# Behavior of Drilled Shaft with Different shape in Groups, which installed in Soft Rock, considered with its Characteristics of Load Distribution

## Comportement de l'arbre percé avec la forme différente dans les groupes, qui a installé dans la roche molle, considérée avec ses caractéristiques de la distribution de charge

Dae- Sung Lim, Jae-Ku Jeon, Sang-Jong Yoon, Tae-Hyun Kim
*R&D Team, SAMBO E&C, Republic Of Korea, dslim@samboenc.co.kr*

ABSTRACT: Currently, the applications of large diameter drilled shafts have been increased, in accordance with the magnification of the structures in the field of buildings and industrial plant, also with the increase of the material costs.
Considering of the site workability and also economical efficiency, the drilled shaft, which installed in soft rock, shall ensure the stability of the structures.
For the purpose of the checking to the bearing capacity and behavior characteristics of drilled shaft with different shape in groups, which installed in soft rock.
In this Study, bearing capacity was evaluated by performing bi-directional loading tests on the drill shafts, and the load distribution was compared and analyzed using the three-dimensional finite element method.

RÉSUMÉ : En raison de l'agrandissement des structures dans le domaine des batiments, les pieux forés avec le coulage du béton sur place (drilled shafts) qui peuvent supporter une charge importante, ont connu un très fort développement et par consequent nécessitent une capacité portante appropriée.
Dans cette étude, la comparaison et l'analyse sont faites en effectuant des tests de la capacite portante et de la méthode des éléments finis 3D et de la distribution des charges bi-directionnels entre : la méthode foreuse rotative à percussion PRD (Percussion Rotary Drilling Methods, Ø1500) appiliquée au diamètre faible et moyen et les pieux forés composites (Drilled Shaft with Different shape in Groups) avec les grands pieux à barrettes(□2,800×2,000) en utilisant la machine de forage destinée à la méthode paroi moulé (diaphragm wall methods), installés dans la roche molle.

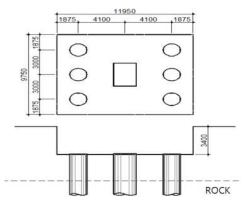
KEYWORDS: Drilled Shafts, Load Distribution, Bi-directional Load Test.

## 1 INTRODUCTION.

The applications of large diameter drilled shafts to the magnification of the structures in the field of buildings and industrial plant have been increased, referred to the requirement of relatively higher capacity loads or higher bearing capacity for them. In this study, the results were compared and analyzed for the throughout the three 3-dimensional finite element analysis and bi-directional load test results for the magnified drilled shaft which socketed into the soft rock layer, constructed by Percussion Rotary Drilling Methods (hereinafter referred to as “P.R.D methods”), its diameter Ø1,500mm, those were applied to the middle to large sized drilled shaft previously and Barrette Pile (rectangular shape drilled shaft, its size are □ 2,800×2,000mm), those were applied to the diaphragm wall methods.

## 2 DESIGN AND CONSTRUCTION OF DRILLED SHAFTS

The Allowable Loads to the foundation, has been decided, considering of the bearing capacity and requirement of the structures, the maximum applicable allowable loads for the P.R.D drilled shaft (its diameter Ø1,500mm) shall be 2,000 ton and for the Barrette Pile (rectangular shape drilled shaft, its size are □ 2,800×2,000mm) are 5,500 ton. The arrangement of in-situ drilled shafts for the foundation of the magnified complex structures and its completion of those application methods (refer to the figure 1).




(a) The Arrangement of Foundations applied by Drilled Shaft

(b) Pile Head Treatment Works

(c) Completion of Foundations for the Magnified Structure

Fig.1 The arrangement of in-situ drilled shafts for the foundation

## 3 BI-DIRECTIONAL LOADING TEST AND NUMERICA ANALYSIS RESULTS

The performance of the pile was evaluated by bi-directional load test in which shall be applied the required test load at the

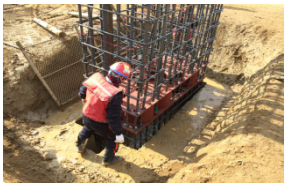
tip of drilled shaft by the load pressure instrument. Throughout the above test results, compared the bearing capacity and skin friction with the theoretical calculation. The sequences of the Bi-directional Load Test are shown as following figure 2.

PRD(Ø1,500)

Barrette Pile(□2,800×2,000)

(a) Bi-Directional Load Test Bearing Plate

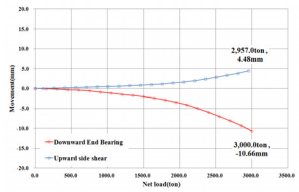
PRD(Ø1,500)



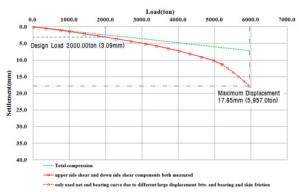
Barrette Pile(□2,800×2,000)

(b) Bi-Directional Load Test Instrument Assembly on site and Insertion

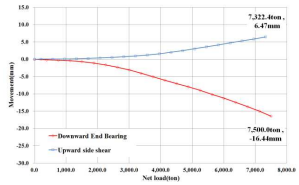
Fig.2 Sequences of the Bi-directional Load Test



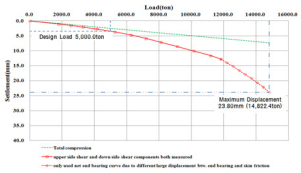

(a) Load - Movement Curve (P.R.D)




(b) Load - Settlement Curve (P.R.D)




(c) Load - Movement Curve (Barrette Pile)




(d) Load - Settlement Curve (Barrette Pile)

Fig.3 The results of the Bi-directional Load Test

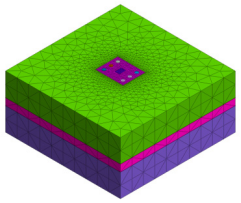
Refer to the result of the Bi-Directional Load Test, the drilled shaft which constructed by the P.R.D Methods (Ø1,500mm), the estimated movement(settlement) shall be 3.09mm in application of 2,000 ton load and the maximum movement(settlement) shall be 17.85mm in application of 5,000 ton load. The allowable load shall be 2,978.5 ton, which considering of safety ratio 2.0 into the test results.

Also for the drilled shaft which constructed by the Barrette Pile Method (□2,800×2,000mm), the estimated movement(settlement) shall be 3.47mm in application of 5,000 ton load and the maximum movement(settlement) shall be 23.80mm in application of 14,822.4 ton load, which shown on the figure-5, hence the allowable load shall be 7,411.2 ton, which considering of safety ratio 2.0 into the test results.

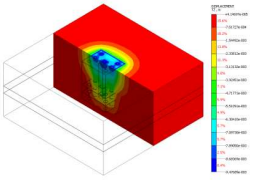
The results of analysis of Bi-Direction Load Test for the large sized drilled shaft, refer to the each construction methods are shown on the figure 3.

In this study applied analysis to those mentioned drilled shaft by the 3-Dimensional Non-Linear Finite Analysis (MIDAS-NX program, the general usage to the drilled shaft and foundation). The condition of test to the drilled shaft have been applied Elastic Modeling Method and to the foundation have been applied the Elasto-Modeling Method, based on the Mohr-Coulomb Failure Criteria.

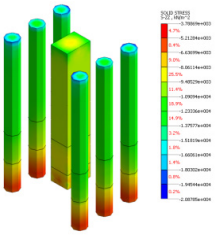
The sequences for the analysis to the constructed drilled shaft into the existing layer from soil, weathered rock and soft rock, are 1) settle the initial stress 2) loading the estimated loads in sequence. The Modeling and the Analysis results are shown on the Figure 4.



(a) The schematic modeling drawing for Calculation Analysis



(b) The result of the vertical displacement of the drilled shaft



(c) The contribution of load to the each foundation (drilled shaft)

Fig.4 Modeling and Results of Numerical Analysis

With reference to the Three (3) Dimensional Non-Linear Finite Analysis, the movement of the drilled shaft which constructed by P.R.D Method (Ø1,500 mm) shows 8.69mm, the movement of the drilled shaft which constructed by Barrette Pile Method (□2,800×2,000) shows 8.75mm, compared with designed load. Those movement results are relatively higher than the Bi-Directional Load Test.

Those results shall be understood that laboratory numerical analysis for the drilled shaft shall be evenly applicable to the same geological layer due to the boundary effect between the drilled shaft and the existing layer, but the actual site test does not shows the same result due to the differences in geological condition.

## 4 CONCLUSION

Bi-Directional Test and 3-dimensional nonlinear finite analysis test was performed to analyze the design and construction of the drilled shaft (PRD (Ø1,500mm) and Barrette Pile (□ 2,800 × 2,000mm)). The results of this study are summarized as follows.

1. With reference to the Bi-Directional Load Test Results to the drilled shaft, which constructed by P.R.D Method (Ø1,500mm) and Barrette Pile (□2,800×2,000mm) into the base rock layer, shows the higher bearing capacity in safe more than design required loads compared with other drilled shaft

2. With reference to the 3-Dimensional Finite Analysis to the drilled shaft, the movement (settlement) shows more than the Bi-Directional Load Test but the movement (settlement) are within the allowable limits and secure the safety.

3. With reference to the above test results, we might be possible to minimize numbers of construction of drilled shaft and to achieve the economical effects by application of the large sized drilled shaft application via P.R.D Methods and Barrette Pile Methods into the Magnificent Structures which required relatively higher bearing capacity.

## 5 REFERENCES

Korean Society of Civil Engineers 2008, Highway bridge design criteria(in Korean), Kimoondang

Park Seoung Wan, Lim Dae Sung 2009. *Evaluation of Load Transfer Characteristics of Barrette Pile Based on Bi-directional Loading Tests*. Journal of the Korean Society of Civil Engineers C 29(2C), pp.41-49.

BK GNC 2016. Pile load Test of Drilled Shaft in 00 Plant Project

Paik ktu Ho, Sagong Mying 2003. *Assessment of Design Criteria for Bearing Capacity of Rock Socketed Drilled Shaft*. Journal of the Korean Geotechnical Society, Vol 19, No. 4,, pp.95~105.

Korean Geotechnical Society 2015, Structural foundation design criteria (in Korean), Goomibook.

ASTM D1143-81(Reapproved by 1994). Standard Test Method for Piles Under Static Axial Compressive Load.

Canadian Geotechnical Society 1985. Foundation Engineering Manual, 2nd Ed. Editored by Meyerhof, G. G