Coastal Engineering 111 (2016) 1–12

Contents lists available at ScienceDirect

Coastal Engineering

journal homepage: www.elsevier.com/locate/coastaleng

# Tsunami evolution and run-up in a large scale experimental facility

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ARTICLE INFO

*Article history:*
Received 28 April 2015
Received in revised form 7 November 2015
Accepted 11 November 2015
Available online xxxx

*Keywords:*
Long waves
Tsunami waves
Wave propagation and run-up
Physical modeling
Large scale experimental facility
Numerical modeling
Fully nonlinear potential theory
Korteweg–de Vries equation

ABSTRACT

In this paper, we study the propagation and run-up of long tsunami-like waves in the 300 m long Large Wave Flume (GWK), Hannover, Germany and analyze the feasibility of experiments on tsunami run-up in large facilities. This paper is the continuation of our previous paper (Schimmels et al., 2015, companion paper). The propagation of long period waves over large distances for different shapes is studied experimentally and numerically. Fully nonlinear potential flow theory has been used to model these cases numerically along with Korteweg–de Vries simulations. The theoretical explanation of the observed effects has been discussed. The run-up characteristics of the studied waves with respect to their shape and beach slope were also investigated. Further, a down-scaled real tsunami time series is also reproduced experimentally and studied with regard to its possible run-up.


## 1. Introduction

For modeling of tsunami wave propagation, shoaling and run-up, often solitary or cnoidal waves have been used (Goring, 1979; Synolakis, 1987). However, solitary and cnoidal waves are rarely observed during tsunami propagation. Furthermore, their characteristics are not comparable with most real-field tsunamis as reported by Madsen et al. (2008). Nevertheless, a set of solitary and cnoidal-like waves can be formed in the far field as a result of long wave transformation into an undular bore, as it was observed during the 2004 tsunami in the Indian Ocean near the coast of Thailand (Fig. 1).

More importantly, one cannot generalize a particular tsunami case. In reality, there is a variety of tsunami waves in terms of both periods and wave shapes. Due to the large-distance propagation and complicated bottom and coastal topography, the initial wave changes its shape. Hence, very often even the same tsunami event has very different manifestations in different locations. Therefore, when modeling tsunami, one should also study different wave shapes.

Fig. 2 illustrates the variations in the tsunami profile that occurred along the Japanese coast during the Japan Sea tsunami in 1983. Based on the past tsunami events, tsunamis approaching the shore may broadly be classified as (e.g. Shuto, 1985)

1. non-breaking waves that act as a rapidly rising tide, observed during small and moderate tsunami events after short distance propagation;
2. breaking bore or hydraulic jump (wall of water), observed as a result of wave breaking during large tsunami events after short distance propagation;
3. undular bore, observed after long distance propagation (in terms of wavelength), i.e. the disintegration into series of solitons, see Fig. 1.

The first rigorous solution to the nonlinear shallow water equations was found by Carrier and Greenspan (1958) for non-breaking wave run-up on a plane beach. Based on this approach various shapes of the periodic incident wave trains such as sine wave (Madsen and Fuhrman, 2008), cnoidal wave (Synolakis et al., 1988) and nonlinear deformed periodic wave (Didenkulova et al., 2007a) have been analyzed in the literature. Relevant analysis has also been performed for a variety of solitary waves and single pulses such as soliton (Kânoğlu, 2004; Pedersen and Gjevik, 1983; Synolakis, 1987), sine pulse (Mazova et al., 1991), Lorentz pulse (Pelinovsky and Mazova, 1992), Gaussian pulse (Carrier et al., 2003; Kânoğlu and Synolakis, 2006), *N*-waves (Tadepalli and Synolakis, 1994), "characterized tsunami waves" (Tinti and Tonini, 2005) and a random set of solitons (Brocchini and Gentile, 2001).

Didenkulova and Pelinovsky (2008) and Didenkulova et al. (2007b) showed that despite the influence of nonlinearity, the differences in shape for all bell-shaped positive pulses, such as solitary wave, Lorentz and sinusoidal pulses are negligible and can be parameterized. This

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http://dx.doi.org/10.1016/j.coastaleng.2015.11.006
0378-3839/

**Fig. 1.** Indian ocean tsunami of 26 December 2004 approaching Koh Jum Island, off the coast of Thailand (Copyright Anders Grawin, 2006).

parameterization is especially important for the estimation of tsunami characteristics at the coast, when the shape of the wave approaching the coast is unknown. Also, the asymmetry of a wave approaching the coast and the steepness of its front leads to significant amplification of wave run-up height and shoreline velocity, which was observed during the catastrophic 2004 Indian Ocean tsunami (Didenkulova et al., 2007a).

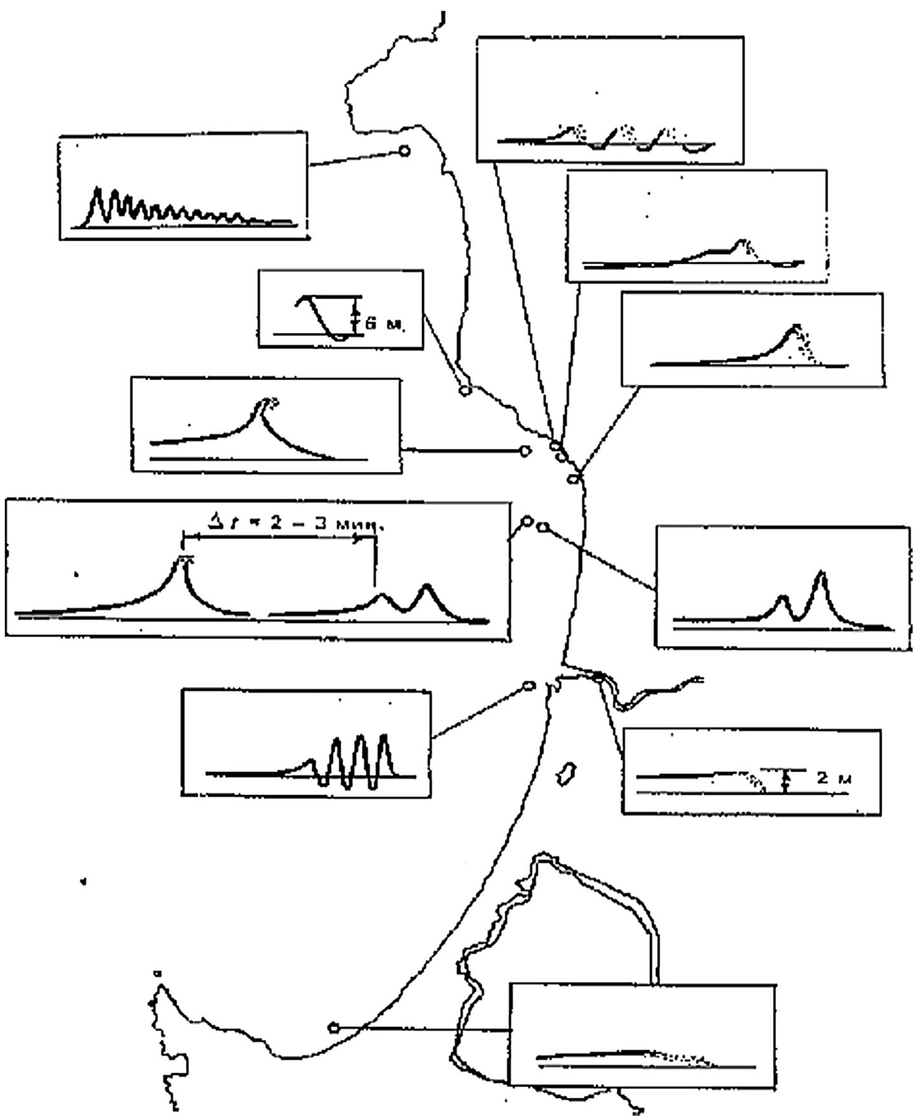


**Fig. 2.** Tsunami wave shapes at the Japanese coast after the Japan Sea tsunami occurred on 26 May 1983 (Shuto, 1985).