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# Enhancing Coastal Resilience by Analyzing Hydrostatic Forces and Generating Renewable Energy

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**ABSTRACT:** This study emphasizes the need to comprehend hydrostatic pressures and incorporate renewable technology for the best possible use of storm surge energy in coastal defense in the endeavour of sustainable coastal resilience. The research aims to create resilient systems with little effect on the environment through interdisciplinary collaboration and creative design techniques. Prototype model evaluation of energy conversion efficiency, interaction simulation, and wave behavior analysis are the main focus areas, along with investigating techniques to quantify hydrostatic stresses and utilize tidal waves for renewable energy. According to recent research, a combination vertical-trapezoidal seawall may effectively prevent overtopping up to 200 ml in 60 seconds. However, the research also highlights the potential of tidal waves as a sustainable power source. Accurate evaluation techniques are required to enhance marine energy systems due to discrepancies in structural integrity and energy efficiency estimates. Integrating theoretical analysis, numerical simulations, practical testing, and feasibility studies provides a comprehensive approach that fosters resilient coastal communities by optimizing coastal defense, understanding wave dynamics, and developing renewable energy sources from tidal waves.

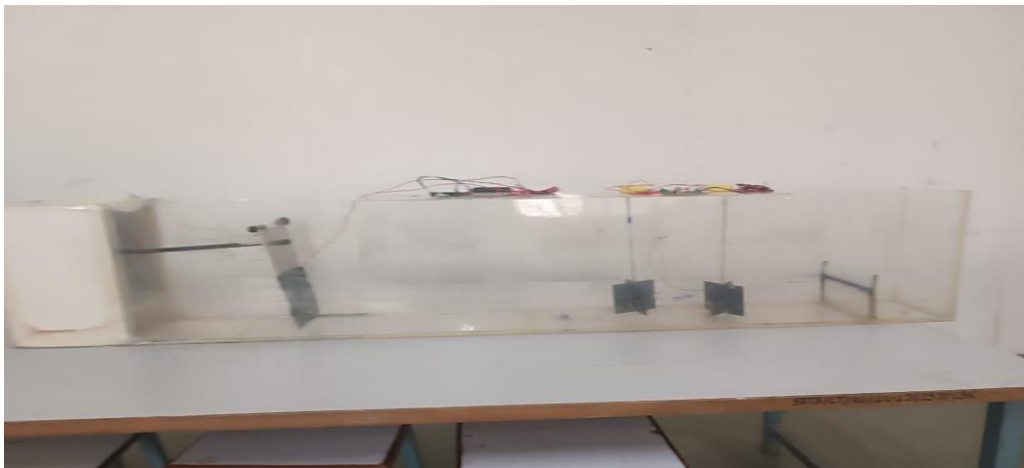
**KEYWORDS:** Sustainable Energy, Hydroelectric Force, Renewable Energy, Tidal Waves.

## I. INTRODUCTION

This report's objective is to give background information and recommendations for the application of models in site-specific tidal hazard assessments (THAs). This project aims to provide more substantive THAs methods and builds on the previous work by providing a conceptual framework for the assessment of flood hazards near coastal areas. Because of the aforementioned guidelines and our current, incomplete understanding of landslide hazards, this document focuses on flooding caused by landslides. Potentially large, local landslides will cause flooding and frequently control the Probable Maximum tide (PMT). The techniques described in this document can be applied to any location where waves are produced spontaneously, particularly those caused by earthquakes, subaerial landslides, and submarine landslides.

Consequently, even though the term "ocean" waves will be used frequently in this document, the information that goes along with it applies to waves in lakes and rivers as well, where waves may be caused by a nearby cliff or bluff failure. Furthermore, any border separating a body of water from land is referred to as "coastal" throughout this document. The important physical process that a flood goes through from generation to inundation is first briefly discussed in this document. This is followed by a discussion of the mathematical theories used to study ocean waves. The paper then goes on to describe the various kinds of numerical solution techniques, ranging from the traditional fixed-grid and finite-difference approaches to the more modern techniques. There are also methods provided for approximating the motion of the shoreline during flood inundation. This document also covers how to properly configure the model, including how to create input initial conditions and how to analyze and interpret the model's output. Lastly, this paper offers a sensible framework for waves with the best possible impact resistance. Through the use of overtopping techniques, hydrostatic force can be dynamically calculated by accounting for the water's flow rate and velocity over a structure. Estimating the hydrostatic force acting on the structure can be done using this. This approach considers the dynamic flow of the water and how it influences the force applied to the structure. This method makes accurate predictions about the hydrostatic forces by utilizing a variety of computational models and equations. It is possible to compute hydrostatic forces using dynamic formulas that account for overtopping, among other factors. The momentum equation and Bernoulli's equation are two popular dynamic formulas for computing hydrostatic forces. These formulas are applied under the particulars of the fluid flow and the geometry of the structure. However, using digital techniques, such as an Arduino Uno meter, requires programming to automate the calculation process. With an Arduino Uno microcontroller, engineers can incorporate sensors that measure variables like fluid pressure,

flow rate, or velocity. The Arduino can then process these sensor readings and calculate the hydrostatic forces in real-time using pre-programmed algorithms. Benefits of this digital approach include improved accuracy, faster data processing, and ongoing system monitoring. Wave energy is a type of renewable energy produced by waves. Ocean wave energy can be captured and transformed into electrical power by devices like wave energy converters (WECs). Usually, these gadgets use the kinetic energy of waves to propel generators, such as turbines, to produce electricity. Wave energy, especially in coastal areas with high wave activity, has the potential to be a substantial renewable energy source. Wave Energy Resources: Around the world, there are numerous coastal areas where wave energy is abundant and accessible. It is especially common in areas with frequent and intense wave action, like coastlines that are exposed to the main winds. Because of its predictability and abundance along coastlines across the globe, it is a resource of interest to nations looking to diversify their energy sources and lessen their dependency on fossil fuels. Wave energy converters (WECs) are among the technologies that use attenuators, point absorbers, or oscillating water columns to capture the kinetic energy of waves and transform it into electrical energy.



**Fig. No. 1 Prototype Model**

There are still issues even though wave energy has much to offer the environment, such as low greenhouse gas emissions and little ecological impact. The need for grid integration solutions to manage variable and intermittent energy generation is one of these, as are the high upfront costs of development and deployment and the technical difficulties in designing robust wave energy converters.

#### Objectives:

1. To analyze wave behaviour, simulate interactions, assess wave traits, and measure the efficiency of energy conversion from the prototype model.
2. To explore and implement methods for measuring hydrostatic forces manually and experimentally.
3. To generate renewable energy from the use of tidal waves.

**Scope of the Project Work:** To measure hydrostatic forces, improve coastal defense systems against tidal waves, analyze wave behavior, and develop renewable energy technologies from tidal waves, multidisciplinary research and experimentation are required. Collaboration, data analysis, ethical considerations, and practical applications are also necessary.

## II. LITERATURE SURVEY

It delves into the intriguing realm of physical stimulation by exploring the intricate interaction between regular waves and a tidal power plant. The study meticulously investigates the profound impact of gravitational waves on a model representing the workings of a tidal power station. Through rigorous analysis, the research unveils a plethora of integral and spectral characteristics inherent in the wave field, shedding light on the intricate wave load exerted on the structure of the power plant model. Furthermore, the study meticulously pinpoints the precise area of maximum loads and wave pressure acting upon the streamlined surface of the tidal hydroelectric power plant model, offering valuable insights into the dynamics at play (1). The embark on a journey of experimental analysis to explore the multifaceted effects of canal geometry and water levels on a remarkable innovation known as the Rotary Hydrostatic Pressure Machine (RHPM). Within the realm of hydropower conversion, the RHPM stands as a groundbreaking mechanism capable of generating hydraulic heads through the ingenious utilization of the dam effect. The paper presents a series of novel experimental findings about the RHPM, unveiling new dimensions of understanding in this domain of study (2). It delves deep into tidal barrage optimization, proposing innovative

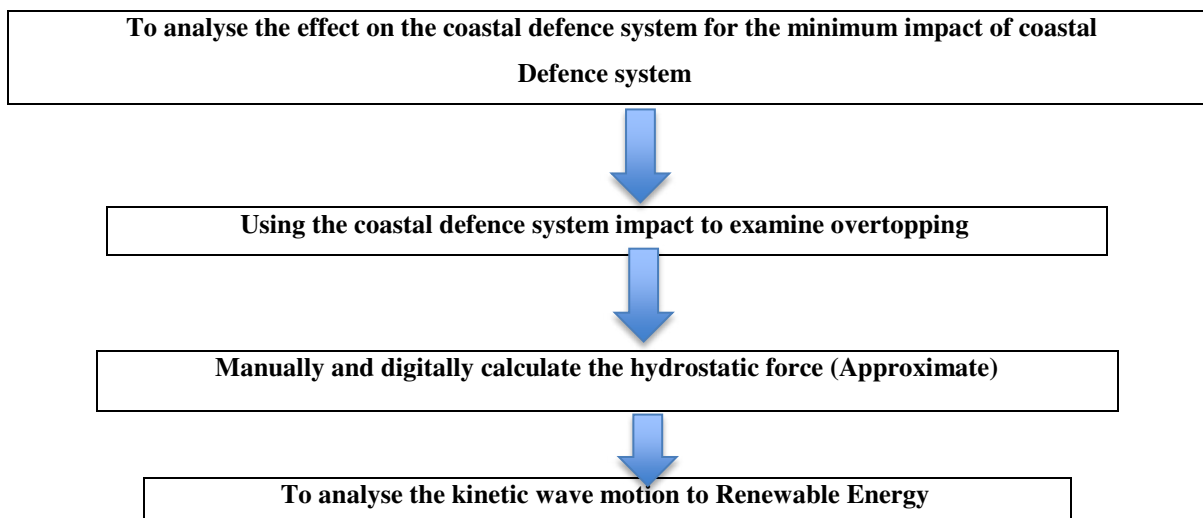


techniques rooted in wave energy control. This thought-provoking paper meticulously examines the insights that can be gleaned from sustainable energy applications, particularly wave energy. Through a comparative lens, the research scrutinizes the characteristics of energy excitation, the array of control protocols available, and the mathematical models underpinning each system. To provide a tantalizing glimpse into the potential of wave energy control concepts, a sample case study is undertaken, showcasing the application of a popular wave energy control philosophy in optimizing the operational efficiency of a tidal barrage (3). A Literature review compares normal concrete to a mix of sawdust and micro-silica, showing an increase in results by 38.84% and 31.46% respectively. Conversely, a decrease of 7.38% is observed when comparing Sawdust plus Micro-silica to normal concrete. Another comparison over 7 days shows an increase of 26.54% for the mixture (4). The impact of wave and tidal currents on the blade motion of an energy-generating turbine is analysed, focusing on integrated wave tidal current action. A numerical simulation determines energy integration's conversion wave coefficient between waves and equivalent flows. Validate dynamic load characteristics on a Tidal Stream Turbine under wave and current interaction using experimental tests (5). comprehensively discuss Sea Wave Tidal Power Plants, covering generation processes, advantages, disadvantages, and case studies (6). The impact of seawalls on beaches during storms is that the beach profile in front of the wall retains a similar amount of sand as a beach without a wall due to the minimal influence of wave reflection on profile shape (7). Focuses on risk assessment for coastal and tidal defense schemes, including hazard identification, key failure modes, structure classification, assessment of hydraulic loading conditions, probability of failure, and consequences modelling for flooded areas (8). study investigated the impact of seawalls on beaches using a model test. Results were analyzed for changes in volume, shoreline, and hydrography. Experiments took place in a wave basin at the University of Florida. A model seawall was installed on a test beach, with hydrographic surveys conducted periodically. The main variable tested was the wave angle, with and without seawall cases examined. (13). This literature review was conducted on the effects of seawalls on beaches. M Jacobson from the Department of Conservation requested the report. It focused on articles related to seawall impacts on beaches, with a special emphasis on Wainui Beach, Gisborne. Reports by Single and Peacock were analyzed to understand the current and historical coastal protection efforts at Wainui (14).

### III. METHODOLOGY

One sustainable and eco-friendly energy source is tidal energy. The possibility of producing power from tidal energy is significant in the modern world since it can help combat climate change and lower greenhouse gas emissions. Using tidal energy effectively can help satisfy the world's growing energy needs. It is a promising power source, and with conventional fossil fuels becoming less viable, interest in investigating alternate energy sources is rising. Coastal security is crucial, especially in light of the increasing hazards associated with climate change and rising sea levels. To safeguard coastal infrastructure and communities, it is essential to comprehend coastal engineering and defensive systems. We generate tidal energy from tidal waves. The waves that generated hydrostatic force and that hydrostatic force is displayed in LCD with the help of Arduino Uno.

Setup procedure –



**Fig. No. 2 Project step by step procedure**

### Linear defences structures

A ‘linear’ flood defence or coast protection structure forms a line of defence with a uniform nominal cross-section. Its simplest form consists of a structure (the main defence body) and a foundation (or bedding structure). The body of the defence or structure is the part of the defence upon which loads act. The foundation is where the structure interacts with the Natural ground. The distinction between the foundation and the body of the structure, however, is not always clear. The performance of a defence structure is controlled by the magnitude of the loads (water level, waves, wind, traffic, etc.) acting on the structure.

1. The response of the structure to the loading.
2. The performance of the foundation. (The performance of flood defence structures, particularly embankments, can be heavily influenced by the nature of the ground on which they are constructed.

Different Coastal defence Systems to be used

- |                      |                        |
|----------------------|------------------------|
| 1. Vertical Sea wall | 2. Re-curved Sea wall  |
| 3. Sloped Sea wall   | 4. Stepped Sea wall    |
| 5. Rock armour       | 6. Offshore Breakwater |

The system model used in this paper includes several components necessary to carry out site-specific tidal hazard assessments (THAs) in coastal areas. The mathematical theories and numerical solution techniques used to assess flood dangers, especially those brought on by landslides, are at the heart of the model. The system’s ability to accurately predict storm surge patterns and evaluate related hazards depends on an in-depth knowledge of fluid mechanics, wave behaviour, and hydrostatic forces. Several basic assumptions form the basis of the system model and analysis for site-specific tidal hazard assessments and wave energy exploration in coastal zones. These consist of a uniform distribution of structures assumption to estimate impacts consistently, the homogeneous medium assumption for uniform application of principles, and steady-state conditions for simplified mathematical modelling. For simplicity, an idealised coastline geometry is assumed, and wave behaviour is approximated using linear wave theory. The analysis is guided by conservation principles, and stable boundary conditions are always taken for granted. Furthermore, wave energy converters are considered to operate at an idealised level, although real-world complexity may be acknowledged. Although these suppositions offer a well-organized structure for examination, continuous improvement is imperative to augment the precision and dependability of the model.



**Fig. No. 3 Different Coastal Defence Systems**

### Materials for prototype model components:

The necessary material components needed for constructing the experimental prototype model include Acrylic sheets, Car wiper motor, Incline steel plate, Vertical spin fan, Dynamo motor, a Piezo vibration touch sensor-based bulb control kit, a Cell socket, Acrylic wall sections, and a Bike battery. Apparatus used for mechanical hydrostatic force are Arduino uno , LCD (Liquid - crystal display), Pizzzo sensor, Wires, Resistor (1 mega ohm, 2 mega ohm), Jumping wire- M to F and M to M,

### Experimental setup

- a. The experimental arrangement is as follows:
- b. The container is constructed using 10 mm panels joined with a solvent-based acrylic adhesive.
- c. Measuring 1500 mm in length, 200 mm in width, and 400 mm in height.

The sizing of the container for this study has been determined through consistent and scheduled communication with different organizations involved in research on wave transmission.

### Methodology be Used by using the numerical model

The forces acting on waves are as follows.

1. Hydro-static force
2. Buoyancy force
3. Hydrodynamic force
4. Flood velocity
5. Surge force
6. Drag force

### Hydro-static force

Manning's formula is extensively utilized in the field of hydraulics to compute the flow velocity in open channels, including rivers and streams. Its application is particularly prominent within the domains of civil engineering and hydrology, where it aids in the design and examination of water flow in channels characterized by either natural or man-made inclinations. The parameter known as the roughness coefficient signifies the level of resistance to flow, a factor contingent upon various channel attributes such as material composition, roughness characteristics, and geometric configuration. Typically, this coefficient is ascertained empirically via practical experimentation or by consulting relevant literature sources. The formula serves as an estimation tool and is most effective under conditions of steady and uniform flow within open channels featuring Manning's roughness coefficients that span a range from approximately 0.01 for exceedingly smooth channels (e.g., concrete surfaces) to above 0.1 for considerably rough channels (e.g., densely vegetated or debris-laden streams).

$$V = \frac{1}{n} \times R^{(2/3)} \times S^{(1/2)}$$

Where:

- V is the velocity of flow
- n is Manning's roughness coefficient
- R is the hydraulic radius (cross-sectional area divided by wetted perimeter),
- S is the slope of the channel.

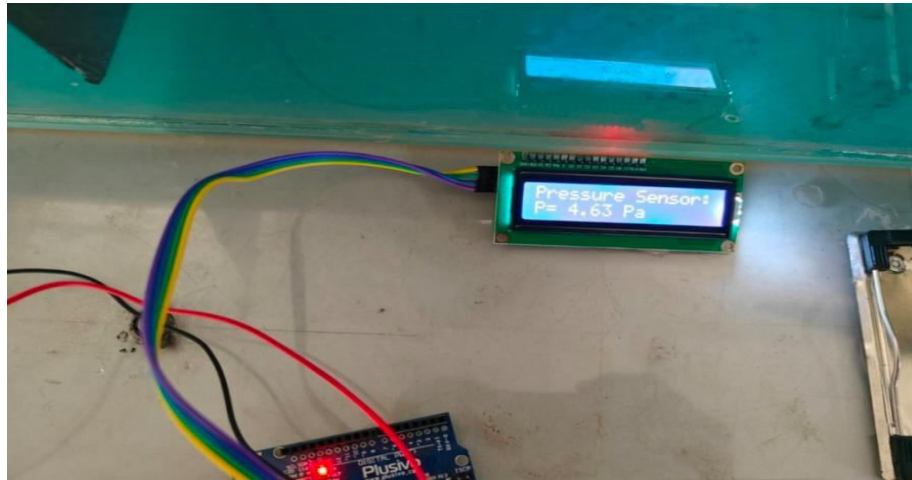
$$\begin{aligned} \text{Dynamic pressure} &= 4805 \text{ kg/m} \\ &= 4.8 \text{ Pa (approximately)} \end{aligned}$$

### Code for calculating hydrostatic force digitally

A code for digitally calculating hydrostatic force can be described as a set of algorithms and computational instructions specifically designed to determine the magnitude of the force exerted by a fluid at rest on a submerged object. This code typically involves mathematical calculations based on the principles of fluid mechanics and hydrostatics, aiming to provide accurate and precise results regarding the pressure distribution and resultant force experienced by the object due to the surrounding fluid. We are currently utilizing the Arduino software platform as our primary tool for coding and programming. This software, developed by the Arduino team, provides a user-friendly interface and a set of libraries that facilitate creating and deploying code for various projects and applications.

### Digital Reading in display of LCD (liquid-crystal display)

Digital Reading is presented on an LCD (liquid-crystal display) indicating the ultimate value of 4.63 Pa in the pressure sensor.



**Fig. No. 4 Digital value of hydrostatic pressure on LCD**

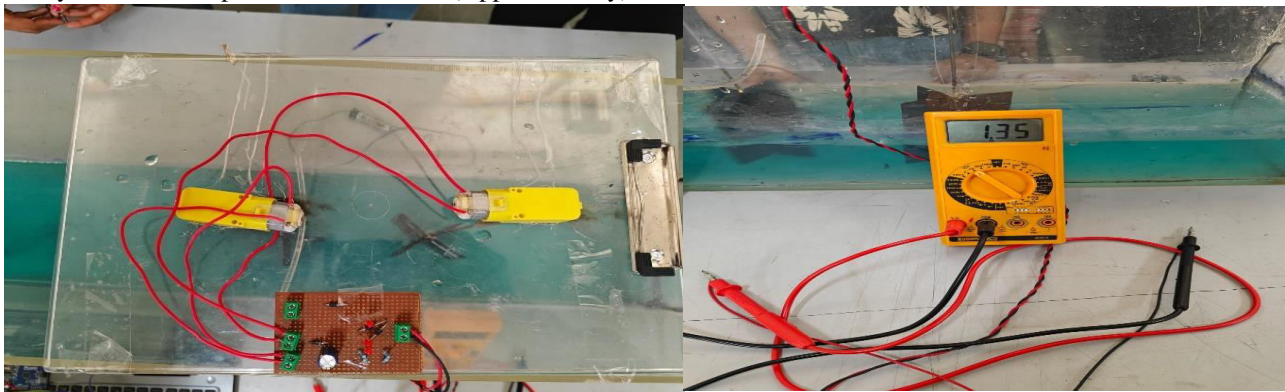
### **Overtopping**

Various elements of the seawall are designed based on idealized conditions, where waves are generated by a 3 mm thick stainless-steel sheet of grade 306. A reciprocating motor sets This sheet in motion, causing water to move to create a sequence of waves. These waves then collide with the seawall, spilling over its surface and resulting in water overflowing the wall's crest. The amount of water that overtops and flows into coastal regions can be determined by collecting it in a measuring cylinder. Furthermore, an analysis of different types of seawalls is required.

Acrylic glass sheet (6 mm for tank, 3mm for seawalls), measuring beaker (400ml), various seawalls, potable water, reciprocation motion motor, stainless steel sheet, adaptor, colouring agent.

### **Renewable Energy**

The concept of renewable energy revolves around utilising a dynamo, also commonly referred to as a generator, which operates based on the fundamental principle of electromagnetic induction. This intricate machine is designed to effectively convert mechanical energy, specifically deriving from kinetic sources such as the motion of an object, into electrical energy, thereby contributing to the vast potential of sustainable power generation. The movement of the vertical blade within the renewable energy system is intricately linked to the motion of the sea waves, illustrating a complex interplay of natural forces at work. It is important to recognise that the kinetic energy inherent in the waves plays a pivotal role in activating the dynamo motor, ultimately driving the mechanical components forward. Through this process, the kinetic energy undergoes a significant transformation, culminating in the generating of renewable energy through the intricate workings of the dynamo motor. Digital Reading is displayed on the multimeter, showing the dynamo motor's peak value of 1.35 V (Approximately).



**Fig. No. 5 Setup for Energy Generation with Digital Reading on Multimeter**

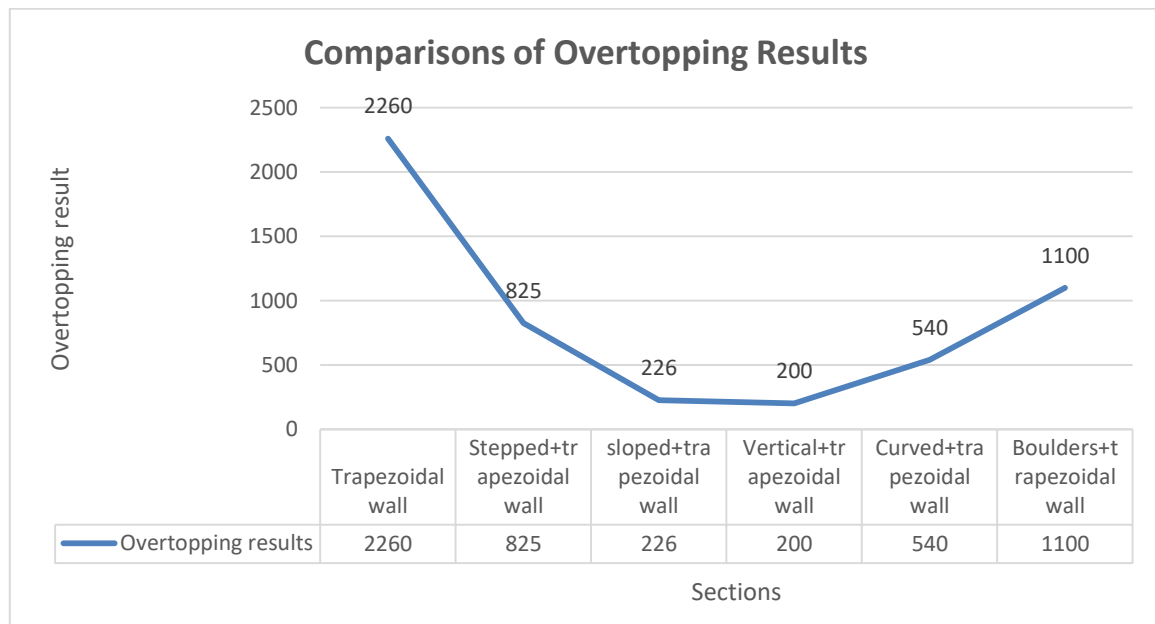
**IV. RESULT AND DISCUSSION**

This section presents the graphical and tabular examination of the overall performance of evaluated seawalls against the influence of tidal waves, concluding with the enhancement of resilience in coastal defense systems regarding the force of overtopping. The analysis involves a model comprising six variations of seawalls, each a scaled replica of conceptual coastal defense structures, and offers insights based on the findings.

Previous research conducted experiments using only one coastal defense wall, whereas, in the current study, trapezoidal structures were utilized in combination with other coastal defense walls. The findings from the previous research indicated that curved walls were effective for coastal defense, whereas, in the present investigation, trapezoidal structures in conjunction with vertical walls demonstrated effectiveness. Our study suggests that vertical walls are superior in defending against storms, hurricanes, and other hazardous activities in coastal regions.

**Table No. 1 Comparisons of Overtopping Results**

| Sr. No. | Overtopping (previous)    | Overtopping (Latest)                     |
|---------|---------------------------|--|
| 1       | Trapezoidal =95 ml/min    | Trapezoidal =2260 ml/min                 |
| 2       | Step wall =330 ml/min     | Step wall + Trapezoidal =825 ml/min      |
| 3       | Slope wall=270 ml/min     | Slope wall + Trapezoidal = 226 ml/min    |
| 4       | Vertical wall =206 ml/min | Vertical wall + Trapezoidal = 200 ml/min |
| 5       | Curve wall =0 ml/min      | Curve wall + Trapezoidal = 540 ml/min    |
| 6       | Boulders =12 ml/min       | Boulders + Trapezoidal = 1100 ml/min     |



**Graph No. 1 Graphical analysis of seawalls**

**Hydrostatic force result**

Our study determines the hydrostatic forces through manual and digital methods. The manual calculation yields a hydrostatic force of 4.8 pascals per minute, while the digital calculation results in 4.63 pascals per minute.



**Table No. 2 Manual & Digital Hydrostatic Force Calculation Difference**

| Hydrostatic Force | Average Time(T) | Manually Calculated | Digitally Calculated | Difference Between Digitally & Manually Calculated |
|-------------------|-----------------|---------------------|----------------------|--|
| In Pa (pascal)    | 60 min          | 4.8                 | 4.63                 | 0.17   |

Table 2 compares the Manual and Digital Hydrostatic Force Calculations, highlighting the differences between the results. The table shows the average time taken for each method of calculation, the corresponding hydrostatic force values in Pascal, and the discrepancy between the digitally and manually calculated results.

**Renewable energy result**

Wave Star has successfully engineered a 0.6 MW wave machine combining wind energy and wave power. This innovative Wave star machine harnesses energy from wave power utilizing floats that oscillate with the motion of waves. These floats are connected by arms to a platform supported by legs anchored to the seabed. The following data from Table 3 represents the manual and digital hydrostatic force calculation difference to compare the electricity output of the prototype model and the original unit.

**Table No. 3 Manual & Digital Hydrostatic Force Calculation Difference**

| Sr. No | Types of renewable source | Electricity output by prototype model | Electricity output by the original unit |
|--------|---------------------------|---------------------------------------|---|
| 1      | Hydro                     | 1.35V (0.54W)                         | 0.6 MW                                  |

**V. CONCLUSION**

1. According to the latest research, the most effective coastal defence structure is a combination of a vertical seawall and a trapezoidal seawall. This structure produced the lowest amount of over-topping, at 200 ml for 60 seconds, and is deemed satisfactory for current coastal conditions.
2. The prototype model showed disparities in structural integrity and energy efficiency assessments between manual and digital hydrostatic force is 4.8 and 4.63 from the prototype model respectively, emphasizing the need for precise assessment methods to advance marine energy systems.
3. Tidal waves can be the optimistic solution for sustainable power generation as a constant and reliable source of renewable electricity that doesn't harm the environment.

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