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IMPROVEMENT CHARACTERISTICS OF GROUND USING C.G.S THROUGH FIELD CASE STUDY

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ABSTRACT

Compaction Grouting System is widely used in densifying loose soils or fill voids caused by sinkholes, poorly compacted fills, and soft ground improvement. Also, it is used in preventing liquefaction, re-leveling settled structures, and using compaction bulbs as structural elements of minipiles or underpinning. But the effects of ground improvement depending on the type of soil must be studied in order to adopt in various soils. In this study, characteristics analysis of the ground improvement and the effectiveness of reinforcement were grasped by this study which shows applied ground by Compaction Grouting System in domestic 6 sites. After Compaction Grouting, strength characteristics of the ground are much better than before Compaction Grouting through the results of the standard penetration test, the dynamic cone penetration test, the vane test and laboratory test using performance Evaluation of Linear Regression. Especially improvement of strength was shown over 17% by Compaction Grouting through prediction formulas in sand.

INTRODUCTION

Both civil and building structures are constructed on soft ground & uneven soil layer these days due to lack of building site. Also, structures undergo excessive differential settlement and have a tilt due to fraudulent construction works or extension and reconstruction of the building, etc(Al-Alusi etc., 1997 ; Boulanger R. W. 1995)). Thus, it brings about problems in not only structures themselves but also their surroundings. If there is problem in stability of structure itself or need to demolish previous structures and build new ones to secure stability because of such excessive differential settlement and tilt, it may bring about huge loss to the nation(Arvind V. Shroff etc., 993). For more effective utilization of the land, construction of structures on coast areas and soft ground are inevitable and possibility of differential settlement and tilt of structures always lies behind caused by changes such as fraudulent construction works, surrounding ground conditions, ground excavation, etc(Bowen R. etc., 1981). Therefore, studies on development of construction method to restore structures to their original state and its practical applications should be carried out(Byle. M. J. etc., 1991).

GROUND IMPROVEMENT MECHANISM

Low slump mortar injection method is the ground improvement method that compacts and strengthens the surrounding ground by pressing in low slump mortar injection to the ground and forming even consolidation in cylinder shape. It was designed by injection technicians from California, USA whom perceived the fact that low slump mortar type grout can be applied to make loose soil composition of bottom of the reloaded structure dense artificially while carrying out test using low slump mortar type grout in early 1950's (Wong H.Y., 1971). It is also widely known as the C.G.S. (Compaction Grouting System) method. According to the definition of C.G.S. announced by Grouting Committee of ASCE in 1980, Compaction Grouting refers to "Slump mortar less than 1 inch (25mm) that consists of fine-grained soil (size of silt particles) for securing the plasticity and granular (size of sand particles) for increase in internal friction. Soil-Cement is its basic material and it is improving the density of ground by reducing the openings between the soil particles not by infiltrating to the openings of surrounding grounds but by compacting the soil inflicting the pressure in radial shape to the ground with consolidation(Wong, H.Y., 1974).

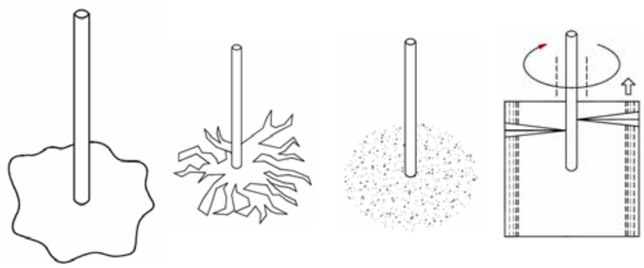


Fig. 1. Injection method comparison (Wong H.Y., 1971)

Namely, it is unique technique called 'non-discharged transposition' that is completely different from previous 3 injection methods including venation consolidation of cement, penetration consolidation of liquid chemical and discharged transposition of jet grouting as Fig. 1. Other methods to increase the density of ground includes the dynamic deep compaction and vibrofloatation method that carry out compaction by applying vibration or impact on the surface of ground but there is limitation in application due to influence of vibration, noise, etc. However, low slump mortar injection method has advantages in that it has high applicability since there is no damage done by surroundings including noise, vibration, etc and it can set the range of improvement and form the shape of consolidation without restriction in aspect of constructability. Also, it is superior in aspect of construction management in that construction can be carried out in rather small space and amount of injection can be confirmed by the measurement probe. Since main material applied in this method is Cement Mortar (Cement + Sand + Water) different from general grouting method of which its main material is Cement Paste (Cement +Water), it has compaction strength of over 30~200kgf/cm2 as a type of plain concrete. Thus, it can be used as the base file of structure having same function as previous concrete files just like in advanced countries (USA, Japan, etc). In aspect of applicability on improvement target soil, it can be carried out in ground likely to undergo liquefaction. When low slump mortar injection method is applied in marine clay ground, it is not influenced by the ocean water, salinity in original ground, etc since the sphere is formed only with cement mortar regardless of soil in original ground in this method. Thus, it has advantage in that it is rarely influenced by the organic matters contained in marine clay ground, strength reduction by salts, corrosion, etc compared to the high pressure jet methods such as JSP, Jet Grouting, etc that inject the cement milk using the soil of original ground. Especially, it is effective to use blast furnace slag instead of generally used normal Portland cement to prevent the strength reduction caused by salinity. Also, the original ground would not be softened since it is perforated with rotary percussion equipment or air track drill instead of water jetting. Since, the mortar with low water contents is used in this method, it does not soften the original ground by injecting materials compared to other methods. Recently, C.G.S. method is widely used in underpinning technique that reinforces the foundation of tilted structures by lifting the foundation as much as it is demanded by applying principle to compact and inflate the surrounding ground with high pressure injection. Fig. 2 is the drawing of C.G.S. method and Fig. 3 presents the injection types.

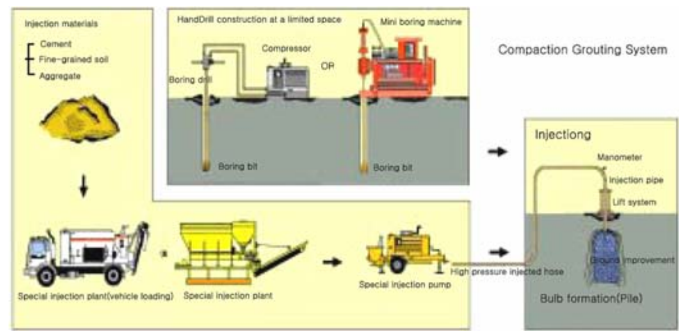


Fig. 2. C.G.S Method (Woo-jong Kim, 2001)

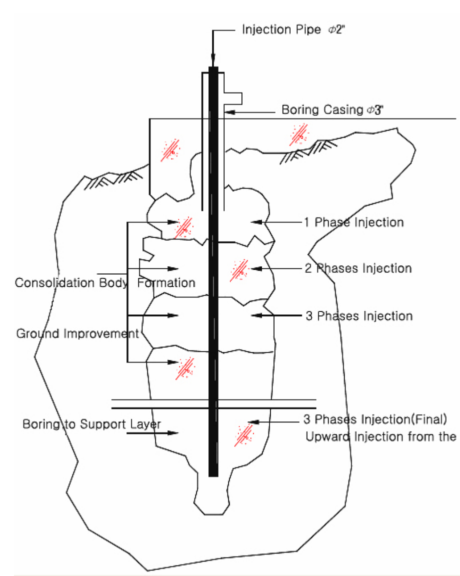


Fig. 3. C.G.S Injection Form

C.G.S METHOD APPLIED FIELD ANALYSIS AND FIELD TEST

<u>Standard Penetration Test before and after injection</u>

There are 7 locations where C.G.S. method are applied to the site and summary of initial ground condition, distribution form and injection interval of each site is as table 1.

Table 1. Field case of C.G.S

Field Case	In-Situ Ground Condition	diameter (mm)	Arrangement Form	Injection Interval(m)
Sok-Cho1 (SC-site(test))	Sandy Soil Clay Soil Mixed	ϕ_{800}	Square	2
Sok-Cho2 (SC-site)	Sandy Soil Clay Soil Mixed	ϕ_{800}	Square	2
		ϕ_{600}	Square	

		ϕ_{800}	Triangle	
Kang-Reung1 (KR-site(test))	Sandy Soil Clay Soil Mixed	ϕ_{800}	Square	2
			Triangle	
		ϕ_{1000}	Square	2.4
			Triangle	
Yong-In (YI-site(test))	Sandy Soil	ϕ_{400}	Square	1.4
			Square	1.8
			Square	2
Kang-Reung2 (KR-site)	Sandy Soil Clay Soil Mixed	ϕ_{800}	Square	2.4
		ϕ_{800}	Square	2
		ϕ_{600}	Square	2
		ϕ_{600}	Triangle	2.4
Ik-San (IS-site)	Sandy Soil Clay Soil Mixed	ϕ_{600}	Square	2
Kwang-Joo (KJ-site)	Sandy Soil	ϕ_{400}	Square	1
			Hexagon	2

Standard Penetration Test

Standard penetration test was carried out once before and after the injection conducted in 7 sites to confirm the effect of injection. Regarding the tendency toward the change in N value based on injection. it was increased about 20% after the injection as you can notice in Fig. 4.

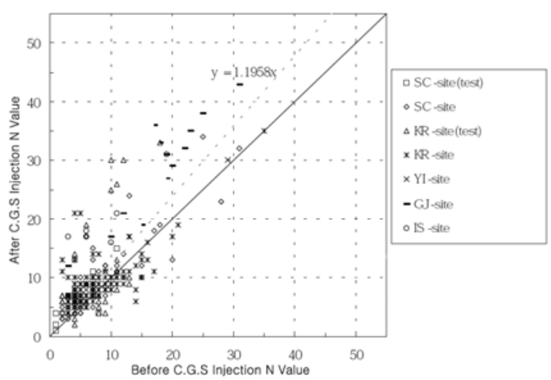
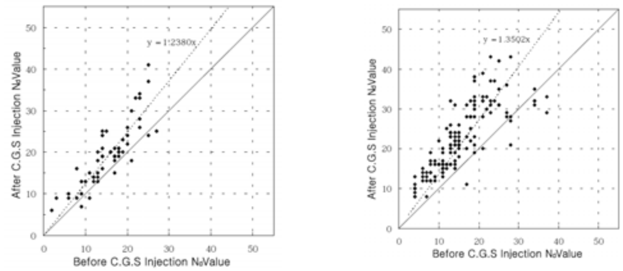


Fig. 4. Standard Penetration Test

It can be considered that the ground has been improved due to density of ground or dispersion of interstitial water inside the soft ground with compaction in radial direction by C.G.S. injection.

Dynamic Cone Penetration Test

Dynamic cone penetration test was carried out to the KR-site (test) and SC-site (test) in table 1 before and after the C.G.S. injection. We found out that value of Nd increased about 20~30% as a result of C.G.S injection as you can notice in Fig. 5.



(a) SC-site(test) (b) KR-site(test)

Fig. 5. Dynamic Cone Penetration Test

Field Vane Shear Test

Field Vane Shear Test was carried out to the KR-site (test), KR-site and SC-site (test) in table 1 before and after the C.G.S. injection. We found out that maximum shear strength increased about 42% as a result of C.G.S injection as you can notice in Fig. 6.

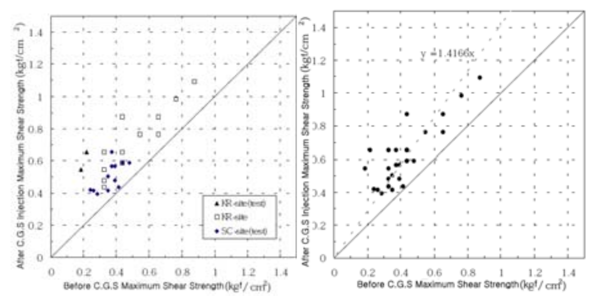


Fig. 6. Field Vane Shear Test

Cone Penetration Test

Cone penetration test was carried out to the KR-site, SC-site and US-site in table 1 before and after the C.G.S. injection. We found out that cone point resistant increased about 19% as a result of C.G.S injection as you can notice in Fig. 7.

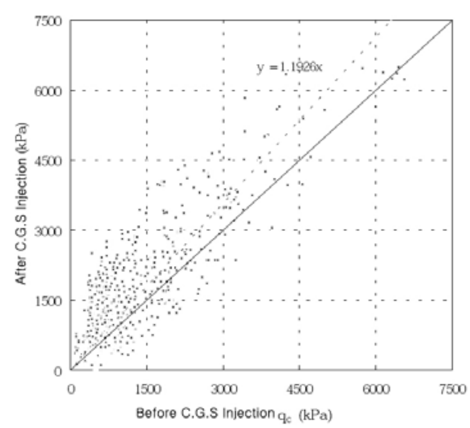


Fig. 7. Cone Penetration Test

CONCLUSIONS

Analysis on traits of improved ground and ground reinforcement effect were carried out through case studies of 7 C.G.S. method applied sites and the summary of results is as following.

1. As a result of carrying out standard penetration test to entire field applications through linear regression analysis, we found out that value of N increased about 20% after the C.G.S. injection.
2. Value of Nd increased about 32% after the C.G.S. injection as a result of dynamic cone penetration test.
3. As a result of field vane shear test, shear strength increase about 42% after the C.G.S. injection.
4. It was found that strength of surrounding ground significantly improves after C.G.S. injection. However, result of this study alone is insufficient to generalize the traits of normal ground improvement by C.G.S. Thus, in-depth study on the subject is necessary approaching with up-to-date technologies including advanced geophysical prospecting, measurement management, etc.

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