CONSTRUCTION OF A PLUNGER TYPE EXPERIMENTAL WAVE TANK FOR VALIDATION STUDIES

by

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Declaration of Candidate

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any Degree or Diploma.

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Abstract

The design and construction of a small wave tank (flume) and associated equipment has been described. The wave tank is equipped with a plunger-type wave generator, capable of producing both regular and irregular waves. A variation of the rack and pinion gear mechanism often known as the reciprocating rack mechanism is utilized to transmit power from the motor to the plunger. A triangular wedge is used as plunger in the setup. Instrumentation includes a vernier depth gauge. The wave-maker is controlled by an induction motor via a Variable Frequency Drive (VFD) or inverter drive. From the survey reports by Khalilabadi et al. of wave absorbers used in different laboratories, a beach was designed for absorbing the waves coming from wave maker. The quality of waves is improved by keeping as little room as possible behind the plunger. The main advantage of this system over previous ones is the novelty of the plunger type wavemaker and low level cost utility.

Chapter 1

Introduction

1.1 Background and Motivation

The use of physical models in marine engineering would be limited if we were unable to create waves in small scale models that exhibited many characteristics of waves in nature. A common approach is mechanical wave generation where a movable partition is placed in the wave facility and waves are generated by oscillation of the partition.

So far most laboratory testing of floating or bottom-mounted structures and studies of wave profiles and other related phenomena have utilized wave flumes, which are usually characterized as long, narrow enclosures with a wave-maker of some kind at one end.

For all of these tests, the type of wave-maker is very important.

In laboratory studies, there are two main classes of mechanical type wavemakers often utilized to generate waves. The first is the movable wall type machines including those known as piston- and paddle-type wavemakers, which are generally actuated by a simple oscillatory motion in the direction of wave propagation. The second is the plunger type wavemaker, which generates waves by oscillating vertically in the water surface.

In this paper the design and construction of a small wave flume using the plunger type wavemaker, which was built and instrumented with a limited budget is described. This flume is constructed out of the need of an experimental setup for modeling waves at the Fluid Mechanics Lab at the Islamic University of Technology. In order to design the wave flume the several reports (e.g. Khalilabadi et al 2012) were carefully reviewed. The main advantage of our system over many others is the novelty of the plunger type wavemaker and the small effort in system setup. Due to time constraints, no experiments have been conducted and as such no measurements have been included in this paper.

Chapter 2

Overview of the Setup

2.1 Channel Design

The wave flume was built for conducting laboratory tests of floating structures and validation studies in the Fluid Mechanics Laboratory at IUT. This wave flume design includes a 1750-mm long, 300-mm deep and 250-m wide channel. The dimensions are shown in Fig: 2.1. The bottom of the flume is constructed of a plastic sheet of 7-mm thickness. The sides of the flume are made of the same 7-mm-thick sheeting, which are held in place by Thai aluminum angle rod structural frames. The tank rests on a Thai aluminium angle bar frame base mounted on 10-mm-height screws which act as legs. The frame of the final wave flume design is sketched in Fig. 1. No pump or piping is provided for discharge of fluid from the flume.

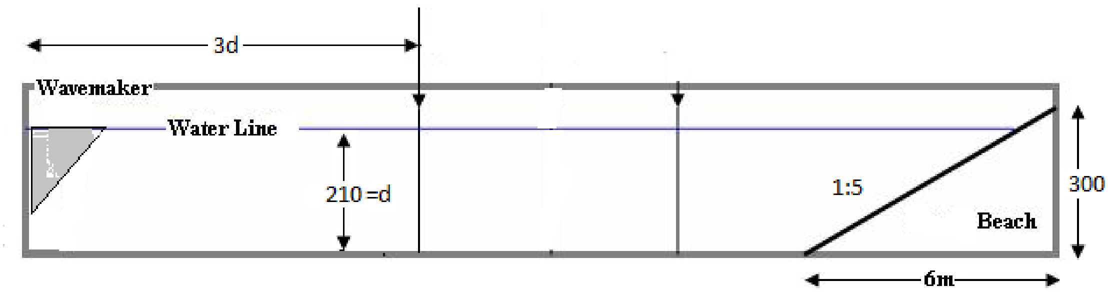

Figure 2.1: Wave flume schematic

The wave maker system in the tank is a piston paddle oscillated up and down using an electric motor. A variation of the rack and pinion gear mechanism often known as the reciprocating rack mechanism is utilized to transmit power from motor to the piston paddle. The gear assembly and piston paddle are made of nylon while steel is used for the base plate to provide rigid support to the wave maker system.

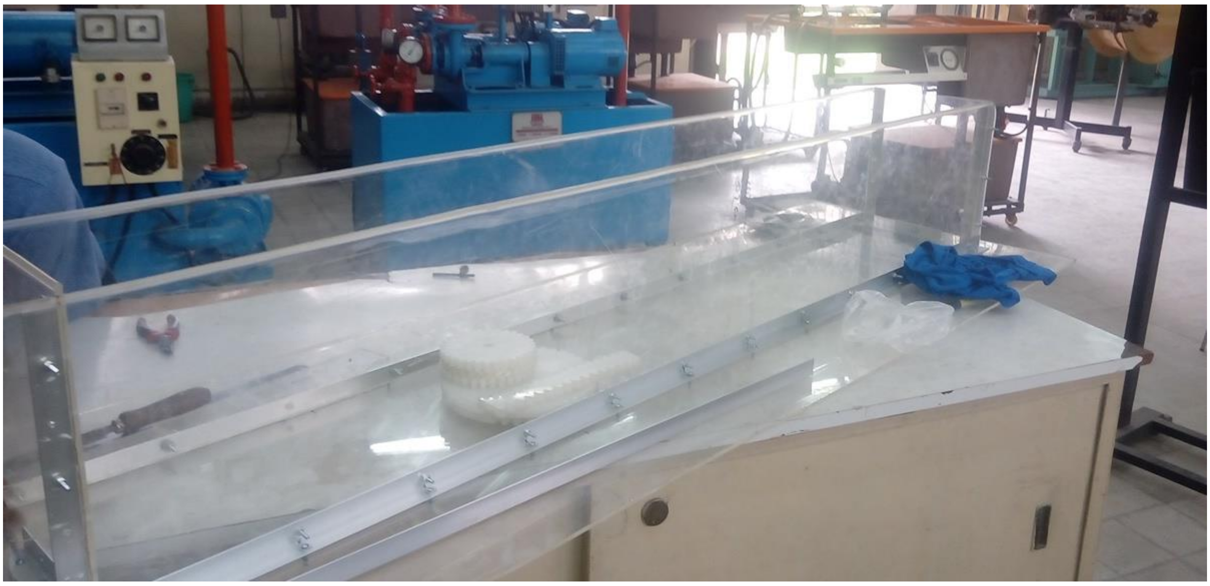

Figure 2.2: Standalone tank

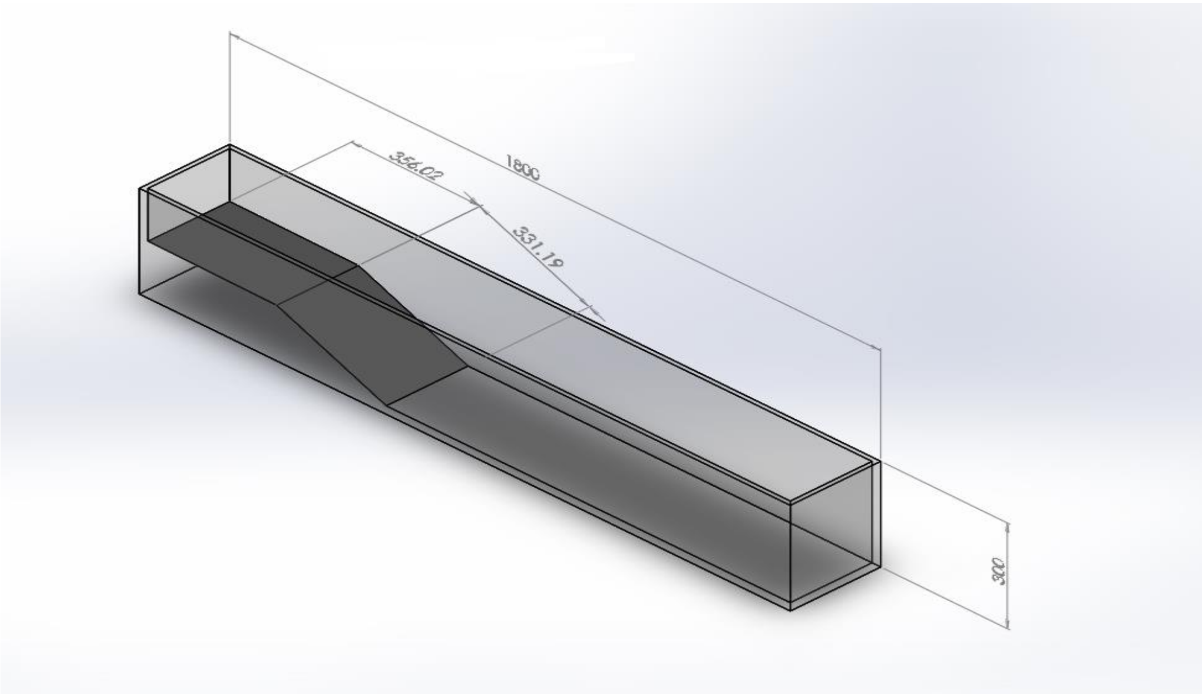

Figure 2.3: Wave Tank Dimensions

2.2 Wave -Maker Design

A plunger-type wave-maker at one end of the tank can generate both regular and irregular waves. The plunger-paddle is a triangular nylon wedge which is installed right along the end wall of the tank to minimize leaking. The dimensions of the paddle are discussed in the next section. The plunger is driven by an induction electric motor. To control the wave-maker, a Variable Frequency Drive (VFD) is utilized which controls the motor speed by varying the motor input frequency. The installed wave-maker is capable of generating regular waves and irregular waves for a range of time periods. The wave-maker generates irregular waves by superposition of multiple sinusoidal waves with different wavelengths.

2.2.1 *WEDGE DIMENSIONS*

The optimum wedge dimensions were determined from the experimental work done by Rytkonen et al. on plunger type wave makers. The dimensions were based on Wedge type B whose d/b ratio corresponds to 1.5.

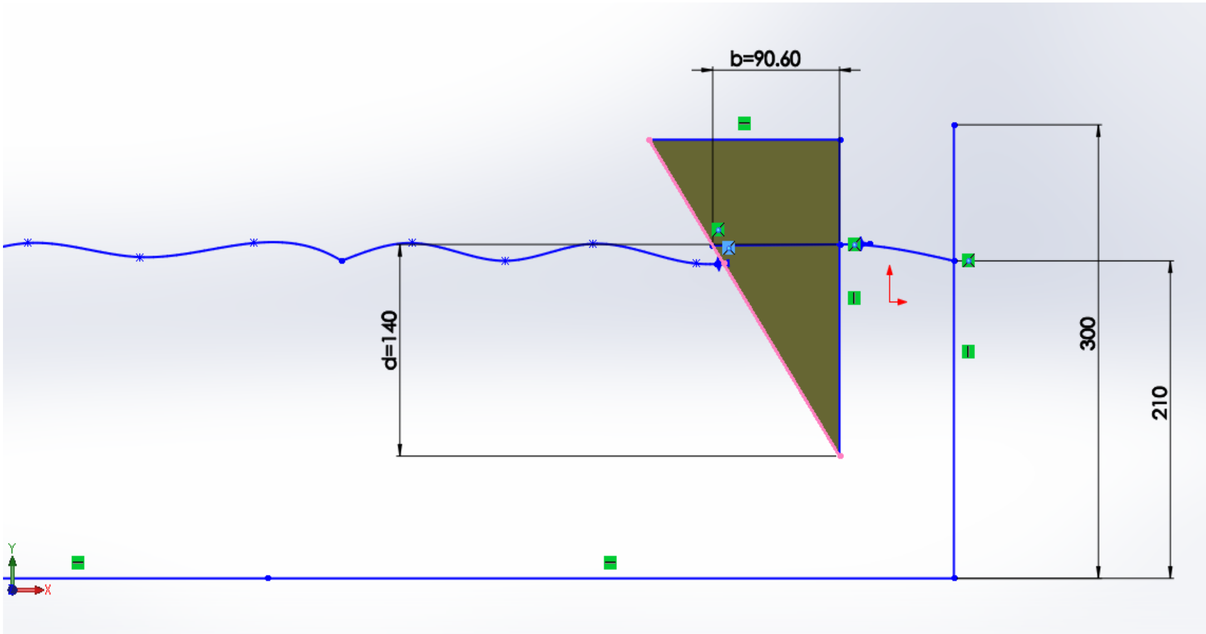

Figure 2.4: Wedge Schematic

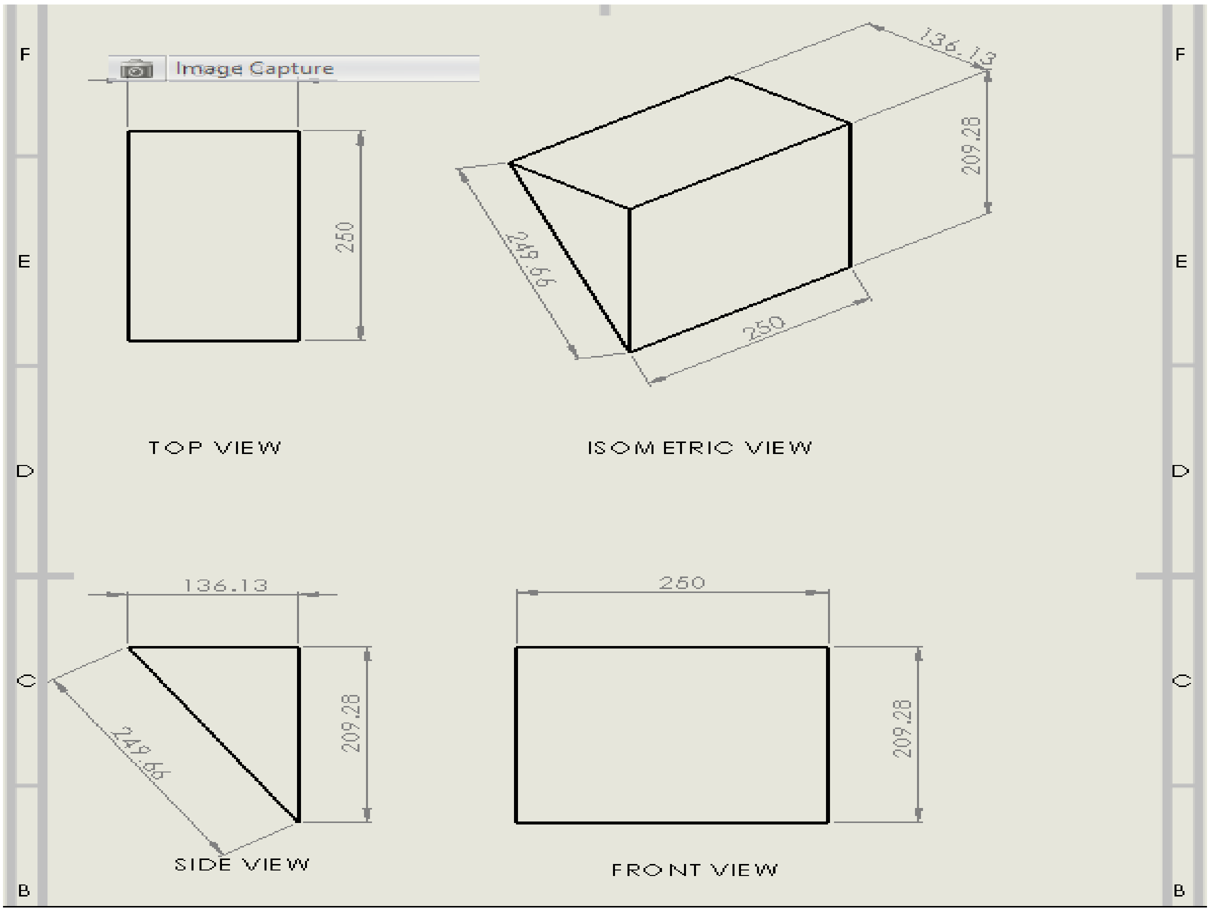

Figure 2.5: Drawing file for wedge produced in Solidworks

2.3 Mechanism

A continuous rotary motion of the center gear gives a reciprocating rectilinear motion to the double rack. The teeth on the center gear act upon those of the spur gears and the two semi-circular toothed sectors attached to the spur gears operate upon the teeth on the double rack. The two stops on the rack shown by dotted lines are caught by the curved piece on the center gear, and lead the toothed sectors alternately into gear with the double rack.

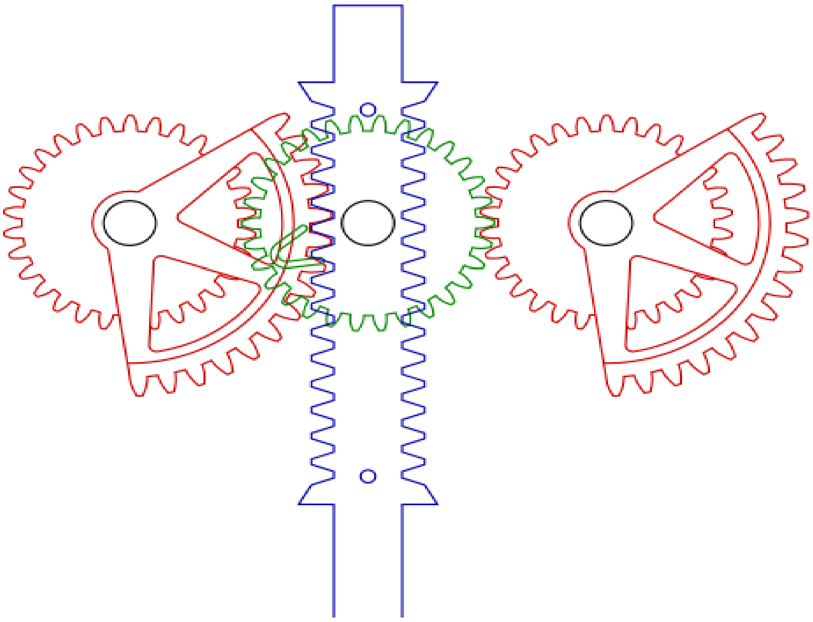

Figure 2.6: Wavemaker Mechanism

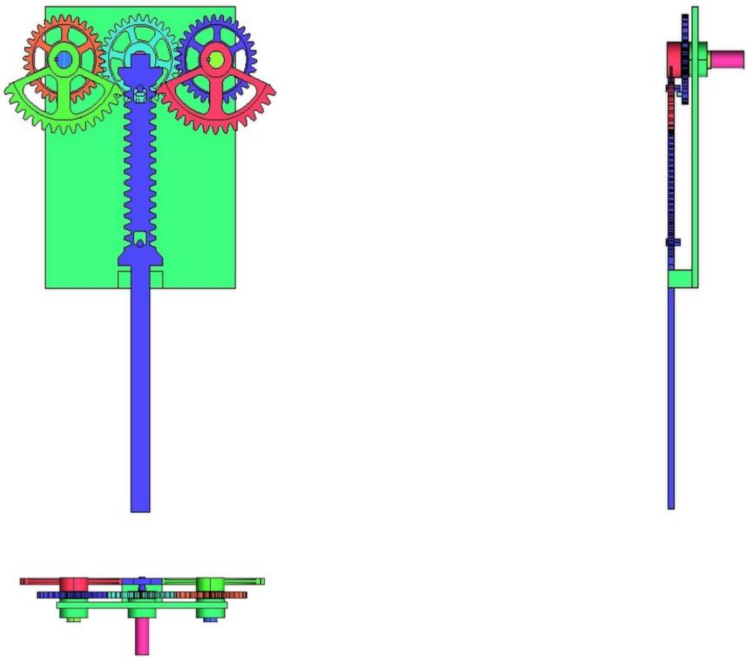

Figure 2.7: Third Angle Orthogonal Projection of the Mechanism

2.4 Wave-Absorber Design

After the wave generator, wave absorber is the most important part in a wave flume or basin. A great variety of designs and materials have been used throughout the world for the construction of wave absorbers. Wave absorbers could be classified into two main categories: active and passive absorbers. However the use of active absorbers owning to its high cost is still very limited, except in a few cases where the wave board itself is programmed to absorb the reflected wave. Hence passive absorbers seem to be the most popular arrangement. The slope of these absorbers has to be mild so as to obtain a good dissipation of wave energy. This usually means a long wave absorber, thus using up valuable tank space (Dalrymple et al. 2002).

In the paper by Khalilabadi et al 2012 a survey of laboratory facilities around the world was conducted in order to find an optimum wave absorber satisfying the constraints mentioned above. From 43 laboratories which investigated in this study only four laboratories use active absorbers. Most other laboratories use passive absorbers. Passive absorbers are mainly made up of beaches of constant or varying slopes. One of the important criteria to be satisfied is that the variation of the water depth over a wavelength is small, because abrupt changes of the bottom profile lead to reflection. From 43 laboratories which use passive absorbers, 27 of them use a beach of constant slope reaching the bottom as wave absorber, 7 of them use a variation of this type of wave absorber as a mean of absorbing wave energy, 4 of them use a parabola beach reaching the tank bottom, and 3 of them use a parabola not reaching the bottom. The last two laboratories use a combination of different mechanisms to absorber wave energy. It is clear that most wave flumes tend to use simpler types of absorber shapes.

One of the main parameters to be considered is the ratio of the absorbers length to the water depth. Most absorbers have slopes lower than 1:5. In the present work, the slope of absorber was selected 1:4 because of dimensions of the wave flume. Passive wave absorbers are placed on the basin termination opposite to the wave maker. In this case a nylon beach with a 1:4 slope is located at the end of the tank opposite to the wave-maker. This beach absorbs wave energy both by causing the incident waves to break. The beach is 1120-mm long and 250-mm wide.

2.4.1 Parts

Following are the main parts of the wave tank:

1. Center Gear
2. Spur Gears
3. Sector Gears
4. Double Rack
5. Piston Paddle
6. Base Plate
7. Inverter and Motor
8. Mild Steel Shaft
9. Collar and Bearing

2.4.2 Cost Estimation

The cost estimation for each part is summarized in Table 2.1.

Table 2.1 Cost Estimation

No.	Part	Quantity	Material	Material Quantity(mm)	Cost(BDT)
1	Center Gear	1	Nylon	450x150	500
2	Spur Gears	2	Nylon		
3	Sector Gears	2	Nylon	500x250	500
4	Double Rack	1	Nylon	700×90	500
5	Piston Paddle	1	Nylon	N/A	2000
6	Base Plate	1	Steel	N/A	2000
7	Inverter and Motor	1	N/A	N/A	12000
8	Shaft	3	Aluminium	N/A	1500
9	Collar and Bearing	1		N/A	1000
	Total	13	N/A	N/A	20000

2.4.3 Parts Machining

The following steps outline the machining process of the wave flume parts:

1. Each of the three spur gears was cut from nylon sheets. Each gear has 30 teeth which were cut in a Universal Milling Machine. All the spur gears have an outer diameter, inner diameter and pitch diameter of 123mm, 110mmand 116.5mm respectively and a thickness of 12mm. The side gears have a 23mm diameter hole and the center gear has a 13mm diameter hole.
2. The two sector gears were also cut from 12mm thick nylon sheets. Two normal gears were first cut using the Universal Milling Machine and then their teeth number was reduced to 6 using the same machine. Each sector gear has an outer diameter, inner diameter and pitch diameter of 210mm, 190mm and 200mm respectively. Each has a 23mm diameter hole in the center.
3. The double rack is 250mm long, 43mm wide and 12mm thick. Each side of the double rack has 15 teeth cut into it. A 225mm long slot runs along the middle of the rack as part of the mechanism's locking system.
4. The base plate was cut from a 12mm thick cast iron block. The base plate dimensions are 318mmX400mmX12mm. Three holes are drilled in the base plate to accommodate three shafts that will support the gears. A constricting pathway is placed at the bottom of the plate to constrict the movement of the double rack in only one direction.
5. The plunger is a triangular wedge made out of nylon. Its dimensions have been discussed in the earlier sections.
6. Three mild steel shafts were machined in the lathe machine. They each have varying diameters along their lengths for accommodation of the plate and gears on them.

2.5 Date Acquisition

The most common wave gauges are the twin-wire resistance wave gauge and the single-wire capacitance wave gauge (Markle and Greer 1992). However, due to the unavailability of such equipment, a single vernier depth gauge is used to measure water surface elevation in the present wave flume.

Chapter 3

Conclusion

A wave flume is designed for general validation studies and built with a limited budget. The wave flume has a plunger type wavemaker which is rare in such experimental setups. Although this wave flume is small compared to most wave flumes, it is well-suited to educational and basic research studies. Larger flumes require a staff and funding to operate and maintain them, and these overhead costs often prohibit their use in small-scale experiments. Instead of reserving a period of time well in advance to conduct experiments, the researchers using this small flume only need to change it easily to investigate a physical behavior or try out an idea. These initial studies can then be refined and eventually expanded to more complex experiments in large wave tanks or flumes. In order to absorb waves coming from wave maker in a typical wave flume of restricted dimensions, the choice of a passive absorber is selected. In this wave flume, a beach with a 1:4 slope is located at the end of the tank opposite the wave-maker. This beach absorbs wave energy by causing the incident waves to break to minimize reflection.

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