A Case Study on Seismic Response Analysis on Improved Ground with Compaction

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INTRODUCTION

Effectiveness of the compaction method represented by the Sand Compaction Pile (SCP) method has been verified in the past earthquakes [1]. In the engineering practice, it is evaluated by the increase in SPT *N*-value measured in the ground between sand piles where effect of compaction is weakest. Here, increase in SPT *N*-value is caused by two mechanisms, i.e., densification and increase in coefficient of earth pressure at rest, K_0) [2]. However, current design specifications [3] take only the increase in density into account. However, this treatment is clear to result in too conservative design; it is necessary to evaluate both effect properly in order to make rational design In this paper, effectiveness of the ground improve method by compaction is examined by using YUSAYUSA-2 [4], which is a computer program for the seismic response based on effective stress.

SEISMIC RESPONSE ANALYSIS ON THE IMPROVED AND UNIMPROVED GROUND

Analytic condition

A residential area at the Urayasu city where significant liquefaction was observed during the 2011 Tohoku Earthquake. There was no evidence of liquefaction such as sand boils on the ground improved by the SCP method, while many sand boils were observed on the road surrounding the improved ground.

Seismic responses of the improved and unimproved ground are investigated in this paper. At first, the input seismic motion at the engineering seismic base layer is calculated from the earthquake record at the Urayasu K-NET station (EW component) [5] by the equivalent linear method. Then, it is applied at the target ground as input motion.

The ground properties such as SPT *N*-value, fines content F_c, and unit weight γ_t etc. were read from the borehole data conducted before and after the earthquake, and elastic and nonlinear properties are evaluated from them by means of empirical equations. The coefficient of earth pressure at rest K_0 was set 0.5 for the unimproved ground and 1.0 for the improved ground; the K_0 value after the improvement is evaluated from the relationship between improvement ratio a_s and K_0.

Since duration of the earthquake is very large, number of effective cycles also becomes very large. However, many empirical equations for liquefaction strength is applicable up to 20 cycles or a little larger than 20. The authors developed empirical liquefaction strength curve applicable up to 100 cycles [6], and parameters of YUSAYUSA-2 related to excess pore water pressure generation is determined to agree with this empirical equation. The effect of K_0 is considered from the observed result that liquefaction strength ratio is constant when it is defined as the ration of shear stress amplitude to the effective overburden pressure σ_m' [7].

Results of analyses

Excess pore water pressure hardly generated at the improved ground whereas significant excess pore water pressure generated causing liquefaction in the unimproved ground. This results in significant difference not only between excess pore water pressure but also maximum shear strain. Those in the improved ground is order of 0.1 % whereas those in the unproved ground sometimes exceeds 5%. However other maximum responses such as maximum accelerations, maximum velocities and maximum shear stresses are similar to each other. This indicated that liquefaction occurred because of large number of cycles; maximum response value occurred before the liquefaction.

SUMMARY AND CONCLUSIONS

Seismic response analyses based on effective stress were carried out in order to confirm effect of soil improvement by the SCP method at the residential area in the Urayasu city where significant liquefaction occurred in the unimproved ground during the 2011 Tohoku Earthquake. Two effects of improvement by means of the SCP method, i.e., densification and increase of coefficient of earth pressure at rest are rationally considered in the seismic response analysis. The seismic response analyses showed little or no excess pore water pressure generation in the improved ground whereas it increases significantly causing liquefaction in the unimproved ground. This agrees with the observed fact that no evidence of liquefaction such as sand boils was observed and no damage to houses in the improved ground and significant sand boils were observed in the surrounding road.

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