MATHEMATICAL MODELLING OF WAVE IMPACT ON LANDWARD-INCLINED AND SEAWARD-INCLINED SEAWALLS

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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STUDENT’S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Struktur pantai dan lautan tertakluk kepada beban gelombang terpisah yang mungkin mencapai $690 kNm^{-2}$. Untuk mengurangkan beban ini, kita mungkin mencondongkan permukaan benteng ke arah lautan ataupun ke arah daratan. Walau bagaimanapun, tidak dijelaskan bahawa kecerunan banteng boleh mengurangkan kesan gelombang dan eksperimen menggunakan model baru-baru ini menunjukkan bahawa benteng yang condong mungkin terdedah kepada beban lebih tinggi daripada benteng yang menegak. Dipengaruhi oleh penemuan ini, kami melakukan kajian secara teori mengenai pengaruh kecerunan benteng terhadap kesan gelombang. Model-model kesan gelombang matematik terhadap benteng yang condong ke arah lautan dan daratan dipertimbangkan dengan menggunakan lanjutan model Cooker iaitu benteng laut yang menegak. Teori impuls tekanan yang dicadangkan oleh Cooker diterapkan ke dalam dua masalah ini yang akan memudahkan masalah yang bergantung pada masa dan sangat tidak linear dengan mempertimbangkan masa integrasi tekanan selama jangka waktu utuk impak tekanan impuls. Penyelesaian masalah ini ditemui dengan menyelesaikan Persamaan Laplace untuk sempadan tertentu. Teori perturbasi diterapkan ke dalam model-model ini dan masalahnya diselesaikan dengan menggunakan MATLAB. Hubungan antara tekanan impuls dan sudut kecenderungan dinding disiasat. Keputusan menunjukkan terdapat persamaan dengan kajian eksperimen. Telah didapati bahawa tekanan impuls paling rendah berlaku apabila kecenderungan kecil berlaku menghampiri tembok yang menegak. Kajian juga menunjukkan bahawa tekanan impuls meningkat apabila impak permukaan meningkat. Tekanan gelombang meningkat kepada 17% untuk tembok yang condong ke arah daratan dan 20% untuk tembok yang condong ke arah lautan jika dibandingkan dengan tembok yang menegak pada kecenderungan sudut 10° dengan impak permukaan 0.5. Cadangan reka bentuk untuk tembok didapati konservatif.

ABSTRACT

Shoreline and ocean structures are subjected to breaking wave loads which may reach $690kNm^{-2}$. To reduce these loading, we might slope the exposed surface seaward or landward. However, it is unclear that sloped walls can reduce the wave impact and recent models tests indicated that sloped walls might be exposed to higher loads than vertical walls. Motivated by these findings, we perform a theoretical study of wave impacts on sloped seawalls. The mathematical models of wave impacts on landward-inclined and seaward-inclined seawalls are considered by using an extension of Cooker's model for vertical seawalls. The pressure impulse theory proposed by Cooker is applied into these two problems which simplify the highly time-dependent and very nonlinear problem by considering the time integral of the pressure over the duration of the impact pressure-impulse. The solution to this problem is found by solving Laplace's Equation for specific boundary condition. The perturbation theory is applied into these models and the problems are solved by using MATLAB. The correlation between the pressure impulse and the inclination angle of the wall is investigated. The results are found to be in good agreement with the experimental study. It was found that the lowest pressure impulse occurs when the small inclination happens near to the vertical wall. Study also shows that pressure impulse increases as impact region increases. Breaking wave pressures increase to 17% for landward inclined wall and to 20% for seaward inclined wall compared to vertical wall at 10° incline with impact region of 0.5. Design recommendations were found to be conservative.

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LIST OF SYMBOLS

ε	Angle of Seawall
B	Boundary
ρ	Density of Water
μ	Dimensionless Constant of Impact Region
F	Force
g	Gravity Acceleration
H	Height/ Depth of the Wall
u	Velocity
x	Horizontal Direction
t	Impact Time
$L_\circ$	Length
u_{nb}	Normal Component of the Approach Velocity
n	Normal Direction
p_{pk}	Peak Pressure
β	Porosity
P	Pressure Impulse
p_s	Pressure of Incident Wave
$U_\circ$	Typical Impact Velocity
t_a	Time After the Impact
t_b	Time Before the Impact
Δt	Time Taken During the Impact
u_a	Velocity After the Impact
u_b	Velocity Before the Impact
y	Vertical Direction

LIST OF ABBREVIATIONS

BEM	Boundary Element Method
CFD	Computational Fluid Dynamics
DID	Department of Irrigation and Drainage
FSI	Fluid-Structure Interaction
GIS	Geographic Information System
MNRE	Ministry of Natural Resource & Environment
MOA	Ministry of Agriculture & Agro-based Industry
NAHRIM	National Hydraulic Research Institute of Malaysia
SPH	Smoothed Particle Hydrodynamics
SPM	Shore Protection Manual
TCEC	Technical Coastal Engineering Centre
VOF	Volume of Fluids
VOWS	Violent Overtopping by Waves at Seawalls

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