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Stability of Coastal Defences During the 2011 Tohoku Tsunami in Japan

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Introduction

On March 11, 2011, a large earthquake of magnitude 9.0 on the Richter scale occurred offshore the Tohoku region of Japan, generating a major tsunami that resulted in the devastation of large parts of Japan's north-eastern coastline. It has been said that this "Great Eastern Japan Earthquake and Tsunami" had a return period of several thousand years, and was one of the worst tsunamis that affected Japan since records began. In its aftermath the reliability of tsunami counter-measures is being re-assessed, and a variety of failure mechanisms have been reported for different types of structures [1]. Breakwaters and other coastal defences were damaged throughout the affected area. Generally speaking, composite breakwaters (those protected by armour units such as tetrapods) were more resilient than simple caisson breakwaters. It appears that the armour was effective at dissipating the brunt of the tsunami wave forces on the seaward side of these structures, although damage to armour units was also recorded in many places. For some of these structures, armour units of different sizes and types were used in the same breakwater, and it appears that damage is dependent on the weight of the units (as can be expected from formulas such as that of Van der Meer [2]. At present, however, it is not clear whether any such armoured structures should be given preference when designing tsunami counter-measures, and whether these counter-measures should be attempted at all.

To date, much on the research on the impact of solitary waves on structures has been carried out on vertical structures [3-8]. However, many composite structures exist, where a caisson breakwater is protected by armour on its seaside part. To this effect Esteban et al. [9] calculated the effect that a partially failure armour layer would have on the forces exerted by a solitary wave on a caisson, allowing for the determination of the caisson tilt. However, the failure mechanism of these structures is still not clear. Although many of them are designed primarily against storm waves, it is necessary to develop a design methodology that ensures that these structures do not fail catastrophically under a tsunami event, and that they can provide some protection to the local community.

In the present paper the authors will examine the failures of two types of armoured structures. One of them are dykes protected at its seaward side by a detached rubble mound breakwater, and the second are composite breakwaters (where a caisson is protected at its seaward side by armour units). Through the analysis of these sea defences the authors will highlight some preliminary considerations about the usage of armour units to protect structures behind them against a tsunami. Also, some of the current thoughts regarding disaster prevention philosophy