

## The 1995 Great Hanshin Earthquake and Liquefaction Damages at Reclaimed Lands in Kobe Port

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### ABSTRACT

This paper presents the earthquake damages, especially of the liquefaction of reclaimed fills, at two near-shore man-made islands, Port Island and Rokko Island, in Kobe Port during the Great Hanshin Earthquake of January 17, 1995. The paper first describes a general aspect of the earthquake event and the seismic behavior of Port Island as observed through the records of seismometers in a vertical array and the piezometer monitoring in the seabed. The seismic records show how the man-made island on soft seabed clay behaved during the earthquake. Second, the liquefaction damages at these two islands are discussed in the light of applicability of current evaluation procedures for soil liquefaction. The fill materials used in these man-made islands consist of well-graded coarse materials and judging from their gradation characteristics, these fills may be considered less prone to liquefaction. It becomes clear that the current design procedures are developed based on the available data of very uniform, fine clean sands, and the extension of the design procedure for the other types of soil needs to be made more carefully.

### INTRODUCTION

In the early morning of January 17, 1995, the Great Hanshin Earthquake shook Kobe City horrendously for about 15 s. The result was catastrophic; damages were so extensive they can only be described as the result of a massive air strike. Kobe City, with a population of 1.4 million, had the largest import and export harbour facility in Japan, but the city has lost her function completely because of the total collapse of her harbour facilities and other ground transportation facilities. The main cause of damage to the harbour was the collapse of the shore line of reclaimed lands, such as Port Island and Rokko Island, man-made islands built on the seabed near shore. In these reclaimed lands, extensive liquefaction of fill and complete destruction of quay walls along the perimeter resulted, and the shore line moved 2 to 3 m outward into the sea and settled as much as 1 m.

The earthquake left much damage to the reclaimed lands, but also left a very rare record of very strong seismic motions of Port Island, as well as a rare record of a pore water pressure build-up beneath reclaimed land. No previous records are available of such seismic behavior of near-shore reclaimed land on soft seabed clay.

Although there was nearly complete destruction of quay-walls both in Port Island and Rokko Island, there was a difference in the liquefaction damages to the inner areas of these islands. These were built predominantly by using two different types of fill materials with similar gradation curves. Decomposed granite and crushed mud stone were used, respectively, for Port Island and Rokko Island; both materials are of well-graded coarse granular with a slight difference in fines content. After the earthquake, major revisions were made of several Japanese design specifications for determining the liquefaction potential of ground. However, most of the revised evaluation procedure for the liquefaction still relies on the liquefaction test results of uniform fine sand, such as Toyoura sand. For example, the Road Bridges Design

Specification in Japan relies very much on the liquefaction strength data of Toyoura sand. It is not certain yet that the liquefaction data of fine sand are applicable to that of coarse fill material. Investigations are made herein to examine the liquefaction properties, namely the liquefaction strength and the post-liquefaction settlement, of the fill materials in these two islands. The effect of fines content on the liquefaction strength and on the prediction methods on post-liquefaction settlement of such materials will be discussed.

### GENERAL DESCRIPTION OF EARTHQUAKE AND SEISMIC RESPONSES OF RECLAIMED LANDS

The epicenter of the earthquake was 14 km deep and about 25 km west of Kobe City. The magnitude of the earthquake was 7.2

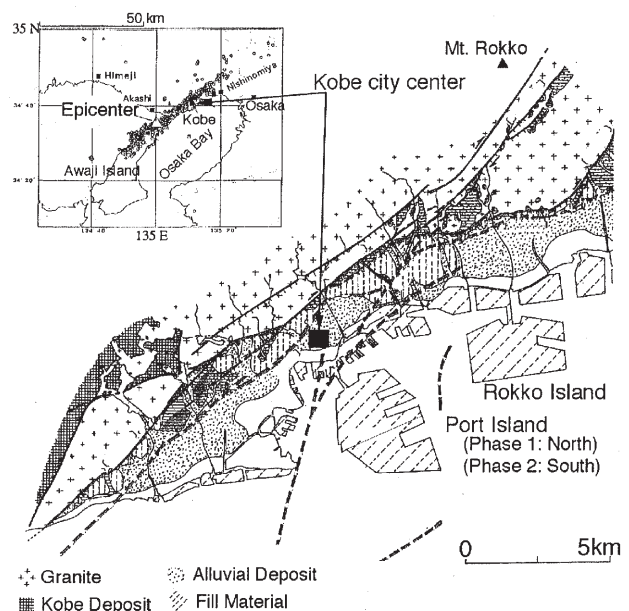


Fig. 1 Location faults in Kobe area and traces of aftershocks due to Great Hanshin Earthquake

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