

Deep-Sea Tunnel Foundation Stabilization by Using Cement Clinker Sand-Bed

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ABSTRACT

This paper presents a case history of the beneficial effects of using cement clinker as a hardening additive in sand deposit for the optimal design of the deep-sea foundation for the Kaohsiung Cross-Harbor Tunnel project, Taiwan. Static consolidated drained triaxial tests and cyclic triaxial tests were conducted on moist cured samples consisting of admixtures of sand and cement clinker. The results showed that an addition of 5% cement clinker to sand results in a factor of safety of about 1.2 against possible liquefaction failure which may be caused by an earthquake of 7.5 on the Richter scale. The corresponding settlement was estimated to be about 2 mm. The project was completed in 1984 and withstood a 5-magnitude earthquake in November 1986.

INTRODUCTION

Adequate attention must be given to geotechnical problems such as liquefaction and settlement when structures are on saturated sand. Even if the increase of pore-water pressure due to cyclic load does not become equal to the initial effective confining pressure, large settlement may still occur. The dissipation of excess pore-water pressure will be accompanied by a decrease in volume of the voids. Depending on the extent of the affected zone and the nature of overburdened material, this may be reflected by corresponding settlement at the ground surface. The excessive settlement of the structure may result in its failure. This research relates to an investigation of seismic stability of the deep-sea foundation improvement against earthquake loading for the Kaohsiung Cross-Harbor Tunnel project.

DESCRIPTION OF KAOHSIUNG CROSS-HARBOR TUNNEL PROJECT

The port of Choosung, located at longitude 120°15' East and latitude 22°37' North, extends as long as 12.0 km² from the first entrance in the northwest to the second entrance in the southeast. The harbor has a total water area of 12.7 km². Kaohsiung Harbor enjoys brisk seaborne traffic and is now the biggest international harbor in Taiwan. It is one of the largest container centers in the Far East. This deep-sea cross-harbor tunnel extends from Hsin-Shen Road along Yukong-Nan-San Road between Chien-Chen Fishery Harbor and container Terminal No. 3, across a 440-m-wide and 14-m-deep fairway to the proposed Chung-Hsin new commercial harbor area at Chung-Ho. The project includes 1,550 m of main tunnel and approaches, 729.84 m of connecting roads, a toll booth, and other mechanical and electrical units. The main tunnel contains 6 units of immersed sections, each 7.72 x 9.35 m in height, 24.4 m in width, and 120 m in length, sunk to an elevation of -24.2 m. Generally the area along the tunnel is covered by a thin layer of soft alluvial sandy clay with some silt as top soil with a thickness between 0.6 m and 1.2 m, below which a layer of

dense gravelly sand is encountered to about 30 m.

The safe shutdown earthquake for the site has a magnitude of 7.5 on the Richter scale and is used for analyzing seismic stability within Kaohsiung City. Although the top soil is capable of supporting the static loads, some treatment was required for stability under dynamic loading condition. An immersed tube was used to provide permanent foundations for the deep-sea tunnel section. The sand admixture was placed directly under the tunnel sections through openings in the tunnel which could be closed by valves or injection equipment. By adding a small quantity of cement clinker to the sand, it was possible to obtain an admixture with strong chemical bonds between the sand grains to prevent liquefaction and settlement. The layout of the Kaohsiung Cross-Harbor Tunnel is shown in Fig. 1.

LABORATORY TESTING PROGRAM

A laboratory testing program was undertaken to determine the strength characteristics of sand-cement clinker admixtures. The grain sizes were required to be medium coarse to coarse; the selected admixture was such that it passed through No. 4 U.S. sieve and was retained on No. 40 U.S. sieve, which was suitable for use as stabilized material (Seed, 1976). The local Li-Kang

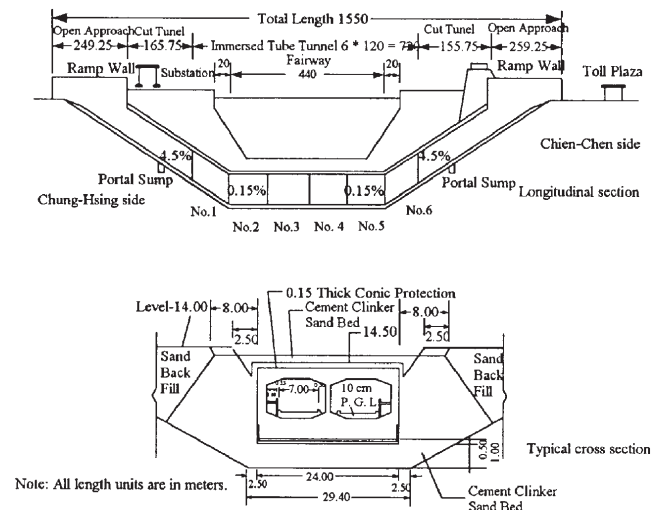


Fig. 1 Layout of Kaohsiung Cross-Harbor Tunnel

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Received August 15, 1996; revised manuscript received by the editors May 22, 1997. The original version (prior to the final revised manuscript) was presented at the Second International Offshore and Polar Engineering Conference (ISOPE-92), San Francisco, USA, June 14-19, 1992.

KEY WORDS: Deep-sea tunnel, cement clinker, liquefaction.