MARE Program Report

Universiti Teknologi PETRONAS, Malaysia (UTP)

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Topic: Characterization of Hydraulic Properties of a Porous Bamboo Wave Screen using Physical Modelling

Program Overview:

The Erasmus+ Marine Coastal and Delta Sustainability for Southeast Asia (MARE) project was initiated to continue the research exchange between the University of Catania, Italy (UNICT) and the partner, Universiti Teknologi PETRONAS (UTP), focusing on the research of the characteristics hydraulics using physical modelling of a porous bamboo screen necessary for the attenuation of coastal waves. The research is particularly significant for Malaysia, especially in areas such as this one, where coastal erosion is increasingly affecting the coast. The institution in UTP has two hydraulic laboratories: one dedicated to Offshore Engineering Centre (OEC) at the Block J-1 and the other is Centre of Urban Resource Sustainability (CURes) at the G7 Lab that is equipped with water flumes and used for the purpose. Field supervisors, Dr. The Hee Min and the PhD student Eric Joseph Pereira have vast research experience in offshore, costal and water engineering. The student will have the opportunity to join the UTP research team in this experimental study to be conducted from July 4 to July 19, 2023.

Introduction:

In Malaysia, the coast of Tanjung Kepah (Perak), located on the west coast of the peninsula, is experiencing degradation of the mangrove forest. These plants serve the purpose of protecting the coast from erosion caused by seawater. However, in recent years, human interference, agriculture and aquaculture activity and climate change has led to rising sea levels and an increase in the frequency and intensity of storm surges. Consequently, the young mangroves are unable to reach maturity, and the existing plants struggle to survive, leading to their death. Furthermore, the regular growth of the mangroves is impeded due to the barnacles' attack on their trunks. The habitat of these crustaceans are polluted waters. Hence, it is highly likely that their spread is a result of the construction of the Lumut port, which led to an increase in sea pollution.

The coastline is swampy, in the ground there is sand and mud, this is carried by the waves. The plants hold the mud with their roots and protect the coast from the saline water. In the past, numerous attempts were made to replant mangroves, but unfortunately, these endeavours proved unsuccessful on four occasions. The baby mangroves were unable to take root well in the ground and the force of the waves uprooted them. Consequently, an alternative approach was considered, involving the collection of young mangroves from the surrounding land, their incubation, nurturing, and subsequent replanting. However, even with this method, the plants failed to survive.

The abstract, objectives and outcomes of the project for this topic are detailed in this report including the daily logbook of the activities executed over the two weeks in UTP.

Abstract

A bamboo breakwater has been proposed to provide wave protection for the depleting mangrove forest in Tanjung Kepah, Perak, Malaysia. The design of the bamboo breakwater will be optimized through a physical modelling study using regular waves generated in a wave flume. Wave reflection and transmission will be measured to assess the energy dissipation caused by different screen configurations. The optimum configuration will be determined as one that provides sufficient wave energy dissipation to protect the mangrove, but still allows sufficient circulation to avoid water stagnation near the mangrove root.

Mangroves require oxygen and sand to survive, so designing a structure that reduces wave height without impeding tidal flow is essential, thus creating favourable conditions for mangrove regrowth. These permeable structures are constructed using locally available natural bamboo with a maximum length of 5 meters. The bamboo will then assemble into a rectangular shape consisting of two rows of poles driven into the ground, extending deeper until it reaches the stiff clay. As the first layer of mud is soft, an additional element is required on one side of the structure to support the bamboo poles. A wire is tied over the fill material to keep it in place. The wire is tied to the horizontal bars attached to the vertical poles. The interior space is then filled with a filling material that has the function of wave attenuation, reduction of flow velocity, and permeability for suspended sediment (such as coconut, tree branches, etc), while a net with a small mesh size is employed to secure the fill material and prevent animals from passing through and trap inside.

Methodology

The waves interacting with our structure are gravitational waves. These waves impact the structure (incident wave), and then a portion of these waves and their energy will be reflected (reflected wave), while another portion will be able to pass through the structure due to its porosity (transmitted wave). In the laboratory, with a water flume and an electronic probe, it will be possible to determine the wave height over time before the screen and after the screen, thereby verifying the dissipating capacity of the element. At a certain period, we apply a specific frequency to the wave paddle, allowing us to map the wave height. The frequency is calculated as 1/T, with T being the period that from other analyses for this place is around 5 seconds.

Wave Characteristics

To calculate wave transmission, reflection, and energy loss of the bamboo wave screen we can use the following equation:

$$1 = C_T^2 + C_R^2 + C_L^2$$

C_T = Transmission coefficient; it describes the amplitude, intensity, or total power of a transmitted wave relative to an incident wave; $C_T = \frac{H_t}{H_i}$, with T = transmission and I = incident

C_R = Reflection coefficient; it describes the fraction of wave energy that is reflected by an obstacle, indicating how much of the wave's energy is sent back instead of continuing beyond the obstacle.

C_L = Dissipation coefficient; $C_L^2 = 1 - C_T^2 - C_R^2$

Every coefficient has a different way to be calculate that depends by the depth of the sea ground.

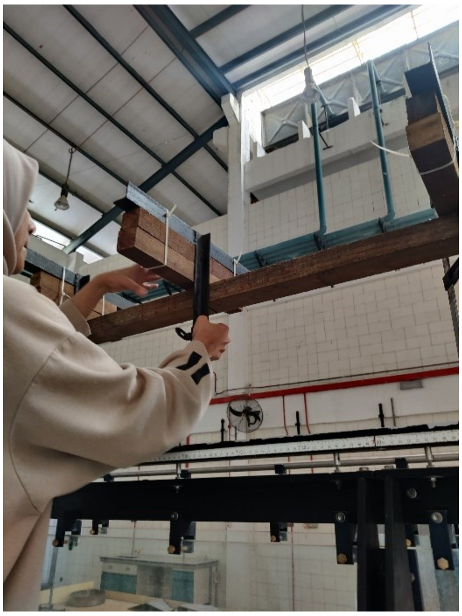
Experimental Setup

To perform the test, the first step is to calibrate the water channel used to test the structure. The tools used were:

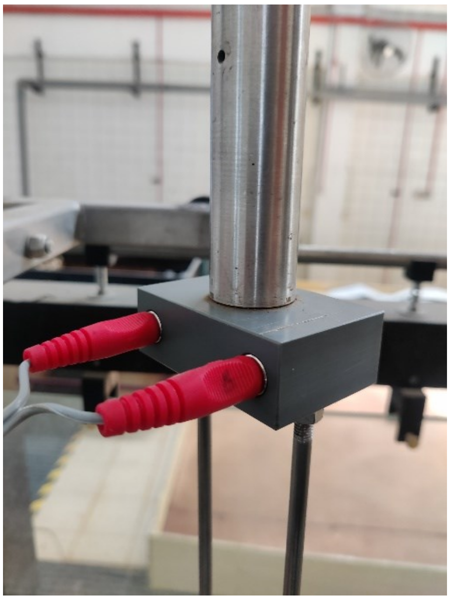
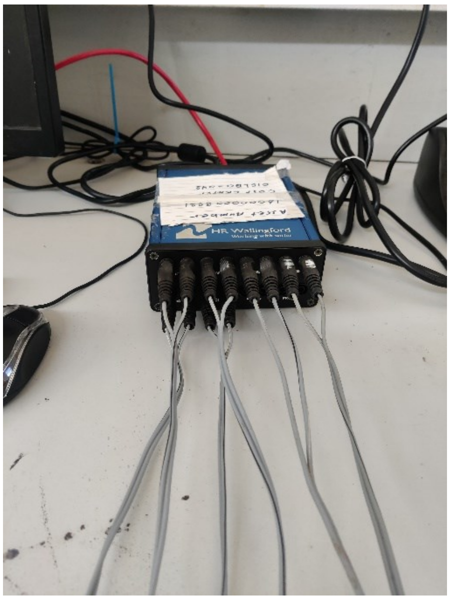
- Water Flume
- Probes
- Cables
- Software HR DAQ

Steps of the calibrations test:

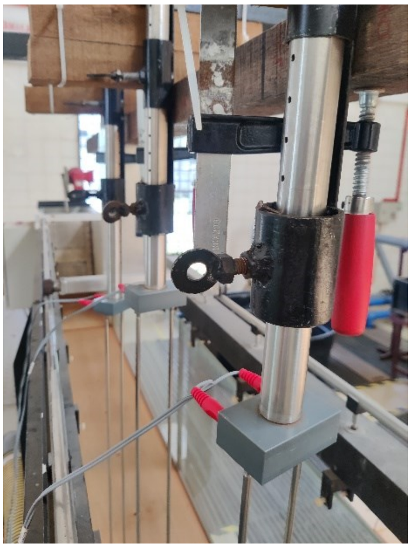
1. Arrangement of supports for the probes




2. Insertion of cables for electronic evaluation into the probes and connecting them to the control unit

3. Fixation of the probes to the structure (3 before the breakwater and 3 after)



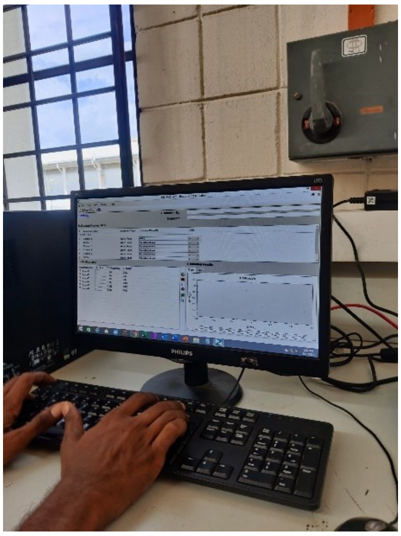
4. Adjustment of the water flume's inclination

5. Release of water into the water flume

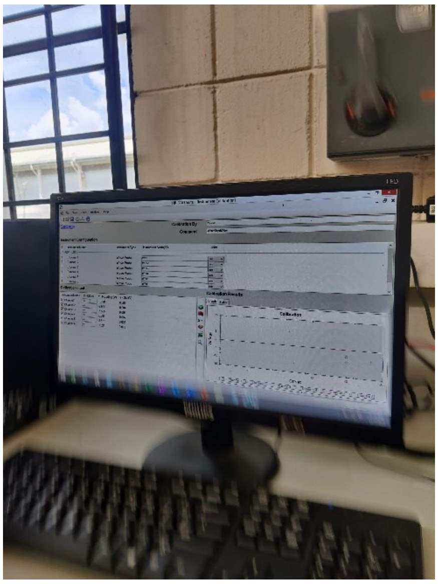
6. Evaluation of the percentage of probes submerged in water (approximately 30%)

7. Then, 4050 maximum * 30% = 1215, for each probe, the resistance data must be adjusted to obtain a value of 1215 (or very close).

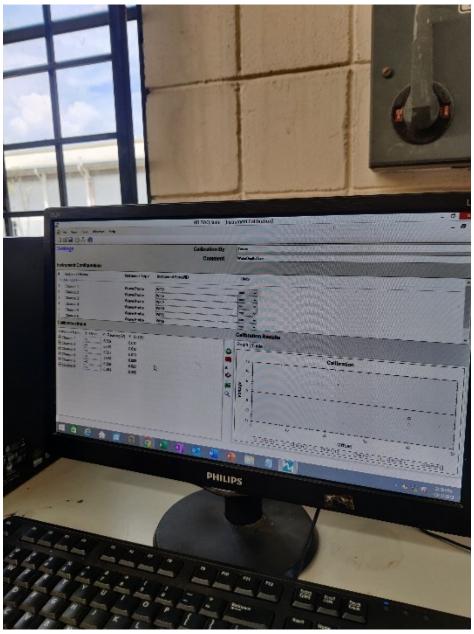
8. Using the HR DAQ software, indicate the type of instrument and enter a reference ID for each of the 6 channels, for a water depth of 25cm, and refresh the reading of the screen every 2 seconds, then start the first analysis to obtain the "zero" value.



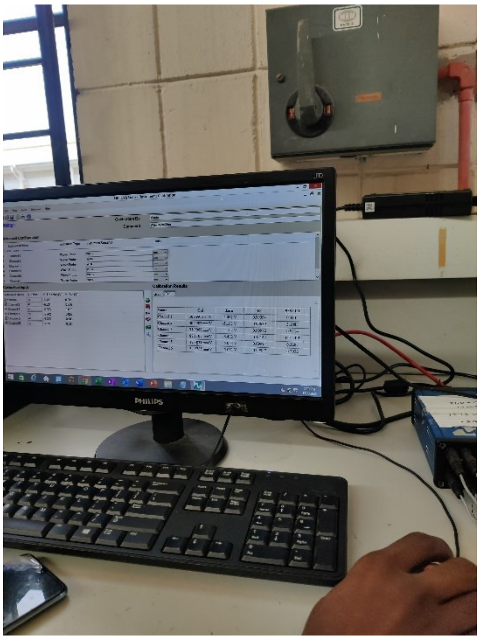
9. To obtain a positive value of 4cm, the test must be repeated, lowering the probe by 4cm (2 holes) and changing the "X-Offset" setting in the software to 40mm.

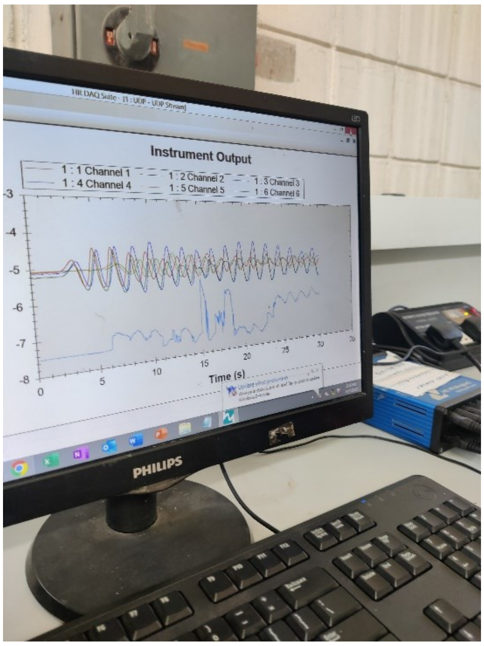


10. Repeat the process to obtain a negative value of 4cm, raising the probe by 4cm (2 holes) and modifying "X-Offset" to -40mm.

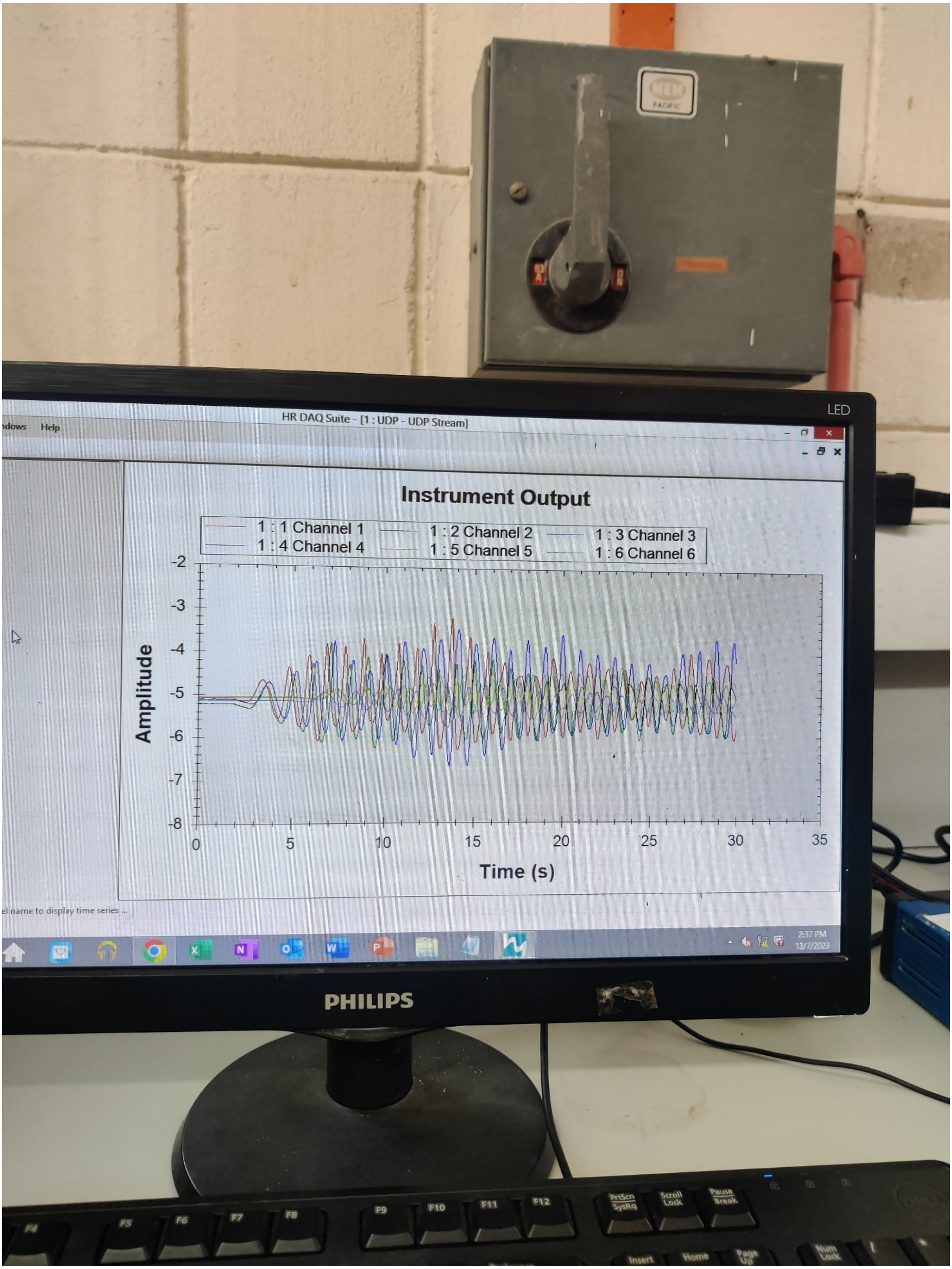


11. In the end, the calibration results will give a value in mm/V around 30-32mm/V.
    The value of 88mm/V for the 4th probe is due to a cable problem.





12. Save the analysis results and start the test with a frequency of 4.87Hz to obtain the wave amplitude variation over time.



Reflection

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Climate change and human activities have disrupted the natural balance of ecosystems. However, nature is difficult to control, often even impossible. This structure represents a challenge to restore the environment to its original equilibrium, utilizing natural materials as much as possible, such as bamboo.

Several laboratory tests are required, preferably on a bamboo model, to verify the material's characteristics and gain a better understanding of how it responds to wave forces. Additionally, it is crucial to test various geometries to identify the best configuration with minimal material usage. It is possible to consider a structure with a triangular section, fixed at the vertex, to make the structure more resistant to the force of the sea waves. However, the fixed constraint must be designed correctly to prevent the structure from yielding, preferably using only sustainable materials.