A NEW JET GROUTED GRID FORM METHOD WITH HORIZONTAL SLAB FOR LIQUEFACTION MITIGATION

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出版情報：Kyushu University, 2020, 博士（工学）, 課程博士
バージョン：
権利関係：

（様式２）

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論 文 名 ：A NEW JET GROUTED GRID FORM METHOD WITH HORIZONTAL SLAB FOR LIQUEFACTION MITIGATION
(水平スラブを有する格子状ジェットグラウト工法による液状化防止対策)

区　　分 ：甲

論　文　内　容　の　要　旨

Earthquake induced soil liquefaction is a phenomenon that causes tremendous damage to many infrastructures, due to loss in foundation's bearing capacity, excessive ground deformations, tilting/overturning of structure. According to the Ministry of Land, Infrastructure, Transport and Tourism, Japan (MLIT 2015), approximately 27,000 houses were damaged due to liquefaction during the 2011 off the Pacific coast of Tohoku earthquake. Therefore, to mitigate the damage caused by liquefaction, it is necessary to take appropriate remediation measures in geotechnical engineering practice. The grid shaped deep cement mixing method (called hereafter grid form method) is a well-known soil-remediation method and its effectiveness in liquefaction mitigation has been proved through earthquakes case histories, numerical analyses and experimental studies. Nevertheless, grid form method is still unable to reduce the potential risk of the liquefaction completely. Moreover, this conventional method has some limitations when applying it in residential areas. Firstly, it will not be economical to use in the constructions of normal detached houses. Secondly, the equipment used in conventional method requires large space and is difficult to utilize in residential areas. Thirdly, the grid spacing ratio becomes wide since the construction of grid form directly under the existing houses is impossible. Subsequently, it can increase the liquefaction potential. In addition, many other aspects of the conventional grid form method have not been fully explored yet. They are ground settlements resulting from liquefaction and overlying infrastructures, interaction between grid wall and surrounding soil, as well as the distribution of shear stress and shear strain in improved ground.

To overcome the above limitations of the conventional grid form method, and, thereby achieve an economic and efficient design methodology, a new liquefaction countermeasure is introduced in this research, in which horizontal slabs are additionally installed within the grid. In order to evaluate the effectiveness of the grid form method with horizontal slab in reducing liquefaction risk, in this research, both physical modeling and numerical simulation were performed for various ground conditions under different dynamic loadings. For the physical modelling, a series of 1 g shaking table tests were performed. Here, the effectiveness of the grid form method with horizontal slab was evaluated based on the response of acceleration, excess pore water pressure ratio and ground surface settlement of both the improved and unimproved ground. On the other hand, the settlement and the distribution of shear stress and shear strain within the foundation soils were evaluated for the unimproved ground and improved ground by using the numerical simulation. The physical modelling and numerical simulation results

confirmed that the grid form with horizontal slab reinforced method is effective in controlling the settlement of the structure and the ground. Furthermore, an extensive parametric study was performed to investigate the effects of important key parameters for grid form method horizontal slab in the mitigation of liquefaction induced settlement. In addition, the effects of the improved ground on seismic response were evaluated in the study.

This thesis is organized into six chapters. The contents of each chapter are summarized as follows:

Chapter 1 highlights the background and past research works and the related problems. Current issues are highlighted, and the necessity of developing new ground improved method is discussed here. Finally, the objectives of the research are introduced. Furthermore, the original contributions of this research are also presented.

Chapter 2 discusses the effectiveness of the grid form method with horizontal slab based on the results of 1g shaking table tests. Comparisons were made for unimproved ground, improved grounds with and without horizontal slab. Effectiveness of the grid form method with horizontal slab was evaluated in terms of the characteristics of ground surface acceleration as well as reduction in settlement and development of excess porewater due to dynamic loadings. It was observed that the grid form with horizontal slab method is very effective in liquefaction mitigation.

Chapter 3 presents the numerical simulations to make clear the mechanism of the reinforcing effect of the grid form method with horizontal slab to sustain the building integrity against liquefaction, by comparing with the conventional grid form method. The procedure for validation of the reliability of numerical model and calibration parameters used were described in detail in this chapter. In this chapter, it was found that the grid form method with horizontal slab is more effective than the conventional grid form method. It is because, the ground deformation could be reduced from vertical support and lateral confinement provided by the grid wall under the building.

Chapter 4 focuses on parametric analyses by considering installation depth of horizontal slab, grid wall thickness, soil relative densities and improvement depth ratios. The results of the parametric analyses were evaluated by examining ground displacement, bending moment of grid wall as well as shear stress and shear strain relationships of the soil. Based on the results of the numerical studies, it was observed that the abovementioned parameters have a great influence on the design consideration of grid form method with horizontal slab.

Chapter 5 mainly concentrates on the effectiveness of the proposed jet grouted grid form in liquefaction mitigation and its impact on seismic ground response. Comparative analyses between unimproved and improved grounds were conducted, and the effects of the grid form method with horizontal slab on shear stress reduction factor, shear strain distribution, excess pore water pressure, peak surface acceleration and spectral acceleration were evaluated. The numerical results showed that the presence of the jet grouted grid walls with horizontal slab greatly influence the shear stress, shear strain of the soil and peak ground acceleration.

Chapter 6 provides the achievements and key conclusion of this research and the recommendations for the future studies.