

# Modernization of Port



R. Sundaravadivelu

**Abstract** India has a coastline spanning of 7516.6 km, forming one of the biggest peninsulas in the world. Central and relevant ministries administer the 12 major ports and 200 minor and intermediate ports. The modernization of ports needs deepening of harbour basin, upgradation of mechanical handling system, use of new type of fenders, etc. The various case studies are explained in this keynote. Behaviour of berthing structure with pile sheet pile wall is analysed through numerical and experimental investigation. The suitable rehabilitation methods adopted for the structures which are damaged due to natural causes. Artificial submerged reef is to stabilize the shore from erosion and stability of these structures proven by physical model study.

**Keywords** Modernization of port · Deepening · Touch pile wall · Rehabilitation Artificial reef

## 1 Modernization of Ports

### 1.1 Introduction

India has a coastline spanning of 7516.6 km, forming one of the biggest peninsulas in the world. According to the Ministry of Shipping, around 95% of India's trading by volume and 70% by value are done through maritime transport. It is serviced by 12 major ports, 200 notified minor and intermediate ports. Central government's shipping ministry administers the major, the minor and intermediate ports which are administered by the relevant departments or ministries in the nine coastal states: Andhra Pradesh, Odisha, West Bengal, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra and Gujarat. All the major and minor ports visualized on India's map are

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shown in Fig. 1a, and the percentage of total commodity is compared in given pie chart Fig. 1b.

## ***1.2 Modernization***

Government of India plans to modernize these ports and has approved a project called Sagarmala. The ports and shipping industry in India play a vital role in sustaining growth in the country's trade and commerce. The Indian Government has allowed foreign direct investment (FDI) of up to 100% under the automatic route for port and harbour construction and maintenance projects. The government has also initiated National Maritime Development Programme (NMDP), an initiative to develop the maritime sector with a planned outlay of US\$11.8 billion.

## ***1.3 Needs for Modernization of Brown Field Port***

The following factors are considered as the need for modernization of brownfield port

- Existence for more than service life of 50 years
- The damages to port structures need to be retrofitted due to Bhuj earthquake on 26 January 2001, Indian Ocean, Tsunami on 26 December 2004 and storm surge and cyclone
  - Existing berths to be deepened while berthing operation.

# **2 Deepening of Port**

## ***2.1 General***

Dredging is the method for deepening of harbour basin. Dredging is the process by which underwater sediments and soils are removed using specialized equipment for the construction and maintenance of waterways, transportation infrastructures. Generally, dredging work in marine areas is carried out where the required draft for safe navigation of vessels is not available naturally and needs to be created artificial depth and/or to maintain already dredged depth to ensure safe movement of the vessels. Dredging during initial stage can be classified as capital dredging.

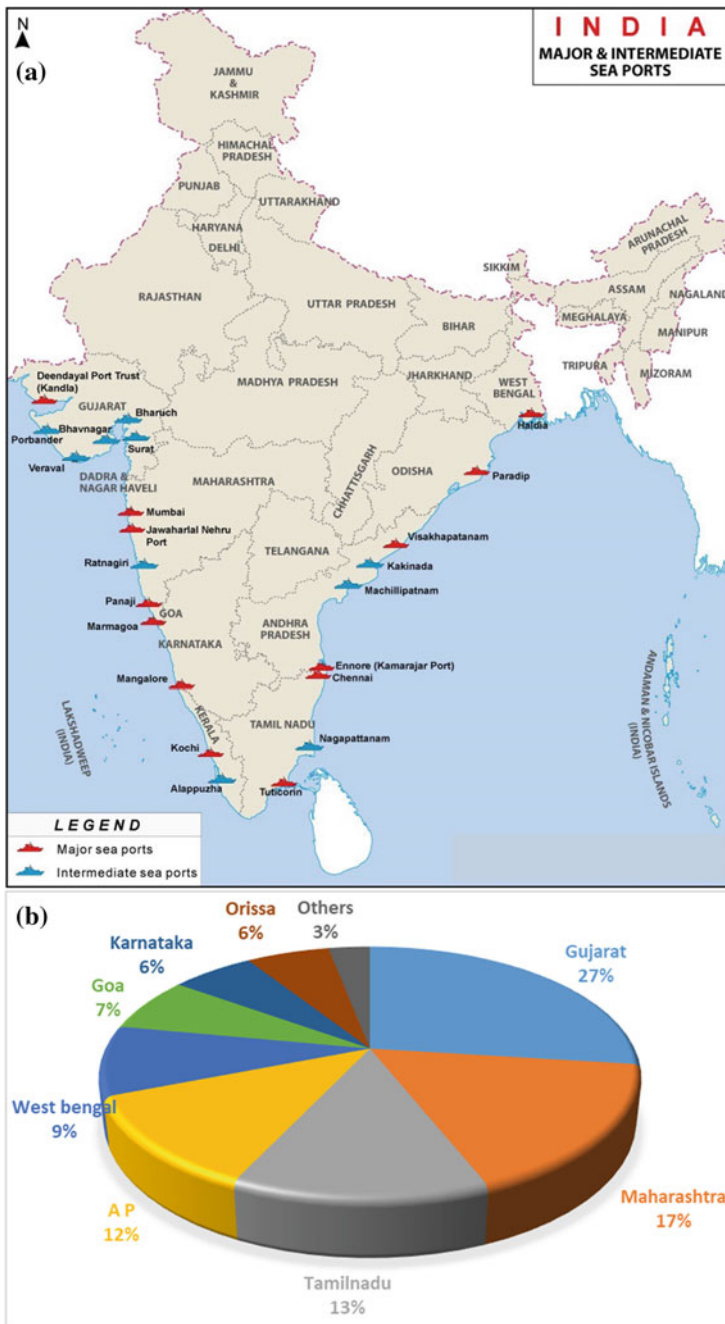


Fig. 1 Ports of India (a) and commodity handled in the various states (b)

## 2.2 Dredging Process

The dredging of harbour basin in Visakhapatnam Port (Fig. 2) and VOC Port (Fig. 3) is planned in such a way that the berths are in operation. The type of structural arrangement used is pile touch pile wall, rear berthing platform or pile sheet pile wall.

## 3 Berthing Structure with Touch Pile Wall

In order to understand the behaviour of this type of berthing structure, the model structure is created with scale ratio of 1 in 50. Aluminium pipes of 25 mm diameter with 1 mm thickness and 600 mm length are used as piles, and the aluminium pipes are welded together to act as touch pile wall. Piles are placed in two rows and three columns with a spacing of 0.12 m. Model of berthing structure is shown in Fig. 4.

The typical berthing structure with touch pile wall (Fig. 5a) is analysed by STAAD.Pro software, and the design is carried out as per IS4651. The cofferdam structure shown in Fig. 5b is analysed using STAAD.Pro and Plaxis. The influence of soil pressure among various loads can be applied on the pile via spring analysis in the STAAD.Pro, whereas interaction of soil with pile structure is directly applied by assigning the properties of soil in Plaxis analysis. The results of STAAD.Pro and Plaxis analysis are compared. The bending moment of pile in seaside and dockside is compared separately which is given in Fig. 6.



Fig. 2 Dredging work in Vizag Port

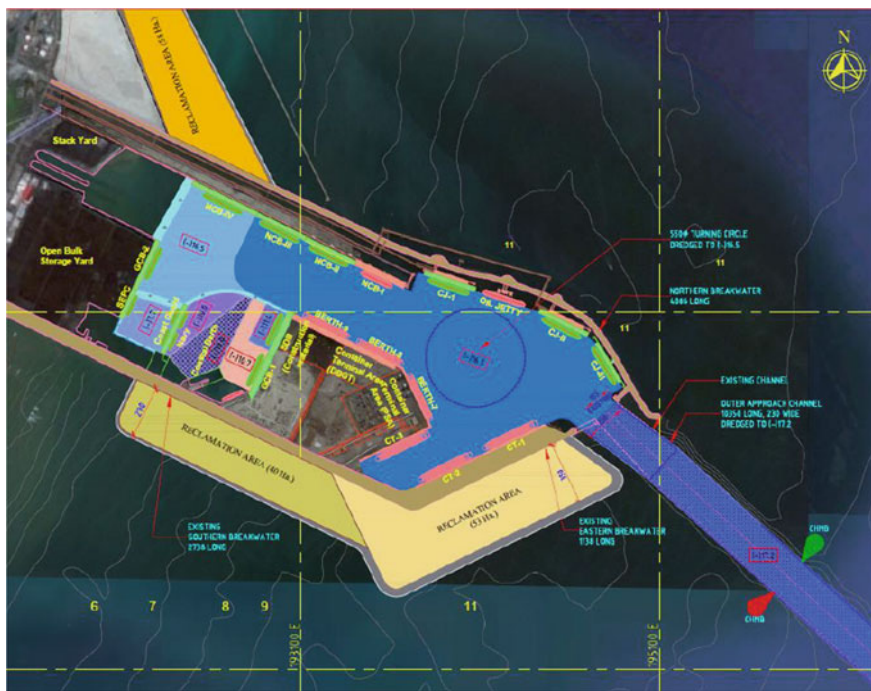
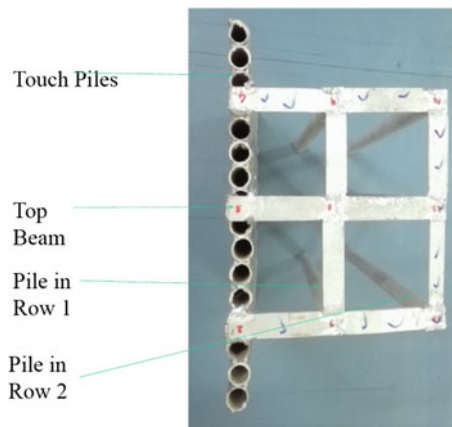


Fig. 3 Proposed dredging layout of VOC Port

Fig. 4 Top view of berthing structure model



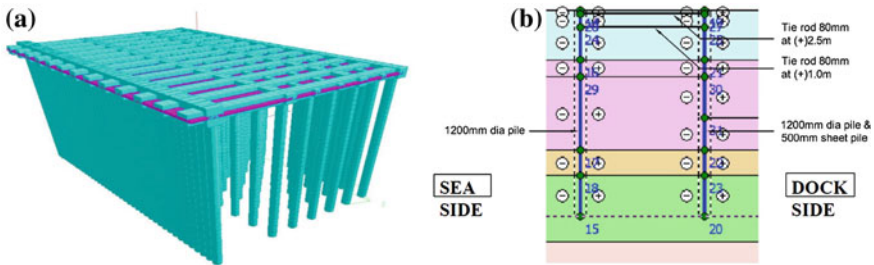


Fig. 5 Modelling of berthing structure in STAAD.Pro (a) and in Plaxis (b)

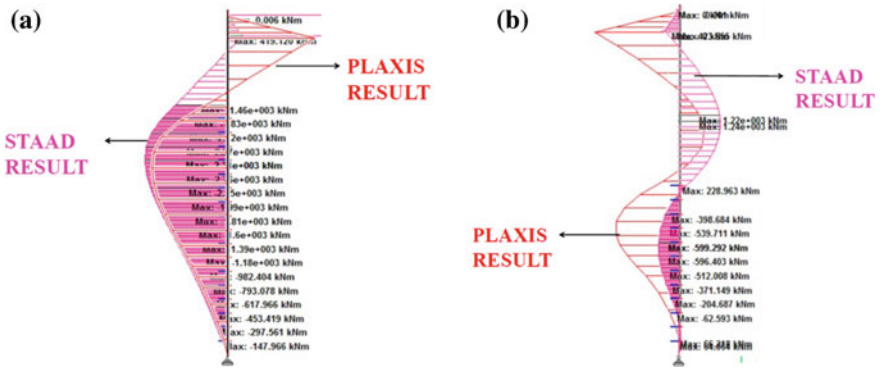


Fig. 6 Comparison of bending moment for seaside pile (a) and dockside sheet pile (b)

## 4 Damage Assessment and Rehabilitation of North Breakwater at Kamarajar Port

### 4.1 Introduction

Kamarajar Port Limited (KPL), the twelfth Major Port of India commissioned in 2001, is located about 11 nautical miles north of Chennai Port along with the Coromandel Coast in the State of Tamil Nadu at 13° 15.50' N and 80° 20.25' E. The northern breakwater is of length 3080 m, and the water depth at the head section is 11 m CD. The south breakwater is of length 1070 m. The primary armour at the head section is 6 m<sup>3</sup> Accropode for the northern breakwater. The initial design of breakwater is given in Table 1.

The breakwaters have been exposed to severe sea states like Fanoos, Nisha, Thane and Nilam cyclones. After the Thane and Nilam cyclones, the port authorities observed damages to the Accropode units as well as the armour layer has got dislodged at many sections. They felt the need to assess the health of the northern breakwater.

**Table 1** Design details as built-in section

| Description                 | Trunk section as built at (-)<br>10.0 m CD | Head section as built at (-)<br>11.5 m CD |
|-----------------------------|--|---|
| Water level (m CD)          | (+) 1.68                                   | (+) 1.68                                  |
| Design wave height (Hs) (m) | 6.1  | 6.6                                       |
| Accropode size (T)          | 12   | 15  |
| Crest level ( m CD)         | (+) 5.55                                   | (+) 5.75                                  |

## 4.2 Site Investigation

Based on the physical observation from the crest of the northern breakwater, it was found that the Accropode units have been dislodged and even some Accropods units had a severe structural damage. Significant movement of the armour units compared with the completion drawings of the breakwater was observed. There is a considerable gap between wave wall and armour units for a stretch of 15 m from the northern breakwater head section, and the under layer units were exposed. It may be noted that interlocking and gravity are governing the stability. The observed displacement and structural damage of the Accropods units were beyond the acceptable range.

The underwater survey using echo sounder was conducted to explore the damaged portion underwater. Based on the analyses of both profiles, it was inferred that the breakwater had undergone severe damages due to cyclones. The results also indicate that the crest level changes are in the range from 10 to 20 cm.

## 4.3 Mitigation Measures

The failure of the northern breakwater at Kamarajar Port Limited was mainly due to the inadequate crest elevation and hydraulic instability of Accropods during severe cyclones, namely Thane and Nilam. It is proposed to replace the existing dislodged and damaged Accropods units with Tetrapod units. It is envisaged to utilize two-layer armour units considering unequal settlement and requirement to increase the crest level. In this mitigation measure, the base width of the breakwater will change minimum only. So, it will not affect the clear width of the approach channel. The design details after the rehabilitation are given in Table 2.

**Table 2** Design details after rehabilitation

|                               |  |  |
|-------------------------------|--|--|
| Head Section at (–) 11.0 m CD | Seaside  | Harbour side                                       |
| Crest level ( m CD)           | (+) 9.0  | (+) 9.0  |
| Crest width (m)               | 22.0   | 22.0   |
| Side slope                    | 1:1.5  | 1:1.5  |
| Toe mound                     | 15 m top width, 5.9 m height, 2–4.5 T              | 15 m top width, 5.9 m height, 2–4.5 T              |
| Armour layer                  | 25 T tetrapod with thickness of 4.5 m (two layers) | 25 T tetrapod with thickness of 4.5 m (two layers) |
| Under layer                   | 1.5–2.5 T with a thickness of 1.4 m                | 1.5–2.5 T with a thickness of 1.4 m                |
| Trunk Section (–) 10.4 m CD   | Seaside  | Harbour side                                       |
| Crest elevation ( m CD)       | (+) 9.00   | (+) 4.35   |
| Crest width (m)               | 9.0  | 9.0  |
| Side slope                    | 1:1.5  | 1:1.5  |
| Toe mound                     | 15 m top width, 5.85 m height, 2–4.5 T             | 4 m top width, 2.5 m height, 1–5 T                 |
| Armour layer                  | 25 T tetrapod with thickness of 4.5 m (two layers) | 7–13 T rock with thickness of 2.8 m (two layers)   |
| Under layer                   | 0.5–2.5 T with thickness of 1.35 m                 | 0.5–2.5 T with thickness of 1.4 m                  |

## 5 Berm Breakwater in Gopalpur Port

### 5.1 Introduction

Gopalpur port is located along the Bay of Bengal in Ganjam District, Odisha. The geographical coordinates of the port are 19°18'8" N, 84°57'56" E. The length of north breakwater is 435 m up to 7 m contours and 2170 m for south breakwater up to 13 m contour level. A berm breakwater is designed for south breakwater. The estimated total quantity of stone required for construction of berm breakwater is 6,688,563 MT. The quantity of stones dumped before cyclone is 3,429,036 MT.

The very severe cyclonic storm (VSCS), Phailin crossed Odisha and adjoining north Andhra Pradesh coast near Gopalpur in the evening of 12 October 2013. Due to this severe cyclonic storm, huge damage has been occurred on both north and south breakwater in the Gopalpur Port. The berm portion of the south breakwater including wave wall is slipped and flattened due to cyclonic waves. Due to Phailin cyclone, 705,930 MT of stones is washed out. Hence, 3,965,457 MT of stones is required to complete the construction. Also in North Breakwater which 360 m was built with root length of 25 m, the stones in the top (1 m layer) were washed out and the remaining length got flattened. Core layer and secondary armour on top and sides are flattened out due to cyclonic storm waves hitting the breakwater.



### 5.2 Solution to Damage

The section was flattened mostly along with harbour side due to cyclone. So, the centre line of the berm breakwater will be moved towards harbour side.

### 5.3 Experimental Investigation

A well-controlled experimental programme has been performed to ascertain the damage level for the breakwater section in 10 m water depth (Fig. 7).

#### 5.3.1 Experimental Results

For the stability tests that conducted on the section consists of Armour Layer (4–7 Ton)+ Under Layer+Core (model-A; 1:2 slope), and the results clearly demonstrate that the primary layer seems to be very stable as the percentage damage is zero for wave periods of 6 and 7.5 s. Damage level is insignificant for wave period of 9 s. In actual practice, the damage level up to 5% is allowed. Hence, the section adopted is safe and the seaward slope can be increased to 1:1.5. However, if the slope of 1:1.5 is to be adopted, it is recommended to use armour weights of 7–9 Ton. Similarly, model B (Under Layer+Core; 1:2 slope) and model C (Under Layer+Core; 1:1.5 slope) are stable as per the physical model study.



**Fig. 7** Photographs showing the model before and after testing

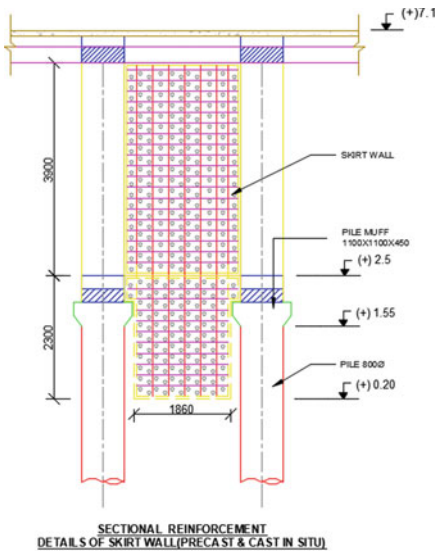


Fig. 8 Sectional view of landing jetty and site image

## 6 Jetty with Wave Breaker at JNPT

### 6.1 Introduction

Jawaharlal Nehru Port, also known as Nhava Sheva, is the largest container port in India, located east of Mumbai in Maharashtra, 18°57' N and 72°57' E. It is proposed coastal berth with landing jetty at JNPT.

The landing jetty has wave dissipater in seaside. It is facilitated to provide the tranquil zone since it will dissipate the wave energy by means of perforated panel. Landing jetty is used as ferry terminal at JNPT. Ferry service from India Gate to JNPT. JNPT is influenced by very heavy tidal variation. To eliminate the wave energy/dissipate, the wave energy skirt walls are provided. Figure 8 shows the sectional view and site image of the landing jetty with skirt wall as wave dissipater.

## 7 Rehabilitation and Retrofitting

### 7.1 General

The following steps to follow in rehabilitation and retrofitting projects.

- Zones of repair
- Investigation

- Repair methodology
- Case study
- Remaining life
- Post-repair monitoring.

## ***7.2 Causes of Damage***

- Wear and tear
- Extreme events like
  - Tsunami/Earthquake/Cyclonic wind, wave
  - Corrosion
  - Poor workmanship
  - Proper materials not used for construction.

## ***7.3 Rehabilitation of Offshore Transmission Tower at Port Blair***

Transmission tower from Suryachakra to Port Blair is present. It was damaged due to Tsunami in 2004. The significant damage was occurred on the junction between pile and pile cap. The pile cap has been dislocated from the original position. Figure 9 shows the offshore transmission tower and displacement of pile cap. The rehabilitation is carried out while the tower is being supported by the deck. The load from the deck is transferred to the pile by passing the damaged pile–pile cap joint. The retrofitting using additional reinforcement, micro-concrete and shear connectors is completed in three months.

## ***7.4 Rehabilitation of Offshore Tanker Terminal at Visakhapatnam Port***

The Offshore Tanker Terminal (OSTT) at Visakhapatnam port is built on the south side of the outer harbour basin and located at 140 m distance from the south breakwater. It was built having five mooring dolphins (MD-1–MD-5), two breasting dolphins (BD-1, BD-2) and a central unloading platform (CUP). The entire terminal is 407 m along with a maximum width of 31.3 m at the breasting dolphins. The depth around the terminal is approximately 19 m. Mooring dolphins MD-1, MD-2, MD-3 and breasting dolphin BD-1 are located west to the CUP, whereas BD-2, MD-4, MD-5 are located eastwards. The eastern side of the terminal suffered heavy damage during



Fig. 9 Displacement of pile cap in offshore transmission tower

Cyclone Hudhud witnessing complete submergence of MD-5 and partial submergence of MD-4 and BD-2. Figure 10 shows the aerial view of OSTT and satellite imagery of the terminal before and after the cyclone, respectively.

Hence, the rehabilitation is to bring the tilted caissons to original elevation by filling with new concrete duly anchoring with old RCC deck slab by inserting new reinforcement rods by drilling holes and grouting the same.

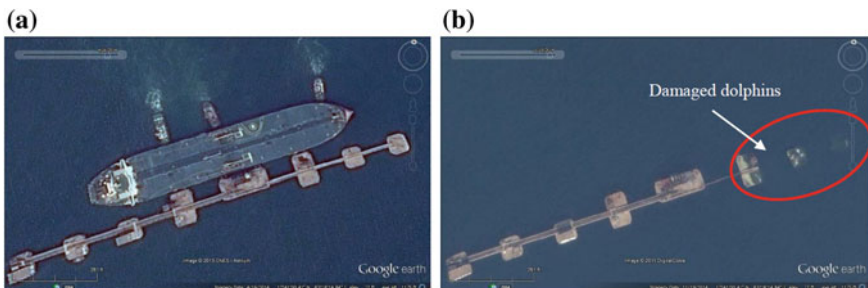


Fig. 10 Aerial view of OSTT before (a) and after cyclone (b)

### 7.4.1 Construction Methodology

- Dismantling and surface preparation on damaged dolphins
- Access working platform
- Drilling/installation of Rebar's
- Shuttering for micro-concrete wall
- Micro-concrete
- Mass concreting on BD and sand filling on MD'S
- Deck slab concrete and facia walls on south side of BD, MD'S
- Construction of facia beam and fixing of fenders on BD
- Fixing of marine fixtures, walkway bridge, foam tower on BD (Fig. 11).



**Fig. 11** View after completion of deck slab (top) walkway between berthing and mooring dolphin (bottom)

## **7.5 Repair Work on Berth Due to Bhuj Earthquake at Kandla Port**

Kandla, also known as the Deendayal Port Trust is a seaport in Kutch District of Gujarat State in western India, near the city of Gandhidham. Located on the Gulf of Kutch, it is one of major ports on west coast. Kandla Port has faced the severe damage due to the major earthquake. The **2001 Gujarat earthquake**, also known as the Bhuj earthquake, occurred on 26 January. The intraplate earthquake reached 7.7 on the moment magnitude scale and had a maximum felt intensity of X (*Extreme*) on the Mercalli intensity scale.

- As a consequence of Bhuj earthquake in 2001, cracks were noticed in 2000 precast hollow piles at a distance of 40 cm from the bracing beam bottom.
- All the racker piles suffered but collapse.
- IIT Madras proposed the repair methodology.
- Since time constraint as well as the tidal variation of 6 m during high and low tide, repair was restricted only to providing a micro-concrete reinforcement between 2001 and 2002 to get berth back into operation.

## **8 Wave Transformation on Submerged Reef**

### **8.1 Introduction**

Coastal areas are subjected to geomorphological changes due to natural and manmade activities. Artificial reef is considered an effective way in preventing coastal erosion due to its multipurpose benefits as compared to other shore protection methods. Artificial reefs are man-made underwater structure built to promote marine life, coastal protection, shoreline stabilization and recreational activities. Increased use of artificial reefs in coastal environment has led to study of the various design parameters of these reefs as the behaviour of waves and beach in the presence of these artificial reefs is not well established. Also, there is no fixed model or design of these reefs available; hence, various mechanisms of waves and beach in the presence of these reefs need to be studied as per the shape and size of the reef. Various construction materials like rock, concrete, geotextiles, steel can be used for construction of these reefs. Submerged wrecks are the most common form of artificial reef. Submerged reefs dissipate the incoming wave energy by forcing waves to break on top of the reef. Wave attenuation also occurs due to turbulence and nonlinear interaction between the reef and the incoming waves. Waves in the leeward side will be shorter and smaller and help in accumulation of sediments. These types of offshore reefs are custom-designed to trap sediment for each unique zone for different application.

The experimental investigation of wave transformation and breaking over the submerged reef with triangular steel wedge connected to shore is carried out. The

submerged reef was tested for regular and random wave at different water levels in Shallow Wave Basin at IIT Madras, India. The reef is designed for conditions of south-east coast of India. The reef makes an angle of  $13^\circ$  with respect to the shoreline and envisaged to trap the sediments from the longshore sediment transport. The submerged reef has a triangular wedge-shaped steel structure with armour stones and concrete cubes, the first of its kind in India. The main part of the submerged reef is triangular-shaped steel wedge weighing 900 t (in prototype scale) with dimensions  $60\text{ m} \times 50\text{ m} \times 2.5\text{ m}$  with slope on either side resting on stone bed. The model studies were carried out in 1:10 model scale for head sea condition with wave height 5–15 cm with wave period 1.9–3 s for three different still water levels, i.e. 50, 54 and 58 cm. The experimental study details of wave transformation and breaking over the submerged reef for regular wave and influence of water levels on these properties.

## 8.2 *Physical Model Study*

A submerged triangular reef was constructed using 25-mm-thick IS2062 grade steel sheets with base length 5 m and base height 6 m. The steel wedge consisted of top plate (horizontal crest) of 1 m length and 4.5 m height followed by slope of 1:0.8 on both the sides of the plate. The steel wedge has a height of 2.5 m and installed in the basin with the toe of the wedge 7.3 m from the wave maker. The horizontal crest of the steel wedge was at the water level for 50 cm water depth. At the opposite end of the wave generator in the basin, a beach with a 1:40 slope was made using 20 mm aggregate. Armour stone of size 10 cm was placed all around the steel wedge for a width of 1 m. Stones were placed for a depth of 10 cm to prevent toe scour. Additional concrete cubes of size 10 with 2 cm holes on all the six sides were placed all around the armour stone for a width of 0.5 m. Concrete cubes with holes were placed in random for a depth of 20 cm to dissipate the wave energy. The experimental set-up inside the shallow wave basin is shown in Fig. 12.

### 8.2.1 Results

- Intensity of wave breaking increases as the relative submergence of reef crest is reduced leading to higher air entrapment and energy dissipation.
- Breaker type is strongly influenced by the water level over the reef crest.
- Transmission coefficient increases with the submergence depth and with wave period.
- Transmission coefficient decreases with increasing wave height.
- When crest of reef is submerged, short period wave passes almost unhindered and longer wave propagates deeper and gets partially attenuated.
- Long waves lose their vertical symmetry and assume saw-toothed shape due to generation of primary secondary harmonics.
- Short waves do not develop tail wave as they grow in amplitude.



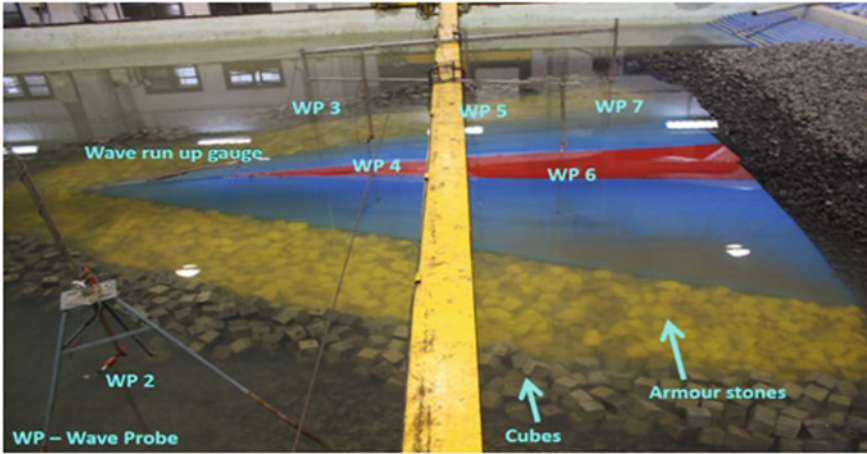


Fig. 12 Experimental set-up (1:10 scale) at shallow wave basin at IIT Madras

## 9 Summary

The modernization of ports needs deepening of harbour basin, upgradation of mechanical handling system, use of new type of fenders, etc. Both numerical and experimental investigations are carried out to understand the behaviour of new type of structures like touch pile wall and pile sheet pile wall. The techniques adopted for retrofitting of structures damaged by earthquake, tsunami and cyclone are explained by case studies. The details of new type of submerged reef which will restore the shoreline eroded by the breakwater constructed for a fishing harbour are also presented.