IMMOBILIZATION OF CONTAMINATED SOIL USING JET GROUTING METHOD

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ABSTRACT

Some hazardous wastes, such as a low-level radioactive waste, have been or will be stored in concrete pits constructed under the ground. In order to keep the environment sound, it is necessary to develop assured techniques which contribute to repair a damaged or degraded concrete wall and to prevent toxic substances from dispersing toward the surrounding environment.

In order to immobilize such contaminated soil, we examined the idea of using a conventional jet grouting method through both a demonstrating experiment and laboratory tests. The results indicate that grouting material which is composed of cement, silica fume and blast-furnace slag and so on, has 10^{-10} to 10^{-11} m/sec in hydraulic conductivity, 5 to 9 MPa in unconfined compressive strength, when it is solidified, and the same order of distribution coefficient as an ordinary cement, also indicate that the solidified column is stick to each other as well as to the existing structure of concrete.

OUTLINE OF JET GROUTING METHOD

Jet grouting method is a kind of soil improvement methods and is characterized by using highly pressurized water jet to excavate the ground and building columns in the ground. Figure 1 explains the procedure of this method.

1. Dig a borehole to a scheduled level.
2. Insert a triple-wall pipe.
3. Highly pressurized water jet, which is shrouded by the compressed air jet, is blown horizontally to excavate the ground while triple-wall pipe is withdrawn upward with rotation.
4. The removal of mud-slime and the injection of cement-type slurry follows.

Specification of the pressure and the flow rate of water, air or slurry and the rate of rotation or withdrawal is decided through the pre-investigation and the results of the past. This method is available to excavate the ground of cohesive soil, sand or soft rock, whose unconfined compressive strength is less than 2MPa. But if the target ground is of many gravels, humus soil or has extreme heterogeneity, it is difficult to make good columns. Table I shows the standard parameter of conducting the grouting and the diameter of columns.

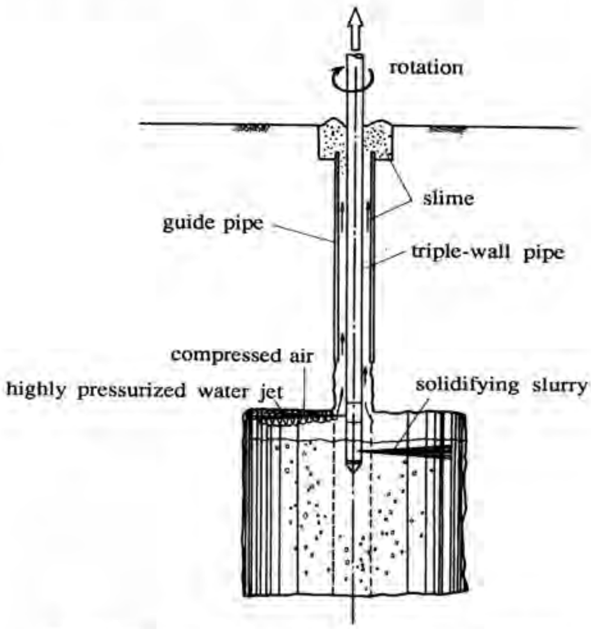


Fig. 1. General scheme of jet grouting method.

Figure 2 shows an example of the column assembly which aims to enclose the soil contaminated by a leakage from concrete structure. Optimized number of boreholes are drilled in concrete wall or the surrounding ground to the level where the contamination spreads out, after that we do the jet grouting. The mud-slurry drawn off from the ground is expected to be contaminated, so that it is necessary to do some proper treatment and to inject it back to the ground with mixing with cement-slurry. After the operation, the boreholes are sure to be filled with cement carefully.

In order to make this method reliable, following items should be assured:

- connection of each column
- connection between columns and a concrete structure
- method to minimize the migration of contamination from the bottom area surrounded by column wall

The third one would be proved by the establishment of the system which can build a column with larger diameter. Following section shows the results of the demonstrating experiment to investigate the 1st and 2nd items as well as laboratory tests.

EXPERIMENT

Demonstrating Experiment

The demonstration experiment was conducted by utilizing a mock-up facility, that is, a concrete model was placed in the sand bath and was supported by steel beams 1.5 m above from the base of the bath. Jet grouting was conducted into the artificial sand ground below the concrete model. Figure 3 shows the arrangement of the model in the sand bath. The model represents a part of wall and basement of a concrete pit. Two boreholes for inserting triple-wall pipe were drilled at a distance of 0.5 m from the wall. The same specification of jet grouting as shown in Table I was taken for the experiment. The composition of the cement-slurry, which is shown in Table II, is determined through some pre-investigation.

Laboratory Tests

The samples for the test were prepared by coring of the completed column. Figure IV shows the location of the sample

TABLE I

Standard Parameter of Jet Grouting and Diameter of Columns

	Pressure [MPa]	Flow Rate [m^3/sec]					
Highly pressurized water	40	$1.7x10^{-3}$			withdrawal rate: $1x10^{-3}$ m/sec		
Compressed air	0.7	$2.5x10^{-2}$ - $5.0x10^{-2}$			rotating rate: 5 rpm		
Solidifying component	2-5	$3x10^{-3}$					
Sandy soil	$N^* < 30$	$30 \leq N < 50$	$50 \leq N < 100$	$100 \leq N < 150$	$150 \leq N < 175$	$175 \leq N < 200$	$200 \leq N$
Cohesive soil	-	$N < 5$	$5 \leq N < 7$	-	$7 \leq N < 9$	-	$N = 10$
Diameter [m]	2.0	2.0	1.8	1.6	1.4	1.2	1.0

*N: Standard Penetration Test Value

coring. The samples were grouped into two: (group 1) No. 1, 2, 2' and 3 were used to examine the column itself, and (group 2) No. 1", 2" and 3" were to the interface between the column and the concrete model.

Samples of group 1 were used to investigate the permeability or the unconfined compressive strength of the solidified column and the distribution coefficient of the milled substance of the column. Samples of group 2 were used to know the degree of stickness of the column to the concrete model. Testing apparatus, shown in Figure 5, is to measure the strength for shearing at the interface, which is one of the factors to evaluate the stickness.

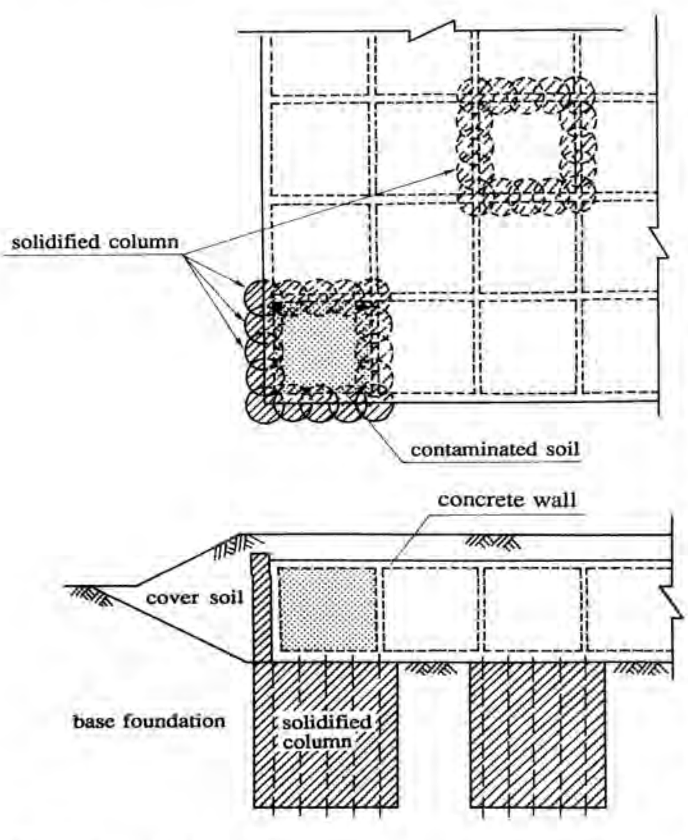


Fig. 2. Example of column assembly enclosing contaminated soil.

TABLE II

Optimized Solidifying Component

Portland cement	331 kg/m^3
Water	655
Silica fume	265
Blast-furnace slag	331
Superplasticizer	6.6

RESULTS

Demonstrating Experiment

Figure 6 shows the shape of the completed column which was measured after the excavation of the surrounding sand. Judging from the condition of the sand ground, it is considered good results that the diameter of the column reached to more than 2 m. The increase of the diameter along the level upward is probably owing to the complicated turbulence of the jet or the fact that the jet can reach far more in air than in water.

Laboratory Tests

Hydraulic conductivity was measured under constant head condition and calculated out according to the Darcy's Law. Table III summarizes results of permeability test and compressive strength test. The results show that the hydraulic conductivity is less than about 10^{-10} m/sec and that the one a the column-column boundary is smaller than that at column itself. It is not sure that this difference is due to the characteristics of this method or a simple fluctuation. Such tendency can be seen in the data of unconfined compressive strength.

Table IV shows the distribution coefficient of several nuclides to the milled sample. The sample was poured into distilled water with a topical nuclide in a polypropylene bottle and stirred twice a day. Each test continued for two weeks. Reference data of mortar and concrete are introduced in the same table. It can be seen that each material except ^{60}Co is much alike in this property. But this would be explained by taking short halflife of it into consideration.

Table V shows the results of shearing test. This indicates rather good connection between the concrete model and the completed column. This is because the water jet washes the

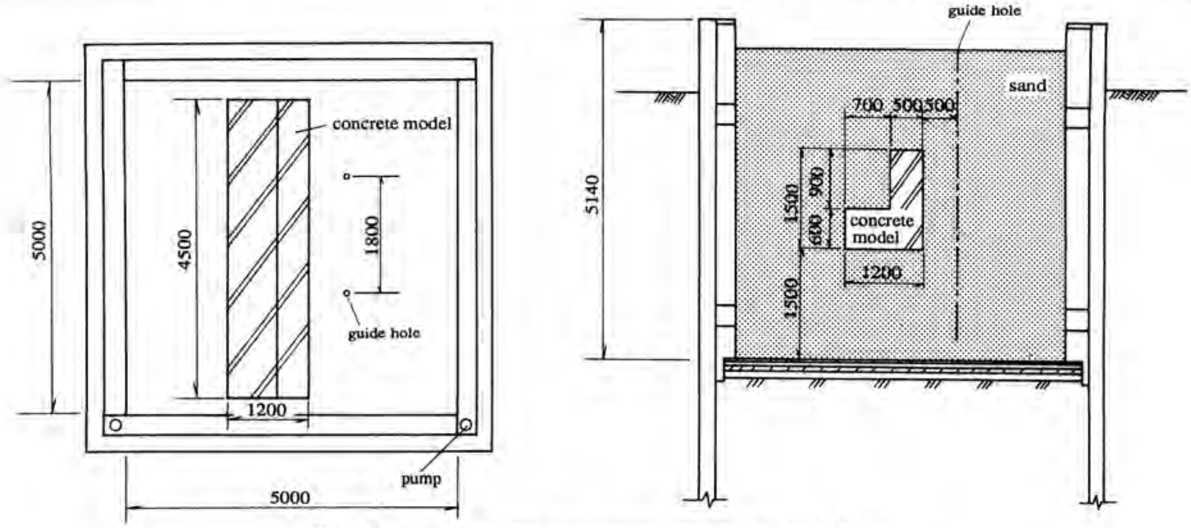
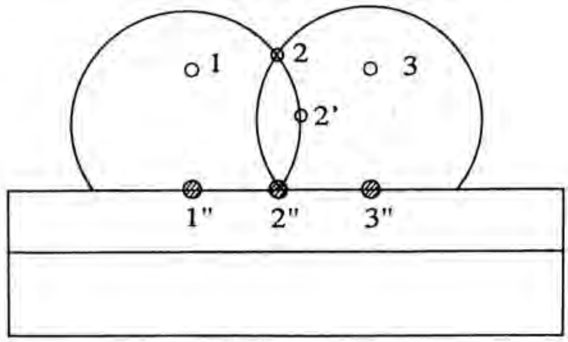


Fig. 3. Arrangement of concrete model in sand bath.



diameter of sample No.1,2,2',3 : ϕ 55mm
No.1",2",3" : ϕ 150mm

Fig. 4. Location of sample coring.

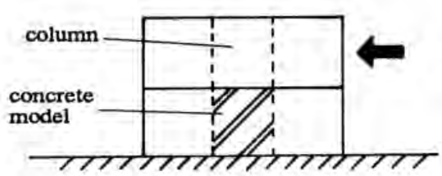


Fig. 5. Testing apparatus for shearing.

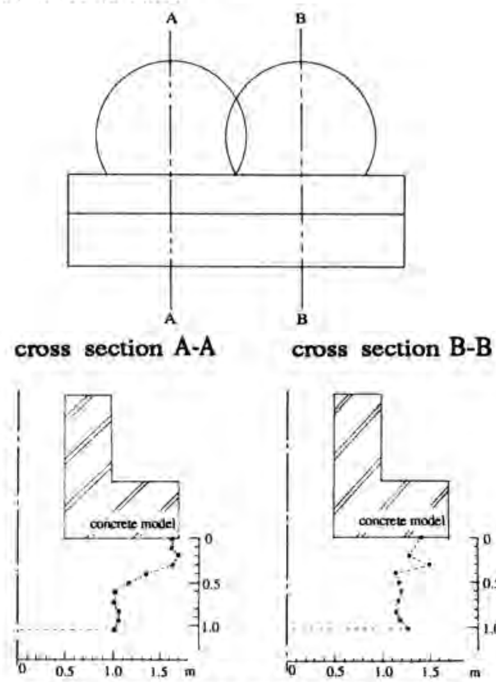


Fig. 6. Shape of the completed column.

TABLE III

Hydraulic Conductivity and Unconfined Compressive Strength of Test Samples of Column

	Column (sample No. 1, 3)	Column-column boundary sample No. 2, 2'
Hydraulic conductivity [m/sec]	9.3×10^{-9} - 1.3×10^{-10}	2.6×10^{-11} - 5.6×10^{-11}
Unconfined compressive strength [MPa]	5.4 - 7.7	6.4 - 8.7

TABLE IV

Distribution Coefficient of Nuclides

	Mortar	Concrete	Column body
$^{14}C^*$	4	3	50
^{60}Co	5000	1900	560
^{63}Ni	3800	2900	4500
^{85}Sr	30	20	130
^{99}Tc	0.3	2	0.2
^{125}I	0.4	0.3	0.7
^{134}Cs	120	70	240

*: organic carbon
unit: cm^3/g

TABLE V

Strength for Shearing at Interface of Column and Concrete Model

Sample No.	Strength [MPa]
1"	1.7
2"	1.5
3"	1.7

bottom of the model effectively, which would set the stage to act cement-slurry on the model.

CONCLUSIONS

Jet grouting method is originally one of the soil improvement methods and another application to immobilize the contaminated soil has been studied. It would be concluded that this method is available to enclose a large area of contaminated soil especially for a quick counterplan.

Though, a further work is needed to make this system reliable: how to control the jetting during operation to make good columns, how to make a column in harder ground and so forth.

ACKNOWLEDGEMENT

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