

SIMULATION OF WAVE BEHAVIOUR AND WAVE BREAKING PATTERNS ALONG THE ROCKY BEACH OF TERENGGANU DURING THE MONSOON SEASON

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ABSTRACT

Coastal erosion caused by high tides during the monsoon season in the east coast of Malaysia has resulted in devastating property losses and poses a significant threat to the coastal ecosystem. While the deformation of the coastline has become a critical issue, there is a dearth of studies specifically examining the foreshore wave behavior along the rocky beach of Terengganu during the monsoon season. Given the difficulty in predicting high tide monsoon waves, this study aims to simulate wave behavior and wave breaking patterns along the rocky beach during this season. To achieve this, Computational Aided Design (CAD) software will be employed to develop a scale model of Pantai Teluk Bidara, while Computational Fluid Dynamics (CFD) software will be utilized to simulate wave breaking. The simulation results demonstrate a gradual decrease in velocity as ocean waves approach the rocky shoreline, with notable energy dissipation and turbulence, followed by irregular variations in velocity, a focused wave energy presence, and eventual dissipation as the waves move away from the shoreline. The CFD simulation provided valuable insights into wave behavior and coastal dynamics at Terengganu's rocky shoreline, highlighting wave energy dissipation, irregularities in wave behavior, the presence of focused wave energy, and the importance of understanding these processes for effective coastal management and erosion mitigation. Further research is recommended to validate the findings, explore additional factors, and improve modeling for enhanced coastal management practices.

Keywords: rocky beach, monsoon, CFD, wave, shoreline

1.0 INTRODUCTION

Malaysia, with its extensive 8,840 km shoreline, serves as a hub for various economic activities, including urbanization, residential development, fisheries, aquaculture, maritime operations, and oil and gas exploration. However, these coastal areas are increasingly vulnerable to the detrimental effects of coastal erosion. According to the National Coastal Erosion Study (NCES), a significant portion of Malaysia's shoreline, specifically 1,347.6 km, is currently experiencing erosion, affecting both coastal structures and beaches [1]. The escalating erosion poses a significant threat to the country's socio-economic and environmental stability. Therefore, a comprehensive understanding of the causes and impacts of coastal erosion is crucial for implementing effective mitigation and management strategies. In this context, this study aims to investigate the mechanisms and consequences of coastal erosion in Malaysia, with a particular focus on the affected coastal structures and beach areas. By examining the current state of coastal erosion, this research endeavors to provide valuable insights for sustainable coastal development and preservation of the nation's valuable coastal resources.

2.0 LITERATURE REVIEW

Coastal areas play a vital role in Malaysia's economic activities, including urbanization, residential development, fisheries, aquaculture, maritime operations, and oil and gas exploration [2]. However, these regions are facing significant challenges, particularly in relation to coastal erosion [3]. To address the complexities of coastal dynamics, Computational Fluid Dynamics (CFD) analysis has emerged as a powerful tool for simulating fluid flow phenomena using mathematical models and computer simulations [4].

CFD, an advanced computational technique, plays a crucial role in simulating the interaction between free-stream fluid flow and boundary-constrained surfaces. By harnessing the computational power of high-speed supercomputers, CFD enables accurate modeling of complex scenarios, including transonic or turbulent flows, at large scales. Continuous research and development in CFD software strive to enhance simulation accuracy and efficiency across various applications [5]. This also include the utilizing CFD analysis to simulate foreshore waves along the rocky coast landform. This approach allows for a comprehensive understanding of wave impact and propagation, particularly in the vicinity of coastlines during the northeast monsoon season. Furthermore, the versatility of CFD enables the investigation of wave behavior even in challenging terrains such as mudflats, lagoons, or rocky beaches [6].

By utilizing CFD analysis, valuable insights into the impact of waves and their behavior, facilitating a clearer understanding of coastal dynamics. This is crucial for coastal management, particularly in mitigating the effects of coastal erosion and implementing effective shoreline protection strategies. Additionally, CFD simulations enable the visualization and analysis of wave-induced phenomena, aiding in the assessment of potential risks and the design of coastal infrastructure [7]. By capturing the intricacies of wave interactions with complex coastal terrains, this methodology contributes to a more comprehensive understanding of coastal dynamics and enhances the capabilities of coastal engineering and management practices.

Despite the growing significance of CFD analysis in understanding the erosive impact of sea waves on coastlines, there remains a noticeable dearth of studies and recorded data concerning shoreline waves during specific seasons, particularly at Pantai Teluk Bidara. This lack of comprehensive data poses challenges in accurately characterizing wave behavior and its effects on the coastal environment. Currently, wave measurements heavily rely on reports from Malaysia's Meteorological Department, which may provide limited information and spatial coverage. Data collected through sampling stations near the coastline offer some insights but are insufficient to capture the complex dynamics of wave propagation and coastal erosion [8].

However, the challenges in accurately capturing wave behavior and its impact on coastal regions are further compounded by fluctuating wave heights caused by unpredictable wind speeds. This variability in wave heights poses a significant hurdle in achieving precise and reliable CFD simulations [9]. To address this issue and enhance simulation accuracy, a focused effort was made to gather average wave height measurements specifically during the northeast monsoon season. Overcoming these limitations is crucial to obtain a comprehensive understanding of wave dynamics and their consequences for coastal regions. To improve the reliability and accuracy of CFD simulations, it is essential to incorporate more precise and extensive data sources. By integrating such data sources into the analysis, the simulation could capture the complex interactions between waves and the rocky coast landform more accurately [10]. This becomes especially crucial as collisions between waves and rocks in specific areas can lead to uneven rock measurements and erroneous wave height estimations, further complicating the assessment of wave impact on the coastline. By addressing these challenges and utilizing more comprehensive data sources, researchers

can refine CFD simulations, enabling a better understanding of wave behavior and supporting informed decision-making processes for coastal management and engineering strategies.

Pantai Teluk Bidara, with its stunning blue-green waters and refreshing sea breeze, attracts visitors seeking tranquility and serves as a notable tourist attraction. However, the coastal cliffs of Pantai Teluk Bidara have been significantly eroded by the relentless force of sea waves. Surprisingly, no studies or recorded data exist on shoreline waves at the rocky coast landform near Terengganu's coastline, particularly during the northeast monsoon season. Currently, wave measurements are solely based on reports from Malaysia's Meteorological Department, which may not provide a comprehensive understanding of the wave dynamics.

The objective of this project is to recreate and simulate shoreline waves at the rocky coast landform near Terengganu's coastline during the northeast monsoon season. To achieve this, accurate and reliable data is crucial. Therefore, extensive efforts were made to collect and analyze relevant information through journal searches and comprehensive literature review. However, due to the inherent variability of the acquired data, the CFD research for this project encountered various challenges. The unpredictability of wind speeds led to fluctuations in wave heights at Pantai Teluk Bidara, which posed limitations and introduced flaws in the simulation. To address this issue and improve the accuracy of the simulation, average wave height measurements were gathered specifically during the northeast monsoon season.

By addressing the lack of available data and the limitations posed by variable wave heights, this project aims to provide a comprehensive understanding of shoreline wave behavior at the rocky coast landform near Terengganu's coastline during the northeast monsoon season. The findings of this research will contribute to enhanced coastal management practices, enable more accurate forecasting, and facilitate the development of effective mitigation strategies against erosion in this ecologically significant region.. The study's significance lies in its contribution to improved coastal management practices and the availability of data for researchers studying shoreline waves at a rocky coast landform along Terengganu's coastline during the northeast monsoon season. By enhancing our understanding of wave dynamics through simulations and providing valuable insights into erosion risks, this research enables the development of effective strategies for coastal protection. Additionally, the generated data serves as a valuable resource for researchers, fostering further investigations and promoting informed decision-making in the field of coastal engineering. Ultimately, this study aims to ensure the sustainable use of coastal resources and the preservation of valuable properties in the face of monsoon-induced challenges.

2.0 RESEARCH METHODOLOGY

The methodology for this project comprises three key stages. The first stage involves creating a beach model using CAD software based on a comprehensive site survey of Pantai Teluk Bidara, Dungun, to capture the topography of the rocky shoreline [11]. Using the survey data, a simplified segment model of the shoreline is constructed, which represents the wave behavior before reaching the rocky coast landform. This segment model is shown in Figure 1.

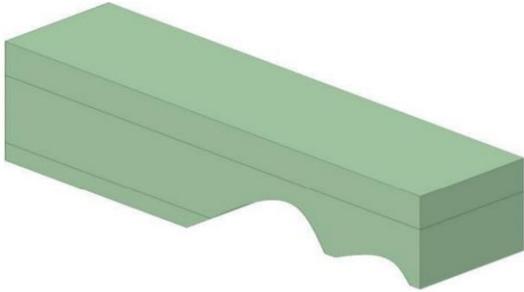
	Description
	<p>The Teluk Bidara Beach, which is located near Kuala Dungun in Dungun, Terengganu</p>
	<p>The model of the rocky beach based on Teluk Bidara shoreline</p>

Figure 1: Modelling of Teluk Bidara rocky beach at Dungun, Terengganu

In the second stage, the model is exported to meshing software, where it is divided into elements with a specific size, typically ranging from 0.01 m to 0.1 m, depending on the complexity of the segment model. This meshing process ensures accurate computation by capturing the fine details of the model's geometry. Additionally, the meshed model is assigned designations for the inlet, outlet, and atmospheric conditions, facilitating the subsequent setup process in the CFD software [12].

Once the meshing is complete, the third stage entails conducting the simulation using CFD software. In the simulation setup, the Solver is configured with specific parameters. Gravity is defined as -9.81 m/s^2 along the Y-axis, representing the gravitational force acting on the fluid. The Fluid Material properties are adjusted to accurately represent air and water-liquid properties during the simulation. Boundary conditions are defined, including wave height and wavelength specifications, which are crucial for reproducing the wave behavior accurately.

Initialization of the model is performed to check for any setup errors. The inlet is initialized using a wavy wave with the Hybrid Initialize option. Once any errors are resolved, the calculation process commences. The number of time steps and the size of time steps are defined to ensure an accurate and efficient simulation. By following this comprehensive methodology, which includes beach modeling, meshing, and CFD simulation with specific parameters and boundary conditions, a realistic representation of wave behavior at the rocky coast landform during the monsoon season can be achieved.

3.0 RESULTS AND DISCUSSION

The results of the wave simulation for a foreshore wave on a rocky coast are presented in Figures 2 and 3, respectively. These simulations aim to replicate the wave conditions observed during the monsoon season at Pantai Teluk Bidara on the rocky coast landform. The setup for these simulations was performed in CFD software, utilizing data collected prior to conducting the simulations. Figure 1 illustrates the visual

interaction of the wave with the shoreline, while figure 2 showcases the wave propagation around the rocky shoreline.

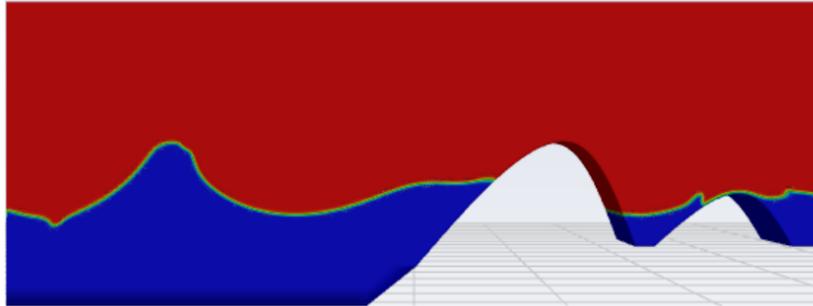


Figure 2: Illustration of the interaction between the wave with the shoreline

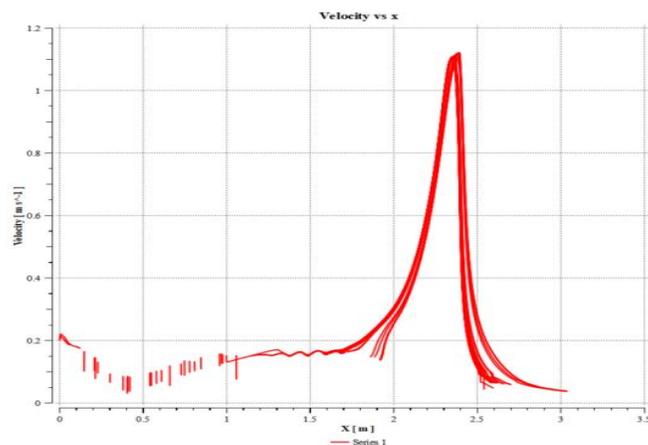


Figure 3: Show cases the wave propagation around shoreline.

From Figure 3, at the initial distance ($x = 0$) along the shoreline, the velocity is recorded as 0.22. This value represents the initial speed of the ocean waves as they approach the rocky shoreline. Moving further along the shoreline, a gradual decrease in velocity is observed. Between $x = 0.1$ and $x = 0.3$, the velocity decreases steadily from 0.17 to 0.1, indicating a reduction in the energy and speed of the ocean waves. This decrease suggests that the waves are experiencing energy dissipation and turbulence due to their interaction with the rocky shoreline.

As the waves progress towards $x = 0.4$, a significant drop in velocity is observed, reaching a value of 0.07. This substantial decrease indicates a notable reduction in wave energy. The interaction between the waves and the rocky shoreline leads to wave energy dissipation, causing a loss of momentum. The dissipative effect of the rocky shoreline further contributes to the relatively low velocities observed in the range from $x = 0.4$ to $x = 0.9$, where the velocities range between 0.07 and 0.13. Interestingly, at $x = 0.10$, a slight increase in velocity is observed, reaching a value of 0.11. This minor variation in velocity may be attributed to local effects or small-scale irregularities in the wave propagation, possibly caused by localized topographic features or the interaction of waves with submerged obstacles.

Between $x = 0.11$ and $x = 0.18$, the velocity exhibits fluctuating behavior, ranging between 0.11 and 0.2. These fluctuations indicate irregularities in wave behavior, potentially arising from the presence of local topographic features or interactions between the waves and submerged obstacles. These factors can cause wave refraction, diffraction, and reflection, leading to the observed variations in wave characteristics. At $x = 0.19$, a sharp rise in velocity is observed, reaching a value of 0.25. The velocity further increases at $x = 0.20$ and $x = 0.21$, reaching 0.3 and 0.4, respectively. These sudden increments in velocity indicate the

presence of an incoming wave or an area where wave energy is concentrated or focused. This localized concentration of wave energy may be attributed to specific coastal features or wave propagation patterns in this region.

From $x = 0.22$ to $x = 0.25$, the velocity reaches its peak at 0.55 and then rapidly drops to 0.3. This behavior suggests a region of high wave energy followed by dissipation. The rapid drop in velocity can be associated with wave refraction, reflection, or breaking as the waves interact with the rocky shoreline. These processes contribute to shaping the coastline and influencing sediment transport patterns. Moving beyond $x = 0.25$, the velocity experiences a significant decrease, indicating the dissipation of wave energy as the waves move away from the shoreline. Towards the end of the simulation, around $x = 0.29$ and $x = 0.30$, the velocity drops to very low values of 0.05 and 0.04, indicating minimal wave activity in these regions.

4.0 CONCLUSION AND RECOMMENDATION

The CFD simulation of ocean waves at the rocky shoreline during the northeast monsoon season in Terengganu, Malaysia, provided valuable insights into wave behavior and coastal dynamics. The findings indicate a gradual decrease in wave velocity as the waves approach the shoreline, suggesting wave energy dissipation and turbulence caused by the interaction with the rocky shoreline. Localized irregularities in wave behavior were observed, potentially influenced by local topographic features and interactions with submerged obstacles. The sharp increase in velocity at certain points along the shoreline indicated the presence of focused wave energy, highlighting areas of potential coastal erosion and emphasizing the need for targeted coastal management strategies.

The simulation results indicated a dissipation of wave energy as the waves moved away from the shoreline, with minimal wave activity observed towards the end of the simulation. Understanding wave behavior and coastal dynamics in Terengganu's rocky shoreline is essential for coastal management, erosion mitigation, and the development of sustainable coastal protection measures. The findings can guide decision-making processes and inform strategies to minimize the impact of waves on the coastline and ensure the long-term stability of the shoreline.

Further research is encouraged to validate the simulation results through field measurements and to investigate additional factors such as sediment transport, wave-induced currents, and their ecological impacts. Such studies will enhance our understanding of the complex interactions between waves, the shoreline, and coastal processes, facilitating more accurate modeling and improved coastal management practices in Terengganu and similar coastal regions.

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