to be noticed here that the direction of grout advancement is from the farthest end of the hole towards the hands of the machine operator which may be called "pulling operation". This is necessitated to facilitate easy discharge of the cuts-containing debris or spoils to open space on the ground surface without clogging the annular space between the drill rod and the surrounding drainage pipe (spoil vent pipe).

In the case of the curved jet grouting, the free outflow of the debris slurry as above must be worked out as easily as intended. Thus, in order to achieve the pulling operation in the curved jet grouting, the curved hole is drilled first until it reaches the ground surface on the opposite side which is located at some distance from the starting point of drilling operation. This is indicated in Fig. 5 as Step 1 operation. After the brim-shaped cutting edge has appeared on the ground surface, the cutting bit is removed and the jet grout rod is fixed to the end of the drill rod together with a flexible long pipe such as poly chlorinated biphenyl pipe which is going to be used as a spoil-vent pipe. The jet-grout rod enclosed by this spoil-vent, both attached to the end of the drill rod, is pulled back to the machine position through the hole already drilled as shown as Step 2 in Fig. 5. Note that when the

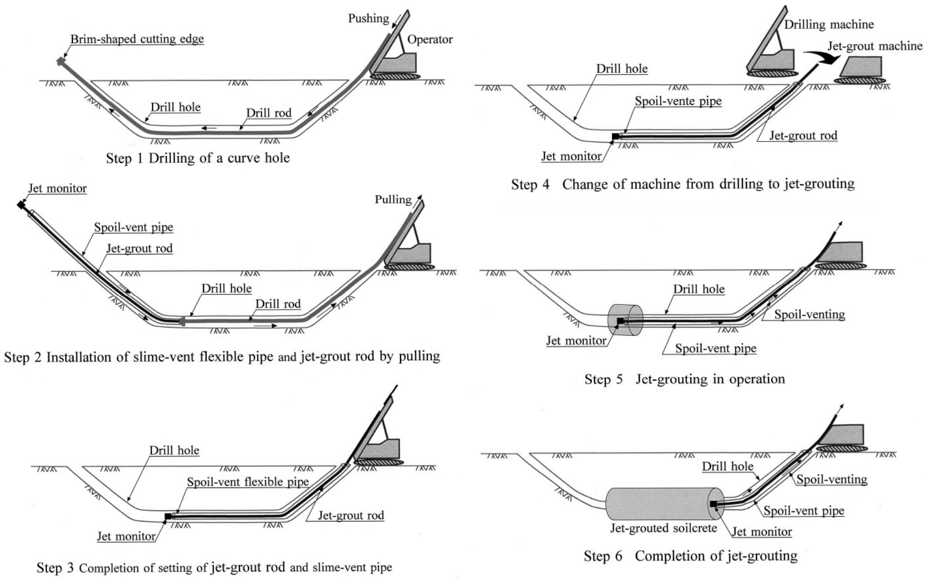

Figure 5. Steps for implementing jet-grouting through a curved hole.

jet grout rod is pulled back to the position of the machine, the jet monitor is still attached to the other end of the jet-grout rod. Then, the drill rod is removed.

The jet monitor and jet grout rod is again inserted in the hole together with the spoil vent pipe to a target place. Then, the jet grouting is started in the same usual fashion as it is done upwards in a vertical hole. Step 3 in Fig. 5 indicated the completed state of setting of the jet monitor and spoil-vent pipe from where the jet grouting starts back towards the machine from the target position. Step 4 simply shows the change of operating machine from drilling to jet grouting. Step 5 in Fig. 5 shows the state of jet-grouting in progress and Step 6 indicates a final completed state of grouting.

4. PILOT TEST OF CURVED JET GROUTING IN TOKAI, JAPAN

To verify how well the above procedure could work in the field, a series of pilot installation was attempted recently at a test yard in Tokai, Ibaragi Prefecture in Japan. A section of an open yard was excavated to a depth of 3.1 m as illustrated in Fig. 6. The native ground consists of clay and loam of volcanic origin and the ground water level is 1.1m below the surface. Then, the open pit was backfilled with a fine to medium sand which was compacted by hydraulic filling so as to have a SPT N-value of about 10. On top of the backfill, cohesive soils were piled up to a height of 1.6 m as a surcharge. Then, the curved drilling was conducted until the end of the drill rod came out on the ground surface 338m distant from the place of the drilling machine as illustrated in Fig. 6. Jet grouting was then conducted in the middle of the excavated pit at a depth of 3.6 m towards the operator as indicated in Fig. 6. In installing the jet grout, water jet was first ejected for cutting the soil and then cement slurry without water wrapping was jetted to solidify the soil. Three horizontally jet-grouted columns each having a diameter of 1.5 m were installed so that there is a overlapping of 20∼30 cm between two neighbouring columns as indicated in Fig. 7. Note that the jet grouting was conducted in the saturated compacted sand deposit below the ground table. After installing the horizontal jet grout, the pit was excavated to examine how well the columns had been formed under the ground. Fig. 8 shows the horizontally laid-down columns indicating that the technique had been implemented to a reasonable level of satisfaction.

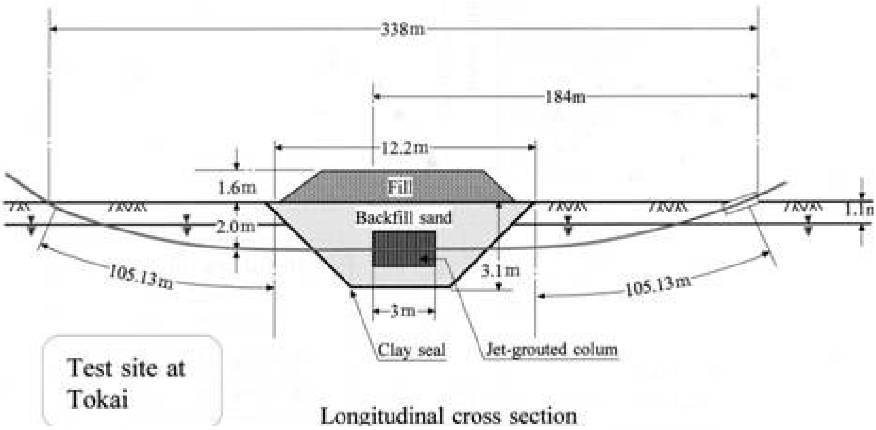

Figure 6. Pilot test site at Tokai for horizontally laid jet grouting.

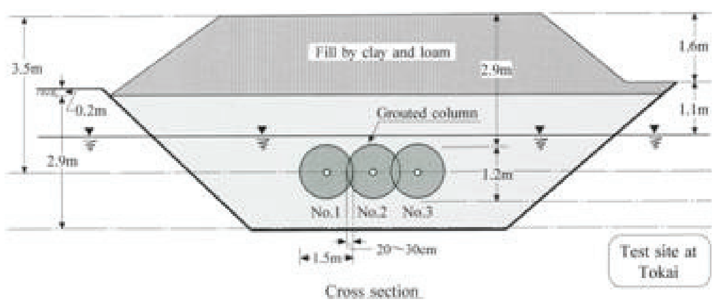

Figure 7. Cross section of the horizontally jet-grouted columns in Tokai, Japan.

Figure 8. Horizontally laid jet-grouted columns at the test site in Tokai after excavation.

5. CONCLUSIVE REMARKS

The technique of drilling curved holes in the ground in three-dimensional manner is a new aspect of development which could be applied for multi-purposes such as soil investigation, improvement of soils under existing facilities, and so on. In this paper, outcome of pilot tests was first introduced for installing horizontal jet grouting using the technique of the curved hole drilling. Exposure of the jet-grouted columns by excavation of the test pit disclosed that in-situ formation of the improvement had been conducted with a reasonable of accuracy.

References

1. M. P. Moseley and K. Kirsch, *Ground Improvement* (Spon Press, 2004).
2. M. Shibazaki, State of Practice of Jet Grouting, in *Grouting and Ground Treatment* (ASCE 2003), pp. 198–217.
3. T. Yahiro, H. Yoshida and K. Nishi, *Soil Improvement Using Water Jet* (Kajima publication, 1983) (in Japanese).
4. T. Yahiro, *Technique of Water Jet Grouting* (Kajima Publication, 1996) (in Japanese).
5. *Newest Soil Improvement Technologies* (Industrials Technique Service Center, 1997) (in Japanese).