

DIFFICULT FOUNDATION PROBLEMS SOLVED

BY JET GROUTING

INTRODUCTION

With the advances in Ground Technology and Foundation Techniques, Difficult Foundation Problems involving Ground Distress, Settlements, Difficult Construction Conditions and Unstable Slopes are finding new solutions that were unheard of particularly in our country until very recently.

One of these solutions now available in the country is Jet Grouting.

Jet Grouting is a process of Ground Stabilization by high pressure injection of Cement Grout into the soil. Because of the controlled insertion, rotation and withdrawal of the high pressure Jetting Pipe, a columnar element of Grouted Soil known as “*Soilcrete*” is produced. The diameter and strength of this solidified mass of “*Soilcrete*” is controlled during the installation process.

Although this description appears to be overly simple, the process is more complicated than the foregoing.

In order to understand this fully, we need to go back to the historical development of Jet Grouting as the evolutionary processes have contributed to the present day technology and its successful application.

HISTORICAL BACKGROUND

The procedure and idea of using high velocity Jet Streams to cut, remove and cement soils were first originated in Japan starting around 1965 by the brothers *Yamakodo*. In early 1970, there were already two competing forms developed nearly simultaneously. The Jet Grouting technique developed by *Nakanishi* utilized chemical and cement grouts injected at ultra high pressure through very small nozzles (1.2 - 2.0mm Ø) which were located at the bottom of a single rod. Because the single rod is both lifted and rotated while jetting the grout, a pile like soil cement column is formed, from where arises the name of this type of Jet Grouting: *chemical churning pile* or CCP Jet Grouting.

The other Jet Grouting technique developed in Japan was termed Jet Grouting by its originator - *Teruo Yahiro*. The most distinctive feature of this method relates to the three rod system employed to cut, replace and cement the insitu soil. The three rod system is required because three different types of fluids are used during the Jet Grouting operation:

Water, Air and Cement Grout. Other variations in Jet Grouting quickly followed. The most important modification being the *Jumbo Special Grout (JSG)* which is essentially CCP Jet Grouting with air encapsulating the Cement Grout Jet. By merely using compressed air, the JSG columns are typically 1-1/2 to 2 times larger than ordinary CCP columns constructed using similar jetting parameters.¹

Following this rapid development in Japan, the technology gained acceptance in Italy, Russia, Western Europe and very much later in the United States.

WHAT IS JET GROUTING?

Having seen the evolutionary process, we are now able to define Jet Grouting in its present form as used here in our country.

Jet Grouting is a ground stabilization procedure which uses the principle of Ultra High Pressure Injection of Cement Grout into the ground.

The procedure employs a bottom-up installation sequence. The Double Tube or Triple Tube Pipe is rotated at a fixed RPM and automatically raised in fixed increments. The double tube system is used in the country.

Cement Injection under Ultra High Pressure is done within a protective encapsulating conical shroud of compressed air. The compressed air allows increased ground penetration (larger diameters) by preventing significant pressure drops as the Grout leaves the nozzle.

Due to the Ultra High Pressures involved, the permeability of the soil is of no critical importance as the procedure relies more on the very high erosive power of the Jets to gain lateral Penetration.

The solidified column of grouted soil is termed as “Soilcrete” and the compressive

¹ Kauschinger, et. al. “Jet Grouting: State of Practice” Vol. 1 Grouting, Soil Improvements and Geosynthetics - Geotechnical Special Publication, ASCE, NY 1992.

The Jet Grouted Pile normally should be terminated 1.0m to 2.0m below ground to allow for confinement of the Grout. The Grout within this space is normally weaker due to the same reasons.

During the drilling, if obstructions are encountered, the jetting pipe can just core through the obstruction and later on incorporate the obstruction within the cemented mass.

Grouting can also be at various levels not necessarily continuous as say to stabilize a weak layer sandwiched in between two dense layers.

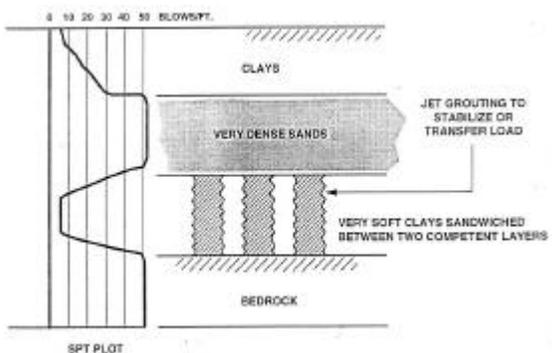


Fig. 3.0

UNIQUENESS OF JET GROUTING AS A SOIL STABILIZATION PROCEDURE

Jet Grouting as a soil stabilization procedure is quite unique as it overcomes some limitations inherent with other procedures such as:

❖ Insensitivity to Low Soil Permeability

Due to the ultra high pressure injection of cement grout, highly erosive forces ensure grout penetration to the desired radius. The reduced permeability of clays does not adversely affect the grout penetration unlike unidirectional grouting procedures.

Thus, the procedure is effective for both clays and granular materials.

❖ Decreased Danger of Soil Fracturing or Heaving

Because the procedure is normally open to atmospheric pressures and because the nozzle is rotated at a constant rate, grout pressure build up which could lead to serious soil heaving or soil fracturing is eliminated.

Even in cases where the hole is blocked, the increased pressure and reduced grout take is detected by the instrumentation to allow quick response of the crew and thus heaving is prevented.

❖ Limited Headroom or Maneuver Space Requirements

The relatively small and lightweight equipment needed for installation allows Jet Grouting to be performed in very tight places for underpinning of existing Buildings or other works.

❖ Automated Installation Process

The automated process of installation by control of rotation, raising of drill string and pressure/volume compensation by the ultra high pressure pump contribute to the highly predictable and consistent quality of the Jet Grouted Column. Thus, minimum compressive strength of the Soilcrete and the diameter of Grouted Column can be predicted with a reasonable degree of accuracy.

❖ Ease of Installation

The procedure can be employed in difficult ground or working conditions and the Jet Grouted Pile can be installed in any angle with the vertical up to slightly less than 90°. Beyond 90° difficulty in retaining the Grout is encountered as grout flow out is possible.

❖ Ability to Bypass Obstructions

Jet Grouting has the unique ability to bypass obstructions such as boulders and buried structures and incorporate these into the cemented columnar mass. Thus, Boulders could be embedded and incorporated into the soilcrete mass and be part of the load support system.

The sketch shows this graphically.

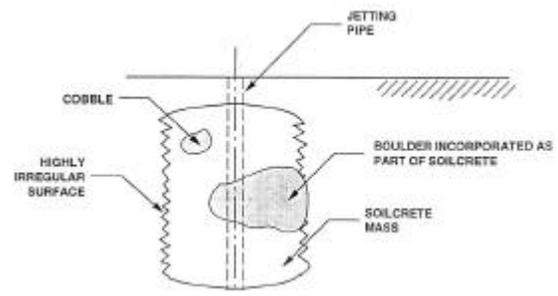


Fig. 4.0

❖ Increased Lateral Compaction of Soil

The ultra high pressure jet other than eroding the soil also increases the lateral compaction of the soil due to high pressure pulsating jet. Thus, some degree of densification is possible particularly for granular soils. The effectiveness of lateral compaction is at least a radius away from the perimeter.

❖ Increased Frictional Resistance

The very uneven eroded surface produces a serrated configuration or a very highly irregular cylindrical surface. This increases the skin side frictional resistance of the Jet Grouted Column.

❖ Reduced Permeability of Soilcrete

Cementation of the soil after washing and disaggregation helps eliminates voids and zones of high permeability because a uniform soilcrete body is formed. The permeability is in the order of 10^{-6} cm/sec very much like heavy impermeable clays.

❖ Control of Depth of Installation

Since this is an insitu Bottom-up Installation Procedure, the depth of installation and the installation length can be controlled to the desired depth without wastage. In addition, the Grouting can be done at selective levels and need not be continuous.

APPLICATIONS IN DIFFICULT FOUNDATION PROBLEMS

Although Jet Grouting is not a cure all for all foundation problems that confront us day to day, there are difficult problems where it becomes the primary solution candidate or the only solution available.

There are myriads of problems in foundation engineering where the effectiveness of Jet Grouting becomes a crucial factor in the selection process for a solution. We therefore group these into several classes of problems as follows:

❖ Underpinning of Structures

Structural underpinning of existing structures becomes difficult particularly due to low headroom or space restrictions. In addition, disturbance of the already distressed structure or adjacent structures becomes a critical consideration.

Jet Grouting eliminates most of these problems as the Jetting Machine can crawl into very tight spaces. Disturbance is minimal and avoided if installation is not concentrated in one area as to allow localized weakening of the soil support while the grout is curing.

In addition, disturbance to adjacent structures is minimal as there is no vibration or shock.

The Jet Grouting procedure could also be called upon to recover from settlements with the aid of chemical jacking.

In addition, very expensive connection details can be avoided with Jet Grouting as the jet Grouted Section is very much bigger than the hole through

the foundation being underpinned. Only a dowel might be required in such cases.

❖ Landslides

The large cross sectional area of the Jet Grouted Pile and the ease of installation enable the use of Jet Grouting for the control of Landslides and creep.

The shear resistance of the cross section can further be enhanced with the addition of soil reinforcement.

The ability of the Jetting Machine to reach inaccessible areas makes it possible to strengthen unstable slopes on impending slide or areas subject to creep movements.

In addition, areas where slides have occurred can be stabilized by the use of Jet Grouting essentially to reinforce the failed mass and strengthen it.

❖ Seepage Cut Offs

The very low permeability of the "Soilcrete" produced in the Jet Grouting Process allows it to be used as an Impermeable Barrier.

Its ability to overlap in Secant Pile arrangement makes it water tight.

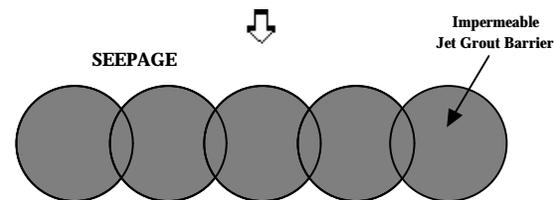


Fig. 5.0

❖ Foundation Piles

Particularly for very shallow applications in very tight or inaccessible areas, Jet Grouting is sometimes the only viable solution.

Its large cross sectional area and highly irregular perimeter allows it to sustain large heavy loads controlled only by the strength of the Soilcrete material.

❖ As Ground Anchors

Jet Grouted Anchors have been used in projects to provide a deadman or a large diameter anchor with appreciable pullout capacity. The use of High Tensile Strands drilled into and subsequently grouted inside the Jet Grouted Pile allows for large pullout loads and resistance against uplift.

This is particularly useful for Temporary Ground Anchors on poor soils where the HTS length can be appreciably shortened or these could be used as Deadman for Anchored Sheetpiles or Bulkheads.

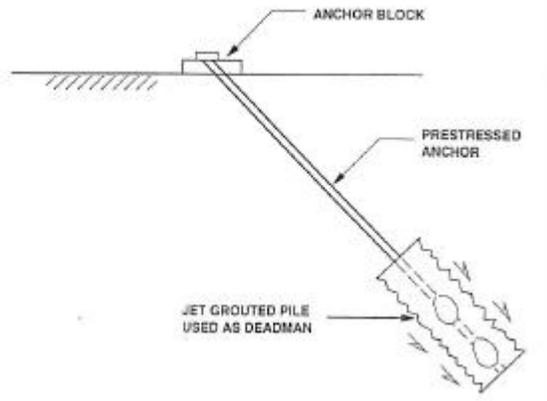


Fig. 6.0

in a double tube system as the soil is not totally replaced by Cement Grout but is mixed with it.

Several other examples of applications are included in the Appendix.

It is hoped that a greater understanding of the system could lead to its full utilization in solving difficult ground conditions where conventional solutions are not feasible.

CONCLUSION

This paper has presented the State of Practice of Jet Grouting in the Philippines.

Clearly, we have seen the versatility of Jet Grouting in the Solution of Difficult Problems in Foundation Engineering.

However, it should be understood that Jet Grouting is not a cure all to foundation problems. There are some deterrents to its successful application, one of which is cost. Also, the procedure becomes non competitive to existing conventional foundation solutions where difficulty or restrictions on the use of such conventional solutions are non existent.

In addition, the load carrying capacity of the Jet Grouted Pile is limited by the quality of the Soilcrete