Effect of Grid-Form Deep Cement Mixing Wall with Horizontal Slab on Ground Displacement Controlling

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INTRODUCTION

Liquefaction is one of the critical earthquake hazards that can extensively damage to buildings, bridges, port facilities and other infrastructures. To mitigate the risks of liquefaction, various ground improvement methods have been utilized such as cement deep mixing, jet grouting, chemical grouting etc. In Japan, Grid-Form Deep Cement Mixing Walls method has been frequently used to increase the bearing capacity of foundations in soft grounds as well as to countermeasure against seismic liquefaction in detached housing projects. In fact, deep cement mixing wall method is a grid-shaped ground stabilizing method in which the high modulus of grid-shaped cement wall provides the vertical confinement for the loose sand layer so that the excessive shear deformation can be reduced during an earthquake as shown in Figure 1. However, the efficiency of control on the amount of ground displacement and excess pore water pressure distribution is still uncertain due to the wide grid spacing ratio (0.5 ~ 0.8) in the design. To overcome the present issues, a new countermeasure approach, with narrow grid spacing (0.2) and additional horizontal slab, is introduced to effectively control the ground displacement. The entire liquefaction prone layer is improved by wrapping with the lattice-shaped grid-form cement mixing wall in both vertical and horizontal directions to restrain shear deformation of the structure during an earthquake. In this research, numerical simulations using PLAXIS 2D software were performed on various ground improved cases to assess the effectiveness of new countermeasure design configurations.

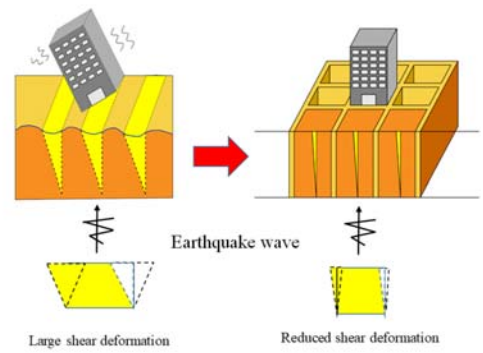

Figure 1. The mechanism of the grid-form deep cement mixing wall method

NUMERICAL MODELLING

In terms of the geometry, the idealized three layers of soil column was used in numerical modelling. The horizontal dimension of the soil profile was modelled as large enough to minimize the boundary condition effect. Moreover, the depth of the soil layer to the bed rock was selected as 36 m while the depth of liquefiable layer was 10 m. The water table was assumed to be coincident with the ground level. The soil types and material models that were used in the study were presented in Table 1. The parameters of soil cement column used in numerical models were tabulated in Table 2. As the seismic input motion for this study, the earthquake data of Loma Prieta earthquake (1989) with maximum acceleration of 0.3 g was used. And, Figure 2 shows the time history of acceleration. The study cases for the numerical analyses are listed in Table 3, in which different wall thickness and additional horizontal slab were taken into consideration. Regarding the boundary conditions, tied degree of freedom was used at the vertical boundaries in the model, whereas the compliant base option was applied at the base. The ground displacement distribution experienced during the earthquake in each numerical analysis was measured at the top canter of the model.

Soil and ground improvement type	Material Model
Liquefiable sand	Hardening Soil/ UBC3D PLM
Clay	Hardening Soil
Bed rock	Elastic
Soil cement column	Mohr- Coulomb

Table 1. Soil types and material models used in the study

Parameter	Symbol	(Unit)	Values
Unit weight	γ_{sat}	(kN/m^3)	20
Young's modulus	E	(MN/m^2)	1,000
Poisson's ratio	υ	(-)	0.3
Undrained shear strength	S_u	(kN/m^2)	400

Table 2. Parameters used in the improved soil cement column

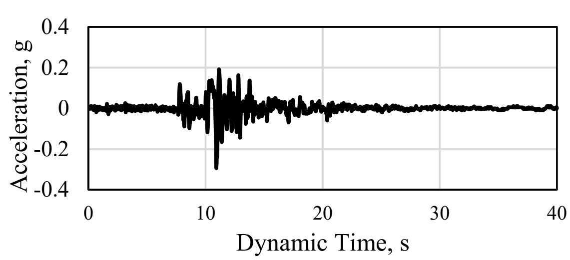

Figure 3. Seismic Input motion applied in the Analyses

Case	Wall spacing, m	Wall thickness, m	Improvement type
Case 1a	2	0.15	Grid form wall
Case 1b	2	0.15	Horizontal slab
Case 2a	2	1	Grid form wall
Case 2b	2	1	Horizontal slab

Table 3. Numerical simulation cases

Keywords: Liquefaction, Earthquake, Ground improvement, Numerical simulation
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RESULTS AND DISCUSSION

Figure 3 presents the comparison results of total ground displacement between the conventional grid-form method and new countermeasure approach with horizontal confining slab. The total displacements with the dynamic time history of various ground improved cases are depicted in Figure 4. Furthermore, the contour of total displacement at the end of the dynamic time for different ground improved cases are illustrated in Figure 5. According to the results, it can be said that the new grid-form deep mixing wall with horizontal confinement is more effective than conventional grid-form deep mixing method. Especially, the new grid-from deep mixing wall with 1m wall thickness is the most significantly effective in ground displacement reduction for liquefaction mitigation. In other words, the resistance to the ground displacement is increased with the thicker wall thickness and additional horizontal confining effect.

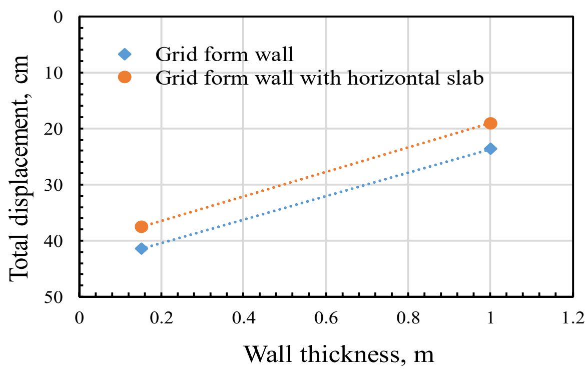

Figure 3. Maximum total displacements measured from different ground improved cases

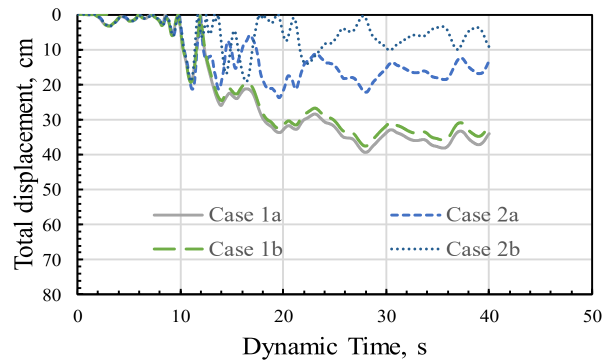

Figure 4. Time histories of the total displacement measured from different ground improved cases

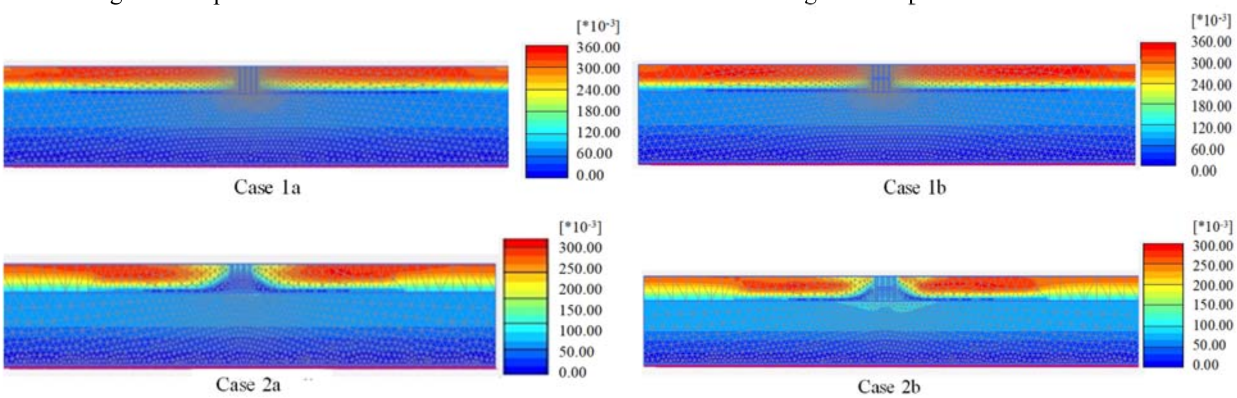

Figure 5. Total displacement due to the various ground improved cases at the end of the earthquake

CONCLUSION

A series of numerical simulation for various ground improvement cases were performed to assess the effectiveness of ground displacement control. As an initial assessment for liquefaction prevention, the study on the effectiveness of grid form deep mixing wall with horizontal confining method were studied. Based on the result observations, it can be concluded that the new grid-form deep mixing wall approach with horizontal slab is more effective in mitigation control compared to the conventional grid-form method. From this study, it can be verified that the improvement with horizontal slab has significant positive influence on ground displacement control. Moreover, it is observed that increase in wall thickness can help control in ground deformation amount due to liquefaction.

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