Case studies on foundation types of super high-rise buildings considering the soil deposit conditions

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ABSTRACT

Applying the super high-rise building design in geotechnical conditions is gradually increasing, and foundation types are evaluated under the conditions of economic and stable concepts to support this high load with safety. The foundation of a high-rise building is displaced by the building load, which influences the behavior of a super structure in reverse. In this aspect, the structural interaction analysis between a foundation and a super structure is necessary. In this study, the relationship of a superstructure of building and a foundation has been reviewed, considering the tendency of design from a capacity driven design to a performance design. The different case studies have been introduced to help understand this relationship in more specific, the first case is the high rise building founded on a raft system on rock and the second is that on piles on soft ground condition. In this study, a database for deciding the measured-to-predicted geotechnical parameters of foundation types in several soil deposit conditions is reviewed such as laboratory to in-situ tests. For this, the pile diameter, raft foundation depth, and the representative unconfined compressive strength of rock are investigated also to be the primary affecting factors on the building conditions. Based on the results of these investigations, it is shown that the prediction of the settlement, bearing capacity and pile installations is modified in the analysis with considering interface behavior in comparison with the analysis considering interface between mat and rock mass under the soil deposit conditions. Uncertainty of the measured-to-predicted geotechnical parameters associated with decision of foundation types also should be assessed in the future.

Keywords: high-rise, building foundation types, raft type

1. INTRODUCTION

Recently, investments in developing roads and housing areas are actively progressed in urban area, Korea, in response to the demands of logistics abroad and the government policy of the balanced investments in the local regions. In the process of developing building structures, urban area is planned to increase the efficiency of the land use. For the site area construction, high-rise buildings are constructed (Yang et al. 2007).

When a temporary embankment is installed on the surface of the seashore clay, soil improvement method along with the compulsory replacement by crushed stone is common. It is inevitable to have unaereplaced area under the embankment when the embankment is constructed using the compulsory replacement method.

In this study, the types of the foundation area under the building are studied before and after the construction using the boring log database. Additional ground investigation and the related analyses are performed for selecting and predicting accurate soil parameters. Engineering characteristics of the original soil is studied through drilling investigation and in-situ field test in two areas of Korea. Changes of physical properties, e.g. permeability, rock strength, are studied. Engineering characteristics of the reclaimed soil, and in-situ soft soil, and rocks are analyzed to predict the suitable values of the design and construction (Yang et al. 2007; Kim et al. 2012).

In this study, the case histories on determination of foundation types of high-rise building were studied, under the ground conditions, in which further investigations and monitoring results in a same area should be analyzed in the future (Park et al 2010; Yang et al 2012).
2. IN-SITU SOIL CHARACTERISTICS AND FOUNDATION TYPES

One case is as follows. It profiles level basements and 80 levels above ground. The site investigation results showed that the building foundation located generally on a moderately weathered rock condition with partly developed highly weathered rock is shown Fig 2. The load at the core area was estimated around 1.75~2.3 MPa and the load at the outer wing area around 0.5~1.0 MPa. The raft was designed with 3.8m thickness of reinforce concrete (Saegil 2013).

It was found that the highly weathered rock conditions cover nearly half of the site and the moderately to slightly weathered rock covers the other areas as show in Fig. 3. The highly weathered rock was judged to be unacceptable for the tower load because of its low bearing capacity and its potential large and differential settlement. It was decided to remove the highly weathered rock until the moderately weathered rock appeared (Bieniawski, 1989; Kim et al. 2009).

The excavation was executed but at the two locations of the southern wings the highly weathered rock could not be removed due to its deep depth and the additional borings were performed to investigate the depth of highly weathered rock. The depth of excavation below the foundation level and the section profile is shown in Fig. 4.
The over-excavated space at the highly weathered rock area was finally filled with mass concrete. It was expected that the mass concrete functioned as medium material to distribute the load to the stiffer rock around the unremoved weak rock by arching effect and reduce the stress on the weathered rock locating at the southern wings.

The schematic section of the ground model for the foundation analysis is shown Fig. 5.

![Fig. 5. Schematic section of ground model](image)

The settlement profile across AA-section after rock mass replacement is compared to the case of the original ground having the highly weathered rock without any replacement. The profile shows the significant improvement of the foundation performance by replacing mass concrete.

The structure checked the original raft foundation design with the reassessed stiffness values and the original raft design was accepted and the raft has been constructed as originally designed.

The other is as follows. The other site investigation results shown that the building foundation located generally on a moderately weathered rock condition with partly developed highly weathered rock as shown in Fig 6 through 8.

The highly weathered rock was judged to be unacceptable for the tower load because of its low bearing capacity and its potential large and differential settlement. It was considered to replace mass concrete in highly weathered rock. According to ground conditions of weathered soils, it was partly suggested by drilled pier foundation type. The dimension of pier is 1,000mm in diameter, 5-22m in length, also after assessment of allowable bearing capacity and settlement through numerical analysis.
RQD values of soft rock layers are shown in Fig. 9 according to depth of excavation below the foundation level, depth of excavation is 18.96m below the ground level.

3. SUGGESTIONS FOR SOIL PROPERTIES THROUGH FOUNDATION CODE TECHNIQUES

According to the cases of construction and design of buildings, further research works for the foundation type and underground materials under the concrete structure are needed for settlement and bearing capacity. It is the most important factor of building construction technology to consider the bedding condition for the safe and economic construction. Evaluating geotechnical characteristics of design and construction method through field application tests is needed. Analysis technologies for design and construction work about stability between building structures and ground are studying and applying to the building design manual. Allowable settlement(s) of structures in Korea, Canada, and USA is presented in table 1 below, which is related to overall stability including qa(allowable bearing capacity).

| Nation | Design Code referred to | Remarks |
|--------|-------------------------|---------|
| S.Korea | Building code, AASHTO, NAVFAC etc | qa, s |
| Canada | Foundation Eng’g Manual etc. | qa, s |
| U.S.A | AASHTO etc. | qa, s |

Standardized design manual should be established through the coded techniques for foundation types during design and construction stage of buildings would be developed, including code system of structures. As establishing unification of design standard on building codes, several design standards should be done periodically to geotechnical and structural engineer. Ordering organization has to retain critical mind and will for applying unified design standard towards stability and maintenance on structures in the future. These kinds of researches were especially tried in tunnel fields, such as rock bolts. Installing the rock bolts into the holes, grouting materials could be leaked. In order not to happen these conditions, a kinds of cement stabilizers(socalled grout cap) may be alternative, but this work was not yet included in coded specifications.

4. CONCLUSIONS

In this study, an overall geotechnical investigation, which covers field and laboratory experiments, is carried out to decide foundation types and show the subsoil condition and its engineering properties. Conclusions are as the following:

1) The design items of a foundation types on weak rock conditions have been discussed. During design stage considering above ground conditions, foundation types and load combinations have been studied.

2) Uncertainty of the measured geotechnical properties referred to determinations of foundation types of high-rise building also should be assessed in the future, including economic efficiency comparison in a proper way.

3) Two cases of different design style for the foundations on a weak rock have been studied. Face mapping and monitoring after site excavation should be needed in the future and will be discussed.

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