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Design And Development Of Piston Type Displacer For Generation Of Unidirectional Random Sea Wave Conditions In A 2d Wave Flume

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Abstract:
A new unidirectional wavemaker of the piston type with a single wave paddle powered by a servo-hydraulic system is designed and commissioned in a wave flume at CWPRS, Pune, India. The dimensions of the flume are 120m long, 4 m wide and 2 m deep, where water depths can be varied up to a depth of 1.5 m. With a working stroke of one metre and a servo-hydraulic system for power, the new wave board is unique in its dimensions and mechanism. In the present trend of conducting physical model studies on coastal and off-shore structures, the generation of random waves has become indispensable at the model testing facilities. This paper describes a wetback piston displacer of size 4 m in width and 2 m deep, developed for the simulation of unidirectional random sea waves. To assess the performance of the wave board, a range of experiments were carried out to generate random waves.
***Key Word**: Wave flap, Wavelength, Wave channel, Wave generator, Wavenumber*

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I. Introduction

The Central Water and Power Research Station (CWPRS) is engaged in conducting studies for the simulation of prototype sea wave conditions in laboratory physical models for the design of port layouts, maritime structures, etc. Physical model studies of coastal engineering applications depend on the ability of wavemakers to produce realistic sea wave conditions in laboratory models (Cornett et al. 2016). Shallow basins at the CWPRS are equipped with top-hinged pendulum-type wave boards, whereas flume models are equipped with piston-type wave boards for the generation of unidirectional random waves. Bottom-hinged flaps are used for the generation of regular waves in 2D flumes and 3D basins at the CWPRS. The vertical wave -board motion is a combination of reciprocating and oscillatory motion in both shallow basins and flume models for the generation of random waves. The vertical wave board reciprocates while oscillating about the top hinge. In these wavemakers, the circular or diamond-section beam carries a vertical wave board that oscillates via a pivoted link mechanism. The wave board swept backward and forward horizontally during its oscillatory motion about the top hinge to establish a wave field. A rigid structure that displaces the volume of water to establish a wave field in physical models such as wave basins or flumes is termed a "displacer" throughout this paper. This term is similar to the term for a wave -board or paddle. The capabilities of the wavemaker mainly depend on the size of the wave channel, stroke of the wave paddle, and the operative frequency range of the displacer. When replicating storm conditions, engineers and researchers are forced to work at a tiny scale because many wave generators are only able to create wave conditions with small wave envelopes. With the finite size of the wave channel or basin, such modeling is prone to the effect of scaling. In addition, the waves produced by the displacer may not contain the desired wave conditions as intended at full scale. The perfect matching of the frequency spectra of incident waves generated by the wavemaker against the target theoretical spectrum plays a vital role in predicting the investigated test results. A wave board with the maximum possible stroke needs to be selected for a wide range of applications.

When the energy provided by the displacements of the displacer exceeds the potential energy of the water body, the surplus energy is manifested as kinetic energy, which is taken up as various combinations of water velocities that create waves. The basic kinds of wave boards are shown in Fig. 1. Wave boards can be classified into four categories (Nikseresht & Bingham 2020), viz., i) the piston type, consisting of a vertical wave board constrained to move horizontally with equal displacement through the depth; ii). The hinged type, consists of a straight wave board hinged at some level beneath the water surface (usually the flume floor), pivoted about the hinge to produce a rotational displacement of the board that decreases linearly with depth. iii). The plunger type consists of a triangular prism that is oscillates vertically to produce water displacement. iv). The wedge type, consisting of a triangular prism, is moved with its front face vertically up and down in an inclined plane. This type is a hybrid of (i) and (iii). Another type of wave board can also be developed with a combination of the above basic types, such as (Nohara and Ben 2000), top-hinged pendulum, top-hinged with curved board, and serpent (snake) wave generator. Depending on the kind of displacer movement, the wave velocity profiles near the displacer vary. According to linear theory, the velocity profiles created by the three most popular displacers close to the wavemaker replicate various conditions.

We have profiles that resemble those for shallow water wave conditions by a linear displacer (Oliveira et al. 2009), intermediate water wave conditions by a wedge, and deep water wave conditions by a bottom hinged flap (Dean and Dalrymple 1991). Experimental research on Havelock's (1929) first-order wavemaker theory was conducted by Flick et.al. (1980) and Ursell et.al. (1960). Design curves for regular and random wave generators have been developed using Havelock's basic theory of wavemakers for forced harmonic surface gravity waves by Gilbert et.al.(1971)h. The wave height-to-stroke ratio for a flap and piston-type WM is formulated as shown in equations (1, 2).

$$\frac{H}{S} = \frac{4\sinh(\mathrm{kd})\,\mathrm{kdsinh}(\mathrm{kd}) - \cosh(\mathrm{kd}) + 1}{\mathrm{kdsinh}(2\mathrm{kd}) + 2\mathrm{kd}} \qquad (1)$$

$$\frac{H}{S} = \frac{2[cosh\ (2kd) - 1]}{2\mathrm{kd} + \sinh\ (2\mathrm{kd})} \qquad (2)$$

where d is the still-water depth, k is the wavenumber = $2\pi/L$, and L is the wavelength. S is defined as the maximum horizontal distance at a still-water level at which the paddle travels in one direction from its neutral position. (Dean and Dalrymple. 1991; Krvavica et.al.2018).

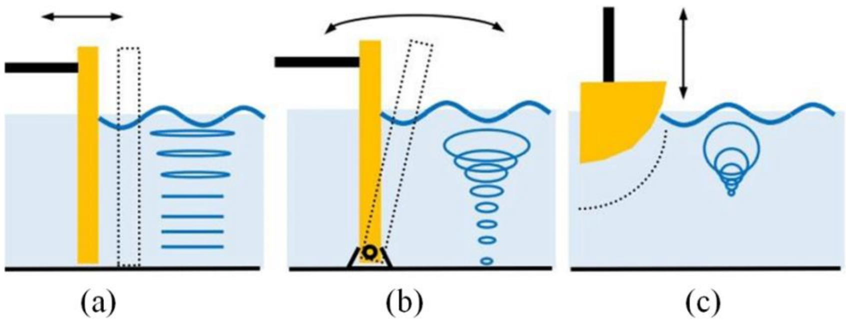

Fig. 1 Schematics of the figures: (a) piston-type (linear); (b) flap-type; (c) plunger-type

Until recent times, the physical model tests at the CWPRS in shallow basins were conducted by using servo-hydraulic random sea wave generators with top-hinged wave boards. Flume models are equipped with a piston-type wave- board that reciprocates through rollers. With available wave boards, imperfections at higher frequencies in the profile of the acquired spectrum are observed. The fidelity of wave-making depends on the accuracy of the displacer action, wave reflections, and control signal. Wave action can be improved by selecting a suitable mechanism that generates wave displacements. Wave reflections can be minimized by adopting active wave absorption (Hirakuchi & Kawaguchi 1990) or modifying the control signal based on the force acting on the wave paddle. (Spinneken & Swan 2009; Spinneken 2010). Currently, we use position-controlled wavemakers with no active wave absorption. The most recent random sea wave generation system needs to be designed with a new type of board for the simulation of irregular waves in channel models to improve the frequency spectra of incident waves generated by wavemakers. To obtain the best wave profiles, special emphasis is given to developing wave board mechanisms. Most of the wave flumes at various laboratories around the world use bottom-hinged generators. In this type of displacer, the stroke length is determined by the angular rotation of the flap. Consequently, only low-amplitude incident waves can be generated. In addition, frequent replacement of the bottom bearings is necessary. In the case of top-hinged wave boards, the leakage of water under the wave board increases with increasing stroke length, correspondingly reducing the amplitude of the generated waves. The water depth in front of the displacer, the wave frequency, and the actuator power all affect the maximum wave heights that a paddle can produce. Wave breaking is dependent on water depth and wave frequency; paddle stroke and velocity are dependent on power.

Some of the wave-flume facilities and their methods of wave generation are presented in this paragraph. Flap-type wavemakers with a 0.9 m wide, 0.0125 m high, and 0.013 m thick, paddle powered by electric servo drive motors, are suitable for carrying out education and research studies (Khalilabadi and Bidokhti 2013). The wave flume is 50 meters in length and 1.2 meters in width at the Physical Experiment Building of the Korea Institute of Ocean Science and Technology (KIOST) uses a piston-type wavemaker with passive wave absorbers at both ends. A paddle 1.6 m in height and 1.18 m in width has an operative stroke of 1.2 m (Lee and Hong 2020).

The Maritime, Experimental and Research Center's CIEM (Canal de Invest igación I Experimentacio Maritima) has a wave flume that is 100 meters long, 3 meters wide, and 5 meters deep. In this flume, a wedge-type wave paddle is employed to produce both regular and irregular waves, which is suitable for waves of intermediate depth (Oliveira et al. 2009). The Ministry of Transport's Tianjin Research Institute of Water Transport Engineering built a massive wave flume measuring 450 m in length, 5 m in width, and 12 m in depth in July 2014. A piston-type wave board with a working stroke of 8 m, driven by a rack and pinion mechanism, is employed in this flume. The width of the wave flumes at Hannover, Germany; Delta Wave Flume, Netherlands; and Tainan Hydraulics, Taiwan, is 5 m (Zhang et.al. 2015). The width of the wave flume at the CWPRS is 4 m, which is one of the largest widths. The University of North Carolina Wilmington (UNCW) installed a wave flume using state-of-the-art technology in 2023. The flume dimensions are 1.5 m wide by 24 m long, and the water depth is 1 m. The flume is equipped with a linear piston-type wavemaker with force feedback absorption that uses a single paddle. This wavemaker is supplied and commissioned by - "Edinburgh Designs". Several articles were reviewed to design a wavemaker. (Galvin 1964; Madsen 1970; and Gyongy et al. 2014) To cover a wide range of amplitudes that scatter the research studies of coastal engineering problems, a single-wave paddle that can be operative between frequencies ranging from 0 to 3 Hz with a rated velocity of one meter per second and an operative stroke of length one meter is considered for development. A flume with dimensions, 120 m in length, 4 m in width, and 2 m deep, was constructed at CWPRS, Pune, India, and was in operation until 2000. A servo-hydraulic random sea wave generator was developed and installed in this flume in 2023. In this paper, the design and development of a 4 m x 2 m piston-type displacer with linear motion guideways is presented. Accurate linear motion with no lateral play is possible on this type of wave- board. The Ministry of Jal Shakti, Government of India, provided funding for the project.

II. Choice Of Wave Board

Based on obtaining the best match of wave board movement to the water velocity profile with depth, it has been conventional to regard the piston machine as a shallow water wavemaker and the hinged boards as a deep water wavemaker (Law et. al. 2020), with intermediate depths sometimes served by a complicated and articulated combination of two methods. Linear theory indicates that all three devices, viz., hinged, piston, and wedge devices, are equally effective at any depth of water. At distances exceeding three times the depth of the water, the propagation characteristics of the wave profile will correctly settle to those appropriate for the water depth. This may not be strictly correct if second-order effects are included. This approach biases the selection of a machine toward practical experience of performance and mechanical design convenience rather than alleged suitability in depth.

The hinged wave board may appear to be the most attractive wave machine due to its low mass, simplicity of movement, and mechanical construction; however, experience has shown that reservations must be placed on its performance. In the top hinged flap-type wavemaker, as shown in Fig. 2, the flap remains perpendicular to the ground by an articulated mechanism while oscillating in a circular path along with a diamond-sectioned beam, and the gap between the wave flap and ground increases during its motion from the mid-position.

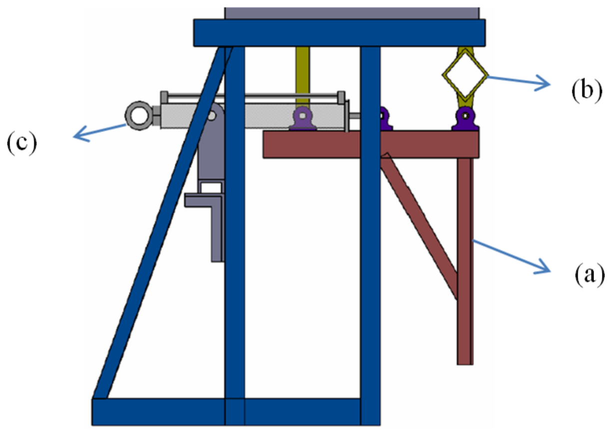

Fig. 2 Schematics of a typical top-hinged suspended pendulum-type wave displacer at the CWPRS: (a) Wave board; (b) Diamond-beam; and (c) Actuator

In practice, the angular displacement of the bottom hinged wave board is acceptable up to ±12º about the vertical, whereas the angular displacement of a diamond beam in the top hinged flap-type wave board is up to ±30º. Larger movements of the board produce only a small increment in wave amplitude, with a deteriorating wave form having secondary crests. This deterioration in performance seems to be due to an increasing mismatch between the wave board movements and free surface wave fields. Top-hinged wave boards are suitable for medium strokes up to 300 mm

In the case of piston-type displacers moving on rollers, frequent wave-board alignment is needed, and lateral play occurs during their motion due to backlash in the roller guide-ways. We have observed peaks in the profile of the acquired wave spectrum by using hinged pendulum-type wave boards, as shown in Fig. 3. This is due to spurious wave content induced in wave flume by backlash in the articulated wave board mechanism, in addition to reflected waves from walls while operating at higher frequencies. However, wave reflection was minimized by providing a passive wave absorber at both ends of the wave flume.

Although the piston machine is not restricted to shallow water, it is eminently suited to model investigations of harbours, beaches, and near-shore developments. The major advantage of a wedge-type board is the absence of a back wave, but the power requirements are quite high. The only wave generator that meets the requirements for good waveforms, sufficient wave height concerning the depth of water, and frequency of operation for a wide range of applications is the piston type, which has precise linear motion.

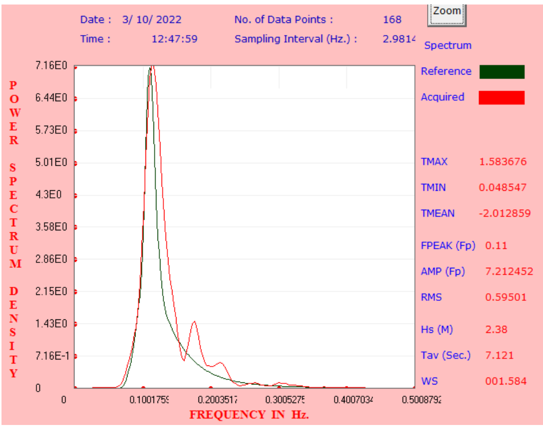

Fig. 3 Generation of the wave spectrum by using a top hinged flap type wavemaker with a passive wave absorber at the CWPRS

A perfect profile in the wave spectrum is expected by using the LM Guide, as it guides the wave board in an accurate straight-line path. The basic theory implies that the wave amplitude at a selected frequency increases with increasing stroke. A piston-type WM is found to be suitable for the generation of higher-amplitude waves, and provides precise guidance to improve accuracy of wave action. The conceptual design of a wave-board is shown in Figure 4. servo hydraulic-driven wave generators are still in use and have advantages over electric drives, particularly for very high-power applications. The decision to use electric drives or hydraulics must be made based on engineering considerations for individual cases.

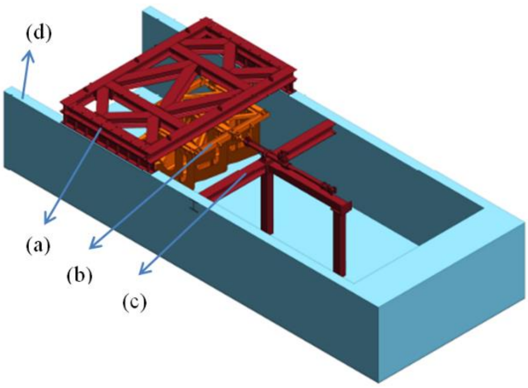

Fig. 4 Conceptual design of a piston-type displacer: (a) stationary frame assembly; (b) moving frame assembly; (c) actuator frame assembly; and (d) flume wall

As a very rough and general rule, wide single paddle wavemakers may be powered hydraulically, while narrow multiple paddle wavemakers are best powered electrically. In segmented or finite-width wave paddles, free higher harmonic waves may arise due to the effect of relative motion between wave paddles. It is envisaged that we select a single-wave paddle powered by a servo-hydraulic system to have the best match between paddle kinematics and free surface water wave kinematics.

III. Design And Construction Of Displacer Assembly

The wave board was designed considering factors such as inertia, maintenance, water on both sides of the wave paddle, the natural frequency of the wave board, and the maximum water depth in the flume. It is essential to assign a small amount of inertia sufficient to assume rigidity to the wave generator. It is obvious that if the inertia of the wave generator, regardless of its nature, is considerable, the stresses on the mechanism might become excessive. To enable the members to resist these stresses, it is necessary to increase the dimensions, hence the mass and, consequently, the inertia of these members. More power is required to overcome the passive resistances and inertia forces. The natural frequency of the board will decrease with an increase in the mass of its members. In the case of a piston board, these effects are reduced by adopting members with a high polar moment of inertia.

The maintenance of the apparatus similarly poses problems for designers. It is necessary to avoid water contamination as much as possible by keeping delicate members such as linear motion (LM) guideways, bearings, rollers, or gears away from water. In addition to the danger of corrosion, the sand contained in the water may increase the wear and tear of these parts. The waves reflected from a given structure tend to depart seaward, where they dissipate. In a wave basin or flume, however, they recoil toward the wave generator. Both theory and practice show that most wave generators are quite reflective. There are two possible remedies for this; the first is the use of a filter. The second is to design wave absorption-type boards. Leakage at the base and sides of the wave generator results in a decrease in the amplitude of the generated waves. On the other hand, certain arrangements for preventing leakage considerably increase friction, resulting in a loss of capacity. Therefore, it is necessary to find a compromise solution. The power requirements are high for a wave generator with a wet rear side. A wave generator with a wet rear side is preferred for relatively small installations where simplicity and low friction losses are of greater importance than the space and power needed. The selection of the water depth in flumes or basins for the replication of prototype sea wave conditions in physical models is dependent mainly on the selection of the model scale.

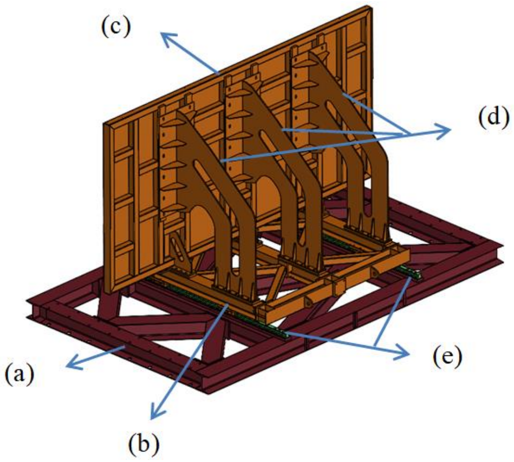

Fig. 5. Details of the wave board assembly in the upright position: (a) stationary frame assembly; (b) moving frame assembly; (c) wave paddle; (d) stiffener plates; and (e) LM Guide rails

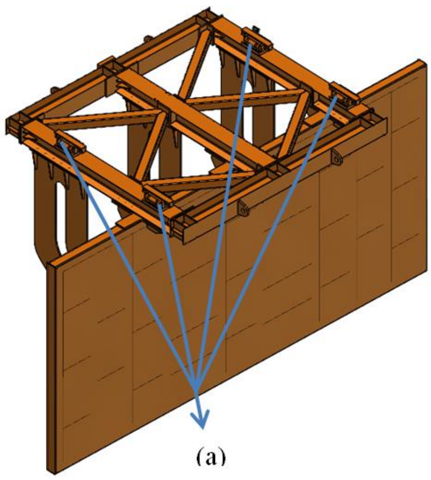

Fig 6. Details of moving frame assembly with the paddle, stiffener plates and LM Guide: (a) LM Guide

It is better to select the maximum possible depth of water and stroke of the wave paddle to cover a wide range of applications. This makes the design of suitable wave generator machinery much more complicated. The designers have met these problems in different ways. It is better to select the maximum possible depth of water and stroke of the wave paddle to cover a wide range of applications. This makes the design of suitable wave generator machinery much more complicated. Designers have met these problems in different ways.

It is seen from the theoretical curves for the variation in wave height with water depth that a maximum wave height of 0.5 m can be generated by a stroke of one meter in the flume with a water depth of 1.2 m. From this point of view, the piston-type wave generator was selected for the generation of irregular waves in the flume. Its width and height were chosen as 4 m and 2 m, respectively, based on the existing flume size. The paddle is designed to have a working stroke of one meter and a rated maximum velocity of one meter per second

Method of Displacer Suspension:

The wave board mainly consisted of i) a stationary frame assembly with guide rails ii) a wave paddle assembly with a moving frame, runner blocks, and stiffener plates, and iii) an actuator frame assembly. An upper stationary frame is used for suspending the moving frame assembly along with a wave board. The stationary frame is mounted on the flume walls through a channel that is an integral part of the flume wall. A moving frame is assembled to the upper stationary frame along with a runner block and guide rails. The wave paddle was bolted to the moving frame through a profiled stiffener plate. The concentrated driving force in the hydraulic ram (actuator) is transmitted to the wave paddle through a moving frame assembly with profiled plates at three locations to match the distributed load along the wave board without unwanted vibrations or distortions. Runner blocks and guide rails hold the moving frame with the wave paddle vertically beneath the stationary frame. While the stationary frame is mounted on the flume walls as depicted in Fig. 5-7, the guide rails are stud-jointed to the stationary frame in an upright manner.

Selection of Structural Members:

For the design of the wave board, the maximum values of the stroke, force, velocity, and acceleration were calculated from wave theory (Gilbert et al. 1971). The calculations are based on the wave dynamics on the front side of the wave board because of the availability of suitable back wave absorbers at the rear side of the wave paddle (Hughes 1993). An ideal wave board should have high stiffness and low mass to have a high natural frequency. This is possible by constructing the board using a hollow section with a large polar moment of inertia. The wave paddle is made up of a mild steel sheet backed up by a "skeleton" structure, and additional stiffness is provided with profiled stiffener plates to offer very low weight together with high stiffness and bending strength (see Figure 5). By achieving a very high strength-to-weight ratio using the hollow I-section, the "Skelton" structured design improves the performance of the wavemaker while requiring less power to overcome paddle inertia and friction. The weight of the moving components is kept below 1500 kg. The guide rails are chrome-plated to avoid corrosion by water contamination, and runner blocks are provided with a wiper to avoid entering foreign particles, although no wetting occurs during normal operation. Details of the LM guideways are shown in Fig. 8.

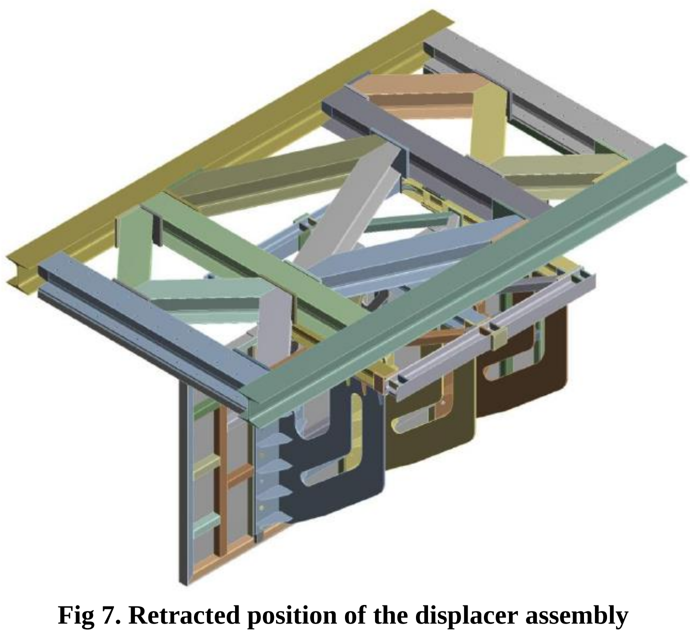

Fig 7. Retracted position of the displacer assembly

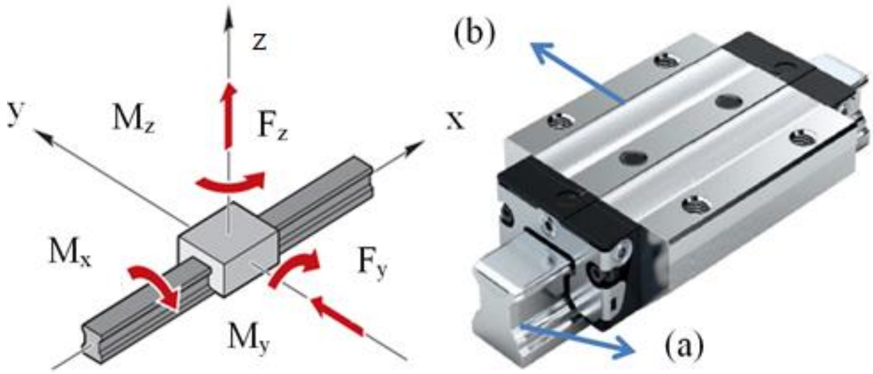

Fig 8. Details of linear motion guideways: (a) Guide rail (b) Runner block, Travel speed: Vmax=5 m/s, Fy=190 KN, Fz=111 KN

Stationary, moving, and actuator frame assemblies, were designed using structural theory. The frame structure was made quite sturdy so that no vibrations in the system were generated during operation. In the design, importance was given to the selection of sections of structural members connecting the wave board and the actuator rod. A finite element study was conducted on the wave board to ascertain its satisfactory performance under cyclic loading. Static structural analysis was carried out along with a fatigue study to calculate the maximum number of cycles the product might undergo before failure. To ensure the better stability of the wave board assembly during its operation at higher frequencies, high-rigidity support frames and wave paddles were designed to have precise wave-paddle motion. The motion of the servo actuator is converted to a very precise linear motion by a backlash-free LM guide-way mechanism. LM rails were mounted at two locations, each one meter away from the center line of the board. Four runner blocks, each with capacity, as shown in Fig. 8, are used. The wave board was constructed at M/s Moog Motion Control Pvt. Ltd., Bangalore, based on conceptual design.

Fig. 9 Installation of the displacer assembly

IV. Experimental Setup And Test Results

The wavemaker is powered by a position-controlled closed-loop servo-hydraulic system using an MC-600 controller from Moog. The wave generation program consisted of modules for simultaneous wave generation and data acquisition. Software modules for the calibration of wave height sensors, spectral analysis, data plotting, etc. were developed in the 'C#' language. Using a graphical wave interface, the experimental wave spectrum and theoretical reference wave spectrum are synthesized to create spectra in a superimposed manner, and the wave height time series derived from the wave spectra are converted to paddle positions. Online graphic representations of generated wave patterns are provided instantaneously and simultaneously by the data acquisition program. Wave gauge measurements are recorded by a capacitance wave height recorder (CWHR) unit via an analog-to-digital converter (ADC) connected to the USB port of the computer. A digital-to-analog converter (DAC) converts a control signal in digital form to an analog voltage form. The wave paddle drive signal is loaded into the servo controller via an active low-pass filter. The position signal generated by the transducer, which runs parallel to the actuator rod, is compared with the control signals in the controller to correct the target position of the paddle that is attached to the actuator. A parallel wire capacitance-type wave gauge is used to measure the surface elevation of the generated waves in the flume. The capacitance of the wave gauge changes with the change in water level, and the voltage output of the gauge is linearly proportional to the variation in water level. These gauges generate a ±5 volt signal as the output. The wave-board is installed at a distance of 6.3 m from one end of the experimental flume, and passive energy absorbers are installed at both ends. An absorber /plane beach with a slope 1:4 is constructed with stones (Finnegan and Goggins 2012). Incident waves break on and percolate through the cavities of an absorber, resulting in reduced wave reflections. Experiments are conducted to investigate the response characteristics of wave production by a piston-type displacer assembly under the following conditions:

- With no model in the flume,
- A limited number of waves are generated to avoid interference of reflected waves with incident waves generated by the paddle.
- The wave paddle positions and surface elevations were recorded for 200 s, and sufficient time was allowed for the wave field to establish. Then the paddle was stopped, and the waiting time continued until the flume was settled

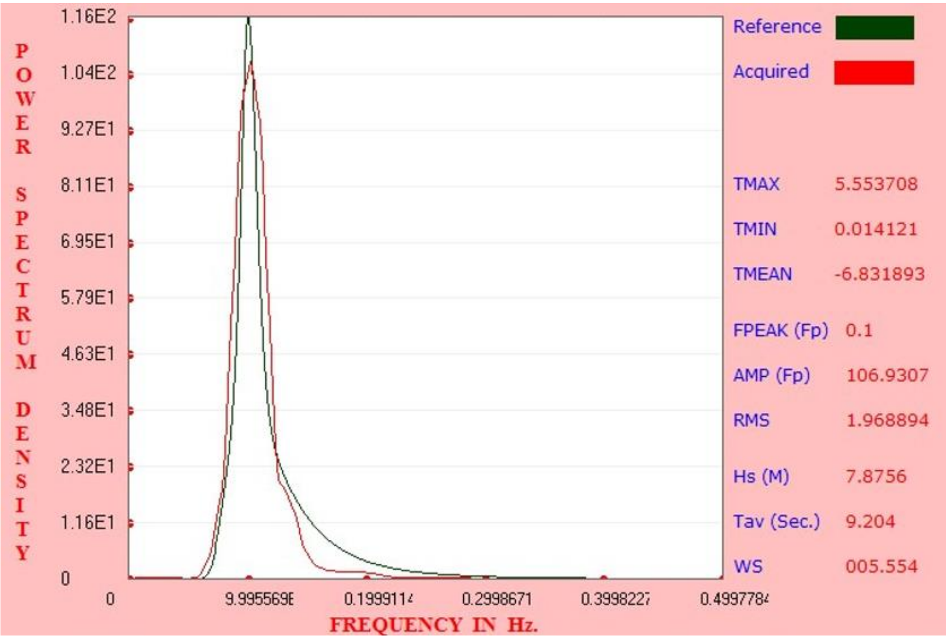

Fig. 9 Matching of the frequency spectra of the waves generated by a piston-type wavemaker with a wave flume of length 120 m and a water level of 0.8 m with the target JOHNSWAP spectra; the model scale is 1:56, reference Hs=7.75 m, acquired Hs = 7.8756 m (the percentage of spectrum match with respect to Hs = 98.4% with a percentage error of 1.6%)

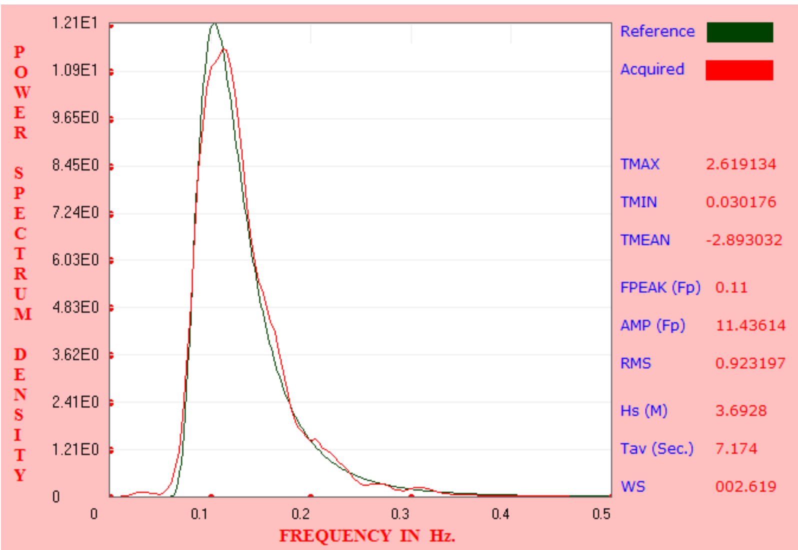

Fig. 10 Matching of the frequency spectra of the waves generated by a piston-type wavemaker with a wave flume of length 120 m and a water level of 1 m with the target Pierson-Moskowitz (PM) spectra; the model scale is 1:25, reference Hs =3.75 m, acquired Hs = 3.6928 m (the percentage of spectrum match with respect to Hs = 98.4% with a percentage error of 1.6%)

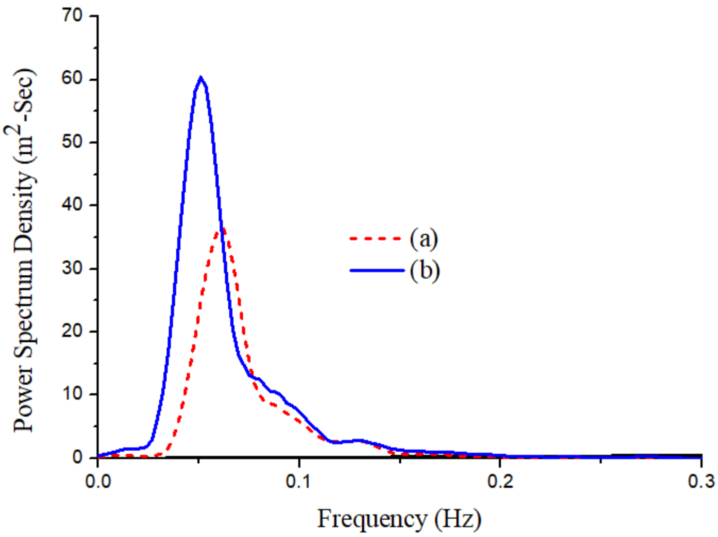

Fig. 12 Experimental results of the target Pierson-Moskowitz (PM) spectra with different significant wave heights (Hs), and a water depth of 1.1 m in the flume; at a model scale of 1:25: (a) Hs= 0.15 m in the model generated using Pierson-Moskowitz (PM) spectra. (b) Hs= 0.27 m in the model generated using Pierson-Moskowitz (PM) spectra.

Irregular waves were generated for target spectra such as JOHNSWAP and Pierson-Moskowitz (PM). The scale ratios, depth of water, wave gauge location, and spectrum type were selected from the experiments that had been conducted in the past using the existing wave flume. A glass window structure with a length of 5 m exists in the walls at a distance of 109 m from the wave board in the existing flume, where the models are constructed for conducting studies. The control signal file was generated considering a model scale ratio of 1:56, a water depth of 0.8 m, and a wave gauge located 107 m from the wave-board. The experiments were conducted in a wave flume without a model. A significant wave height of 0.14 m in the model was recorded during the experiment, as shown in Fig.9. Similar tests were conducted for the generation of Pierson-Moskowitz (PM) with a water depth of 1m and 1.1 m in the flume. A significant wave height of 0.27 m in the model was recorded during the experiment, as shown in Fig. 12. A variety of experiments were conducted in a physical model by varying the model scale and depth of water using target spectra such as JOHNSWAP and Pierson-Moskowitz (PM). From figures 9 and 10, the spectrum profile is improved as compared with the result shown in Fig. 3, which was collected from the studies conducted in the past using a top-hinged flap-type wave maker.

A slight twisting of the actuator frame assembly (I-beam) was observed when jerks in the paddle motion resulted from undesired signals during dry testing (without water) of the system for evaluating the initial performance. The problem was mitigated by providing a square hollow section between the flume wall and frame and adding additional support pillars of two numbers below the frame. However, during the operation of the system, the wave-board works under slightly unstable conditions at a frequency of 3 Hz, which has a negligible effect on random wave generation. Stability could be provided to the board by installing a fiberglass water tank with a pump on the top members of the frame structure or by providing dead weight on the top of the frame. The performance of the wavemaker should also be further investigated by improving the wavemaker's software to provide an active wave energy dissipation system through wave reflection compensation, control signals to be modified using the measured wave spectrum to better align with the intended reference spectrum, and effective calibration of the wavemaker to improve the quality of wave generation.

V. Conclusion

- The predetermined wave spectra were successfully created for the frequency range of 0 to 3.0 Hz using a piston-type wavemaker in a wave flume at the CWPRS.
- The wave flume, measuring 120 m in length, 4 m in width, and 2 m deep, is one of the longest wave flumes in the world.
- The 120 m flume is useful for carrying experiments with scale ratios up to 1:20 for analysis, permitting a decrease in the scale effects that accompany with every scaled experiment. The data obtained from this flume can be used for the validation of numerical models.
- A maximum significant wave height of 0.27 m in the model with a scale ratio of 1:25 was observed for irregular wave generation with the target Pierson-Moskowitz (PM) spectra.

- Compared to the top-hinged flap-type wavemaker, the spurious wave content introduced in the wave flume is significantly reduced in a number of tests.
- A wave spectrum match of 98.4% is achieved using a newly installed WM with the target JOHNSWAP spectra.
- A piston-type wave board width of 4 m which has precisely controlled linear motion by an LM guide and is powered by a servo-hydraulic system is a unique feature of the wavemaker.
- Waviness in the profile of the acquired spectrum is reduced compared with that of a top-hinged flap-type wavemaker.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author's Contribution

V. Prabhakarachary: Conceptualization, Data curation, investigation, methodology, preparation of manuscript, R.S. Erande, and N. Sunil Naik: experimental work, supervision, M. Phani Kumar: formal analysis and validation, R. S. Kankara: project administration, resources, funding acquisition. All authors have read and accepted the present state of the manuscript.

NOMENCLATURE

CWPRS Central Water and Power research Station

PID	Proportional integral derivative		
H	Wave height	ADC	Analogue to Digital Converter
d	Depth of water	DAC	Digital to Analogue Converter
k	Wavenumber	WM	Wavemaker
S	Stroke of wave board	LM	Liner motion guide ways
L	Wavelength	2D	Two- dimensional

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