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Estimation of near-field characteristics of tsunami generation by submarine landslide

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Abstract

Underwater landslide can trigger impulsive waves with high amplitude and run-up, which may cause substantial damage. In this work, the experimental investigations are performed to study the impulsive wave characteristics caused by underwater landslides. The effects of landslide geometry and kinematics on wave characteristics are studied by performing 84 laboratory experiments. The influences of thickness, volume and shape of failure mass on the characteristics of initial wave are discussed. The impacts of water body conditions such as the slope of sliding bed and the initial submergence of underwater landslide are also examined. The present experimental data as well as the available data in the literature are used to provide an applied method for prediction of the initial wave amplitude. The present prediction method is properly verified by several experimental, numerical and real case data.

Keywords: Laboratory experiments; Underwater landslide; Impulsive waves; Submarine landslide

1. Introduction

Submarine landslides, which often accompany large earthquakes, can disturb the overlying water column as sediment and rock slump down slope. Any sort of geophysical mass flow including debris flows, debris avalanches, landslides, and rock falls can generate submarine landslide-generated tsunamis. A number of experimental work have been carried out to study the impulse waves caused by landslide. Some laboratory works have been focused on the impulsive waves caused by sub-aerial landslide (Johnson and Bermel, 1949; Wiegel, 1955; Prins, 1958; Kamphuis and Bowering, 1972; Walder et al., 2003; Panizzo et al., 2005) or sub-aerial deformable failure mass (Fritz et al., 2004). Also, there are some other experimental works focused on the generated waves by submerged rigid landslide (Heinrich, 1992; Watts, 1998; Grilli and Watts, 2005; Enet et al., 2003) or submerged deformable landslide (Watts et al., 2003; Heinrich, 1992). Ataie-Ashtiani and Shobeiry (2007) used Heinrich's data for verification of their numerical model. A comparison of the main laboratory works has been presented by authors (Ataie-Ashtiani and Najafi-Jilani, 2006). Based on the literature review especially for underwater slide, it can be concluded that the main applicable objective of the experimental works is prediction of the initial impulse wave characteristics, which can be applied to engineering design (Grilli and Watts, 2005; Watts et al., 2003; Ataie-Ashtiani and Malek-Mohammadi, 2007). It seems that the main restriction in the previous works was the limitation of the range of effective parameters such as bed slope and slide geometry. In addition, for providing a reliable engineering method for prediction of the amplitude of initial impulse wave, some complementary experimental data are required. An applied approach to predict the amplitude of initial impulse wave caused by underwater landslide has been provided by authors based on numerical investigations (Ataie-Ashtiani and Najafi-Jilani, 2006). The main objective of this work is to provide a reliable method for estimation of the near-field amplitude of impulsive waves caused by underwater landslide. In this regard, a laboratory set-up is utilized to verify the previous numerical-based prediction method experimentally and also to extend

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Nomenclature

γ	the slide mass density [$MT^{-2}L^{-2}$]
θ	the bed slope angle (°)
α	the landslide acceleration along the inclined bed slope [LT^{-2}]
α_0	the initial acceleration of slide mass [LT^{-2}]
a_0	the impulse wave amplitude [L]
B	the length of slide mass along the bed slope [L]
C_m	added mass coefficient
C_d	drag coefficient
g	acceleration due to gravity [LT^{-2}]
h_{0C}	initial still water depth at center point of sliding mass [L]
S	the location of mass center of block parallel to the inclined bed [L]
S_0	the kinematics length scale of sliding mass (Eq. (1)) [L]
t_0	the characteristic time of landslide motion (Eq. (1)) [T]
t	time [T]
T	the maximum thickness of the slide mass [L]
u	the landslide velocity along the inclined bed [LT^{-1}]
u_t	the terminal velocity of slide mass [LT^{-1}]

it to cover a wide range of effective parameters especially for a range of variations in bed slope, slide geometry, and initial submergence. The laboratory investigations have been performed in various conditions of failure mass geometry and water body conditions.

2. Experimental set-up

Experiments were set up in the 2.5 m-wide, 1.8 m-deep and 25 m-long wave tank at the Sharif University of Technology. The experimental set-up included two inclined planes with adjustable slope between 15° and 60°. One of the inclined beds was made for sliding down solid blocks and another for observation of run-up of slide-generated waves. The sliding surface was smooth and was also lubricated in order to provide a frictionless slope. Therefore, the blocks could slide freely on the slope. A picture of wave tank and the adjustable slopes are shown in Fig. 1. There were transparent windows at the tank wall for observation of the free water surface profile. The

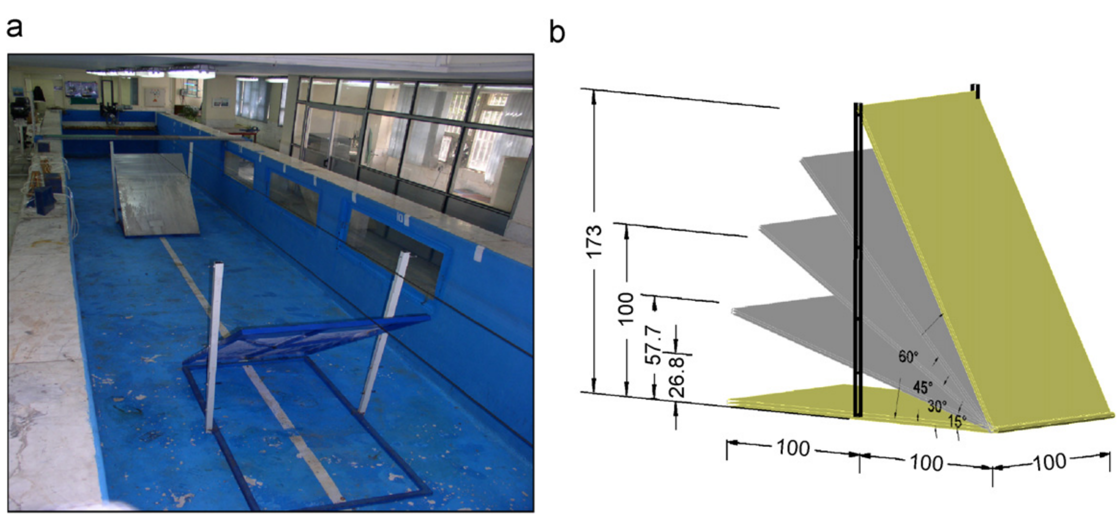

Fig. 1. An overview of two inclined beds installed in the laboratory water tank and the changeable slope angle.

Table 1
The specifications of rigid sliding blocks which are used in experiments

No.	Description	V	W_p	W_i	W_w	W_t	γ
		±0.000001	±0.001	±0.001	±0.001	±0.001	±0.1
1	Box 13 × 15 × 20	0.00390	2.37	1.14	3.90	7.41	1900
2	Box 13 × 30 × 20	0.00780	3.92	3.10	7.80	14.82	1900
3	Box 8 × 12.2 × 20	0.00195	1.57	0.19	1.95	3.71	1900
4	Triangle 15 × 26 × 20	0.00390	2.84	0.67	3.90	7.41	1900
5	Arc 8 × 30 × 20	0.00310	2.52	0.27	3.10	5.89	1900

V, solid block volume (m^3); W_p, weight of perimeter steel plate (kg); W_i, weight of additional insert plate (kg); W_w, weight of water (kg); W_t, total weight of sliding block [$= W_p + W_i + W_w$] (kg); γ, special gravity [$= W_t/V$] ($kg\,m^{-3}$).