

A Case Study and New Concept of Soil Improvement Techniques on Reclaimed Land

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ABSTRACT

This paper presents a precious field practice of the soil improvement on the reclaimed land located at the western coast of middle Taiwan. Two kinds of techniques, Stone columns(SC) and Dynamic compaction(DC), were used to reduce the liquefaction potential of soils. During the progress production, three main concerns were found that influenced the performance. It includes (1) Maintenance of rigs, (2) Existence of clayey soils in the reclaimed layer and (3) High groundwater table, which were highlighted and addressed in the paper for reference. The authors also propose a new concept, named Isolation and Pre-dewatering, to increase performance of DC method.

KEY WORDS: Reclaimed land; Dynamic Compaction (DC); Stone Columns (SC); Isolation and Pre-dewatering

INTRODUCTION

In the past decade since 1995 Hyogoken-Nanbu Earthquake in Japan and 1999 Chi-Chi Earthquake in Taiwan, the soil liquefaction became a very hot issue among the field of seismic design of the buildings or facilities. Many soil liquefaction-induced damages were found at many sites located near the seafront, such as sand boils, lateral spreading, large settlement, structure tilts, dike collapse etc. in the above big earthquakes. In consequence, a more strict regulation on soil liquefaction was emphasized in the revision of both design specifications. (JRA,1996) (SDCB,2005) Soil improvement techniques became an important alternative to conquer the soil liquefaction problems on the reclaimed land.

There are three popular techniques used in the past years in Taiwan, which are Sand compaction piles (SCP), Stone columns (SC) and Dynamic compaction (DC). According to the past experience, SCP performance is enough for the old requirement in soil liquefaction but not good enough for the updated design specification. SC performance is quite enough for old and new design requirement, but in a very high cost.(Kao et al., 2005) While DC performance depends on the Applied Energy (AE) and impact grids arrangement which improvement depth is usually ranged from 10m~13m. (Cheng et al. 1999) However, the cost of DC is the comparatively lowest and the improvement depth can be increased by a new concept changing some parameters in design, such as groundwater table and compaction energy, which will be introduced in this paper.

This paper provides a past practical experience using SC and DC to reduce the liquefaction potential of soils on the reclaimed land. And a new concept for DC to obtain deeper improved depths will be introduced and highlighted for reference.

SITE DESCRIPTION

Plot Plan of Soil Improvement

The project site is located at the western coast of middle Taiwan. Reclaimed by hydraulic method with transporting pipes, the site area is about 30 hectares (ha.) in total, in which 18 ha. was improved by SC (9 ha.) and DC (9 ha.) as shown in Fig.1. For the main buildings and structures, SC was adopted, and DC was applied for the general facilities. The other area was kept for future development. In Fig.1, it can be found that there are three strips of dikes in the site and split the site into two parts as East and West part. These dikes implied that along the dikes, there existed many boulders and cobbles scattered in slope under the ground. These underground objects might be a great uncertainty for the SC production and might damage the expensive vibrator of the SC machine during penetration.

Soil Properties and Groundwater

A typical soil profile at the site is shown in Fig.2 which was formed by two boreholes and three holes of CPT as shown in Fig.1. The reclaimed soils (Layer①), classified as silty sand (SM1), is mainly composed of grey silty fine sand with seams or pockets of silty clay or clayey silt. The fine content ranged from 5% to 30% and about 15% in average. A soft clayey seam was found at around GL-13m, as known as the original seabed. It is noted that a 4.5m-thick clayey soils was found at CPT C-1, where is close to the north dike. The shallow thick but soft clayey soils came from the far-end of hydraulic filling and caused a big trouble in SC production. Beneath the seabed, comes the Layer②, a 7m-thick medium dense silty sands (SM2) with SPT $N_{ave}=22$. Layer③ is a grey, medium to stiff, silty clay (CL1) with SPT $N_{ave}=10$ in average, alternating with medium dense silty sands or sandy silts. Layer ④ is composed of dense grey silty fine to medium sand (SM4) with fine content in the range of 10 to 35%. The groundwater table slightly fluctuated with the tide in and out. It was measured at site ranged from GL-2.55m to GL-3.78m. The groundwater table at GL-2.5m was adopted for the soil liquefaction analysis.