NOVAN TOFANY

DOCTOR OF PHILOSOPHY

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NUMERICAL INVESTIGATION OF WAVE HYDRODYNAMICS AND SCOUR DUE TO OVERTOPPING AND STEEPNESS OF BREAKWATER

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Thesis Submitted in Fulfillment of the Requirement for the Degree of Doctor of Philosophy in Institute of Oceanography and Environment University Malaysia Terengganu

October 2014

DEDICATION

This thesis is dedicated to my mother, Hj. Aida Baharudin, my late father, H. Sarwo Sugeng, my brothers, Ari Aldi and Dohan Palavi, my sister in laws, Nur Endah and Mega Annisa, and my nieces, Amita Kallie Anindinaya, Syahla Yashila Dayinnah Palavi, and Kyna Milka Kailaruna. For their uncountable loves, happiness, and supports in my life. They are my motivation to finish this research and in everything I do in this life.

Abstract of thesis presented to the Senate of University Malaysia Terengganu in fulfillment of the requirement for the degree of Doctor of Philosophy

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Main Supervisor : Assoc. Prof. Engr. Dr. Mohammad Fadhli Bin Ahmad

Co-Supervisor : Prof. Dr. Mohd. Lokman Bin Husain
Prof. Dr. Mustafa Bin Mamat

Institute : Institute of Oceanography and Environment

Wave overtopping and breakwater steepness are believed to significantly influence hydrodynamics and scouring mechanism in front of a breakwater. However, the effects of these two factors have never been clearly described and completely investigated in the existing studies. This problem creates a gap in the knowledge of hydrodynamics and scouring mechanism in front of the breakwater. In the present study, a two-dimensional numerical model based on the Reynolds Averaged Navier-Stokes (RANS) equations and the Volume of Fluid (VOF) method is developed to fill this gap of knowledge. The model is combined with a k-ε turbulence closure, sediment transport, and morphological models with additional bottom shear stress terms in the momentum equations.

Various simulations are conducted to validate the model predictions. The results of qualitative and quantitative comparisons show that the present model can predict velocity, free surface profile, and scour patterns which have a good agreement with analytical solution and experimental data. The predicted scour patterns even show

better consistency with experimental data than the predictions of existing numerical models.

The effects of wave overtopping and breakwater steepness are then investigated in two separated numerical experiments. Detailed characteristics of standing wave, flow condition, scour pattern, sediment transport rate, and turbulence parameters are analyzed in each experiment. Based on the results of these analyses, it is found that the wave overtopping and breakwater steepness significantly influence the hydrodynamics and scouring mechanism in front of impermeable breakwaters. Therefore, they must be considered carefully in the process of designing breakwater.

Abstrak tesis yang dikemukakan kepada Senat Universiti Malaysia Terengganu sebagai memenuhi keperluan untuk ijazah Doktor Falsafah.

KAJIAN BERANGKA HIDRODINAMIKA GELOMBANG DAN KERUKAN KERANA LIMPASAN DAN KECURAMAN PEMECAH OMBAK

NOVAN TOFANY

Oktober 2014

Penyelia Utama : Assoc. Prof. Engr. Dr. Mohammad Fadhli Bin Ahmad

Penyelia Bersama : Prof. Dr. Mohd. Lokman Bin Husain
Prof. Dr. Mustafa Bin Mamat

Institut : Institut Oseanografi dan Sekitaran

Limpasan dan kecuraman pemecah ombak dipercayai sangat mempengaruhi hidrodinamik dan mekanisme kerokan di hadapan sebuah pemecah gelombang. Akan tetapi, kesan kedua-dua faktor ini belum pernah digambarkan dengan jelas dan dikaji sepenuhnya dalam kajian-kajian yang sedia ada. Ini menyebabkan adanya jurang dalam pengetahuan mengenai hidrodinamik dan mekanisme kerokan di hadapan pemecah gelombang. Dalam kajian ini, satu model berangka dua dimensi berdasarkan persamaan purata *Reynolds Navier-Stokes* (RANS) dan kaedah isipadu bendalir dibangunkan untuk mengisi kekurangan pengetahuan ini. Model ini digabungkan dengan model gelora tertutup k-ε, model pengangkutan sedimen, dan model morfologi dengan tambahan persamaan tegasan ricih bawah di dalam persamaan momentum.

Pelbagai simulasi dijalankan untuk mengesahkan hasil ramalan model ini. Keputusan perbandingan kualitatif dan kuantitatif menunjukkan bahawa model ini dapat meramalkan halaju, profil permukaan ombak, dan corak kerokan yang mempunyai kesesuaian yang baik dengan hasil penyelesaian analisis dan data eksperimen. Hasil

ramalan corak kerokan model ini juga menunjukkan konsistensi yang lebih baik dengan data eksperimen berbanding model berangka yang sedia ada.

Kesan-kesan daripada limpasan ombak dan kecuraman pemecah ombak kemudiannya dikaji dalam dua eksperimen berangka yang berbeza. Ciri-ciri terperinci gelombang pegun, keadaan aliran, corak kerokan, kadar pengangkutan sedimen, dan parameter- parameter gelora dianalisis dalam setiap eksperimen. Berdasarkan keputusan analisis ini, didapati bahawa limpasan dan kecuraman pemecah ombak sangat mempengaruhi hidrodinamik dan mekanisme kerokan di hadapan pemecah ombak tidak telap. Oleh kerana itu, kedua-dua faktor ini mesti dipertimbangkan dengan teliti dalam proses mereka bentuk pemecah ombak.