Typical Shore Protection Structures in Indonesia

Julianti Kusumawati Manu1, Ryuichiro Nishi2
1Ph.D student, The United Graduate School of Agricultural Science, Kagoshima University, julianti_manu@yahoo.com
2Professor, Faculty of Fisheries, Kagoshima University, nishi24@fish.kagoshima-u.ac.jp

ABSTRACT

Indonesia’s long shoreline as long as 81,000 km may provide many coastal problems and need proper coastal management. One of the significant problems that need immediate attention and priority is beach erosion control. Therefore, hard and soft engineering approaches have been developed to provide mitigating measures against erosion. Hard engineering approaches such as revetment, seawall, bulkhead, groin, offshore breakwaters and jetty are commonly used in Indonesia. While alternatives for shore protection can be also available, but the engineering aspects of any shore protection design are constrained by the understanding of nature, economics (costs), environmental impacts, social background, and possibly aesthetics. The objectives of this research are (1) to review optimal shore protection scheme implemented in Indonesia (2) to consider the technically sound, low cost and proper shore protection measure in Indonesia.

ADDITIONAL KEYWORDS: Beach erosion, coastal management, hard engineering approach, soft engineering approach, developing country.

INTRODUCTION

Geographic Condition

Indonesia is one of the largest archipelago countries in the world. The shoreline extends for a total length of 81,000 km, whereas the total land area is 1,904,569 km². Total number of islands are 17,508, consists of five major islands (Java, Sumatera, Kalimantan, Sulawesi, and Papua) as shown in Figure 1 and about 30 smaller island groups. The archipelago is on a crossroads between two oceans, the Pacific and the Indian Oceans, and bridges two continents, Asia and Australia.

Lied on the edges of the Pacific, Eurasian, and Australian tectonic plates makes Indonesia the site of numerous volcanoes, frequent earthquakes, and tsunamis. Indonesia has at least 150 active volcanoes, including Krakatau and Tambora, both famous for their devastating eruptions in the 19th century.

Group of coast that have potential of tsunami disaster in Indonesia are western coastal of Sumatera Island group, southern coast of Java Island, north and south coasts of Nusa Tenggara Islands, islands in Moluccas, northern coast of Papua, and almost all coast in Sulawesi Island. Moluccas Sea is the areas with most potential of tsunami, where 31% of total tsunami in Indonesia occurred in this region (Ministry of Marine Affairs and Fisheries Indonesia).

Highest run-up tsunami reached 41 m, in Indonesia ever recorded in history is tsunami in 1883. The tsunami was originated from eruption of Krakatau volcano in Sunda Strait and about 36,000 people were lost washed away. Viewing from number of casualty, Aceh tsunami on 26 December 2004 was the highest in Indonesia. More than 300,000 lives were lost with material lost of more than 50 quintillion rupiah. Run-up wave of tsunami has reached Lhok Nga Coast reaching up to 35 meters.

Several occurrences of tsunami that are Babi Island tsunami at Flores in 1992 (life casualty about...
1,952 people and thousand of houses were destroyed) and wave tsunami reached 26.2 m, tsunami caused by earth quake on southern coastal areas of Banyuwangi Regency, East Java on 3 June 1994 and tsunami reached the height of 13.9 m (life casualty about 240 people), Irian Jaya tsunami in 1996 (life casualty of more than 100 people) and Pangandaran tsunami in 2006 (life casualty of more than 600 people). If inventoried based on newspaper report and other resources along period 1961 until 2009, there has been about 23 tsunamis occurred hitting coastal areas of Indonesia (Ministry of Marine Affairs and Fisheries Indonesia).

**Seasonal Condition**

Most of area has a characteristically tropical climate with high level of rainfall, high temperature, and humidity. The average temperature is 27.7°C. The highest monthly average high temperature is 33°C (September and October) and the lowest is 23°C (June, July, August and September). The average annual relative humidity is 80.6% and average monthly relative humidity ranges from 75% in September to 85% in January and February.

There are two seasons in Indonesia: the dry season which extends from May to September (southeast monsoon season), and the rainy season from December to March (northwest monsoon season). Transition season from wet to dry occurs from October to November.

Winds are moderate and generally predictable. Due to monsoons, winds usually blowing from south and east in June through September and from the northwest in December through March.

Prevailing wind patterns interact with local topographic conditions produce significant variations in rainfall throughout the archipelago. The most precipitation is concentrated in western and northern parts of Indonesia, since the north and westward moving monsoon clouds are heavy with moisture by the time they reach to these high altitude regions. Western Sumatera, Java, Bali, the interiors of Kalimantan, Sulawesi, and Papua are the most predictably damp regions of Indonesia, with rainfall measuring more than 2,000 millimeters per year (Indonesian Meteorology Climatology and Geophysics Agency). In contrast, the islands closest to Australia, such as Nusa Tenggara, the eastern tip of Java and some areas experience less than 1,000 millimeters per year.

Tropical cyclone seasons run from November to April and sometimes occur outside this period, mainly in the Central Indian Ocean southwest of Sumatera (Indonesian Meteorology Climatology and Geophysics Agency). Tropical cyclones are dangerous because they produce destructive winds, heavy rainfall with flooding and damaging storm surges that can cause inundation of low-lying coastal areas.

These cyclones have wind gusts in excess of 90 km/hour around their centres and in severe cyclones gust can exceed 280 km/hour. Heavy rainfall associated with the passage of a tropical cyclone can produce extensive flooding. The heavy rain can persist as the cyclone moves inland and decays, hence flooding due to a decayed cyclone can occur a long way from the tropical coast as the remains of a cyclone move into central and southern parts of the continent. The destructive winds accompanying tropical cyclones also cause serious coastal erosion (Indonesian Meteorology Climatology and Geophysics Agency).

Storm surge associated with tropical cyclones that make the most destructive. Storm surge is a raised dome about 60 to 80 km across and typically about 2 to 5 m higher than the normal tide level. If the surge occurs at the same time as a high tide then the area inundated can be quite extensive, particularly along low-lying shorelines.

Coastal areas that have potential of flood in Indonesia are northern coast of Java, Lampung, Palembang, Aceh, West Sumatera, east coast of Sumatera, Kalimantan, Manado, Minahasa and Sumbawa Island (Ministry of Marine Affairs and Fisheries Indonesia).

**Coastal Zone Utilization**

Indonesia is an island country, the people have utilized the coastal zone covering the seaward and landward areas from the shoreline for support their daily life. Most of population lives within 50 km of the coastal area, there are 60% of the 240 million residents of Indonesia (Research Institute of Water Resources
Development, Ministry of Public Works). This area serves as tourism, recreational, human settlement, pedestrian, industry, commercial, agricultural and aquaculture areas. From this fact it can be realized that how densely the coastal zone of Indonesia has been utilized.

In total 54 million ha of inland waters there are 39.4 million ha of swamp (71.63%), 11.95 million ha of river (22.13%), and 2.1 million ha of lake and reservoir (3.89%) (source: Research of Marine and Fisheries Agency, 2005).

Reclamation works have been done during recent years (2007), amounting about 3,950,026 ha from 10,802,132 ha (40%) of the total marsh area in 5 major islands in Indonesia (Ministry of Public Works Indonesia 2007). Furthermore, Table 1 presents the record of largest marsh areas of Papua, Sumatera and Kalimantan islands which are on the order of 4,932,921; 2,968,049; 1,964,022 ha respectively. The largest land reclamation activities carried out in Sumatera (1,878,604 ha), Kalimantan (1,491,087 ha), and Sulawesi Islands (357,840 ha). Reclaimed land areas have been used mainly for settlement, industry and agriculture.

At first the development of marsh as traditionally started by Bugis (South Sulawesi) and Banjar (South Kalimantan) farmers since the 1920s. Furthermore, Indonesian government introduced the Tidal Swampland Development Project in order to achieve rice self-sufficiency in 1969. Under the project, four ministries (Ministry of Public Works, Ministry of Internal Affairs, Ministry of Agriculture, and Ministry of Transmigration) were began the program known as the” Project on Paddy Field Development on Tidal Swamps through Transmigration” (Ministry of Settlement and Regional Infrastructure 2006).

Indonesia has 813 fishing ports until 2008, whereas 792 of them are managed by regional government through decentralization program. The ports are divided into four groups: (1) Oceanic Fishing Port, (2) Archipelagic Fishing Port, (3) Coastal Fishing Port, and (4) Fishing Landing Center (Ministry of Marine Affairs and Fisheries Indonesia).

### Coastal Problems

The geographic and seasonal conditions have made Indonesia coastal zone effect by wave, current, tide, and wind parameters. As a result, coastal erosion becomes crucial in addressing the natural disasters. The significant natural erosion would occur when high waves propagate on elevated sea level during storm surge and sea level rise.

Human activities such as river damming and diversion within river catchments and watersheds, land reclamation and port development along coastline, and dredging, sand mining and coral mining in offshore zone cause coastal erosion. As shown in Figure 3, erosion in reclamation area at Malalayang

<table>
<thead>
<tr>
<th>Island</th>
<th>type of marsh</th>
<th>number of marsh</th>
<th>marsh area (ha)</th>
<th>reclamation area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sumatera</td>
<td>tidal marshes</td>
<td>458</td>
<td>1,997,465</td>
<td>1,423,393</td>
</tr>
<tr>
<td></td>
<td>swamp</td>
<td>454</td>
<td>970,584</td>
<td>464,561</td>
</tr>
<tr>
<td></td>
<td>total</td>
<td>912</td>
<td>2,968,049</td>
<td>1,878,604</td>
</tr>
<tr>
<td>Java</td>
<td>tidal marshes</td>
<td>5</td>
<td>166,490</td>
<td>150,977</td>
</tr>
<tr>
<td></td>
<td>swamp</td>
<td>13</td>
<td>18,461</td>
<td>18,461</td>
</tr>
<tr>
<td></td>
<td>total</td>
<td>18</td>
<td>184,951</td>
<td>169,438</td>
</tr>
<tr>
<td>Kalimantan</td>
<td>tidal marshes</td>
<td>390</td>
<td>1,539,615</td>
<td>1,090,708</td>
</tr>
<tr>
<td></td>
<td>swamp</td>
<td>213</td>
<td>424,407</td>
<td>400,379</td>
</tr>
<tr>
<td></td>
<td>total</td>
<td>603</td>
<td>1,964,022</td>
<td>1,491,087</td>
</tr>
<tr>
<td>Sulawesi</td>
<td>tidal marshes</td>
<td>172</td>
<td>524,374</td>
<td>279,437</td>
</tr>
<tr>
<td></td>
<td>swamp</td>
<td>72</td>
<td>227,815</td>
<td>78,403</td>
</tr>
<tr>
<td></td>
<td>total</td>
<td>244</td>
<td>752,189</td>
<td>357,840</td>
</tr>
<tr>
<td>Papua</td>
<td>tidal marshes</td>
<td>1</td>
<td>4,216,950</td>
<td>8,655</td>
</tr>
<tr>
<td></td>
<td>swamp</td>
<td>83</td>
<td>715,971</td>
<td>44,402</td>
</tr>
<tr>
<td></td>
<td>total</td>
<td>84</td>
<td>4,932,921</td>
<td>53,057</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1,861</td>
<td>10,802,132</td>
<td>3,950,026</td>
</tr>
</tbody>
</table>

Beach, Manado caused by extreme waves occurred during heavy rainfall in November 2009. Reclamation in this area caused the destruction of coral reef, marine life and erosion around the beach (Antara newspaper, November 25, 2009). Figure 4 shows that coastal erosion in Bunaken Island, Manado, caused of high wave. Human settlement has been very close to the shoreline, this condition is very dangerous when extreme wave attack. In this area, mangroves have been cleared over vast therefore could not serve as a coastal defense system where diminish the wave energy. This is due to the lack of understanding of the local people to the important of mangrove forest. Up date condition, there has been no action to protect this area either from government and local people.

Many coastal front property in Indonesia constructed private low cost erosion control measures to protect their property. As shown in Figure 5 a vertical seawall made of wooden structure built by local people to protect their property. Moreover, nylon sandbag filled with sand had been used to absorb the wave energy and protect the property from being carried away.

Removal of dune, vegetation and mangroves will expose low energy shorelines to increased energy and reduced sediment stability. River diversions also cause reduction of sediment supply to the coast that contributes to coastal erosion. Sand mining, coral mining and dredging may affect coastal processes in various ways such as contributing to sediment deficit in the coastal system and modifying water depth that leads to altered wave refraction and longshore sediment.

In recent, beach erosion is mainly caused by extreme wave condition and sea level rise. Wave height from 2.0 m to 3.0 m are considered as warning stage for coastal user while height from 3.0 m to 4.0 m are classified to be in danger stage and greater than 4.0 m is already in extremely danger stage (Indonesia Meteorological Agency). As an archipelago country with many small islands, mean sea level rise is becoming a crucial problem for Indonesia. A survey carried out in 2007 by Department of Marine Affairs and Fisheries Indonesia, indicated that the sea level in various regions in Indonesia will rise rapidly. For instance, sea level rise in Java Sea region is
about 15 mm per year, in Timor Sea region 19 mm per year, in Sulawesi Sea region 16 mm per year and in South China Sea region 17 mm per year. These rates of sea level rise are one of the highest in the world (Ministry of Marine Affairs and Fisheries Indonesia).

MATERIALS AND METHODS

Literature Survey

Many shore protection schemes are developed to combat the erosion problems in the world. For erosion control, the positive measures depend on the type of shore that is in need of protection as well as the ultimate function and use of the property. According to Pilarczyk (1990), a complete design process shall include the following phases, to wit; (1) identification of beach erosion problem, (2) selection of the type of protective measure, and (3) risk analysis of the project.

There are practical approaches available in addressing erosion protection, namely, the hard approach, soft approach, and nonstructural techniques. Stabilization of coasts has been carried out already over many years. The type, size and location of shore protection approaches must be based on actual needs, benefits, effect on adjacent shorelines, environments, social, esthetics, and economics. Actual design of shore protection is determined by the local conditions, such as bathymetry, waves, tides, morphologic processes, and the characteristics of sediment.

Moreover, alternatives for shore protection category are compiled in CEM (2002); (1) armoring, (2) shoreline stabilization structures, (3) beach nourishment, (4) adaptation and retreat in the forms of elevating structures, flood proofing, zoning restrictions, storm warning and evacuation planning (5) combinations and new technologies, (6) with-no-project (abstention).

There are two major coastal problems in Indonesia, i.e., coastal erosion and sedimentation in river mouth. Counter measures has implemented in certain areas, or not unified because as a developing country with limited budget, the national government must determine priorities by taking following factors; economic (cost), environment, social and cultural (existed traditional village and temple) into account to build shore protection structures in Indonesia. However, high economic value area has a priority to be protected with appropriate measures, while area with low economic value is left unprotected in general.

More than 24 small islands in Indonesia have wiped out due to natural events and human activity. The islands were lost in the tsunami in Aceh, erosion, and uncontrolled sand mining. Amongst these islands are Gosong Sianje Island (Aceh, tsunami 2004), Pulau Malelo (Aceh, tsunami 2004), Pulau Jawi-jawi (Aceh, tsunami 2004), Mioswekel (Papua, erosion), Lereh (Riau Islands, uncontrolled sand mining), and 8 small islands used to be part of the Seribu (Thousand) Island (Jakarta Bay, erosion). Most of the islands that had vanished were uninhabited. According to the prediction of scientists from Ministry of Marine Fisheries Indonesia and United Nation, at least 2,000 small islands in Indonesia by 2030 will be gone as a consequence of sea level rise (source: www.kp3k.dkp.go.id).

Coastal sand mining in Indonesia during 1970-1990 was recorded as much as 54,000 ha, the largest in Sumatera Island (32%), Java Island (15%), Sulawesi Island (23%), and 30% in Maluku and Papua Islands. Sand mining in Java Island outspread on southern coast of Java, started from Penyu Bay at Cilacap to Parang Tritis at Jogjakarta (Statistics Agency Indonesia).

Sand mining project in Riau Island, Sumatera Island, that area adjacent to Singapore has been underway since 1976 simultaneously with Singapore reclamation project. In this area sand mining production is estimated up to 750 m³ per year. Total production in 2001 was recorded only 47,300,000 m³, whereas in fact estimated reach to 253,600,000 m³. This shows that there have been many illegal and uncontrolled sand mining activities. Finally, in 2003 the new role of Minister of Industry and Trade Indonesia under Act No. 117/MPP/Kep/2/2003, coastal sand export has been suspended.

Based on the data from Ministry of Public Works Indonesia (September 2007), 30,000 km
that is nearly 40% of the Indonesia shoreline is undergoing erosion. Coastal erosion started in the northern coast of Java Island in Tangerang, Kerawang, Cirebon, Pekalongan and Tuban. Furthermore in Kalimantan Island, it started from Pontianak, Benkayang, and Sambas (Figure 2). During 2004 to 2009, national government through Ministry of the Public Works Indonesia was undertaken 250 km of shore protection.

Figure 2. Location map of beach erosion in (A) the northern coast of Java and (B) Kalimantan Islands.

Shore protection data in Indonesia compiled by the first author is summarized in this study. Table 2 shows the example of shore protection data in Indonesia. The available data set from 2005 to 2009 includes data from 33 provinces in Indonesia and is provided by the Ministry of Public Works. The provided data included the following: (1) type of shore protection structures, (2) length of structure and (3) project cost.

Coastal zone management in Indonesia is distinguished by an involvement of a variety of agencies that operate on coastal management, respectively. For instance, Directorate General of Water Resources at the Ministry of Public Works has the responsibility for engineering design of shore protection. Currently, there are 5 divisions under this directorate, (1) river, (2) irrigation, (3) flood prevention, (4) dam construction, and (5) swamps and coastal. In 2005 fiscal year directorate of swamps and coastal has been established. Coastal division has a function to carry out research and development in technology of coastal areas in Indonesia which included the collection, processing and presenting data, and providing technical advices and assistance. Before that, coastal directorate was included in the branch of river directorate and the related research activities in this field were in an early stage of development. Tables 3 shows the percentage allocation funding for shore protection structure among 5 divisions, wherein increases from 7,169,882 USD (2.06%) in 2005 to 43,389,224 USD (5.30%) in 2009.

Table 2. Example of Shore Protection Data in Indonesia

<table>
<thead>
<tr>
<th>No</th>
<th>Province</th>
<th>Project 2005</th>
<th>Project 2008</th>
<th>Project 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cost (IDR)</td>
<td>Cost (USD)</td>
<td>Cost (IDR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Bali</td>
<td>1,682,770,000</td>
<td>182,000</td>
<td>39,108,422,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>revetment</td>
<td>revetment, groin</td>
<td>revetment, groin, breakwater</td>
</tr>
<tr>
<td>2</td>
<td>Java Barat</td>
<td>19,900,000,000</td>
<td>2,154,000</td>
<td>9,000,000,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>jetty, revetment (200 m)</td>
<td>jetty, revetment</td>
<td>bulkehead, breakwater</td>
</tr>
<tr>
<td>3</td>
<td>Java Tengah</td>
<td>0</td>
<td>0</td>
<td>9,350,000,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5,897,359,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>groin, revetment, offshore breakwater</td>
</tr>
<tr>
<td>4</td>
<td>D.I.Yogyakarta</td>
<td>6,000,000,000</td>
<td>649,000</td>
<td>69,377,074,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>breakwater</td>
<td>Breakwater</td>
<td></td>
</tr>
</tbody>
</table>

Note: 1 USD = 9,240 IDR
Source: Ministry of Public Works Indonesia
RESULTS AND DISCUSSIONS

Figure 6 shows the annual total cost of shore protection structures at 33 provinces in Indonesia. The available data from 2005 to 2009 fiscal years provided by Ministry of Public Works Indonesia. The annual total costs of shore protection structures are order of 7 million to 43 million USD during 2005 to 2009 and rapidly increasing every year due to awareness of importance of shore protection structure, after the severe tsunami attack Aceh in December 26, 2004. The experience during tsunami disaster in Aceh and Pangandaran (Jogjakarta) in 2006, awaken all of us that better mitigation system is required included shore protection structures.

Figure 6. Annual total cost of shore protection in Indonesia.

In addition, annual total cost for shore protection in North Sulawesi Province, gradually increases from 134,631 USD in 1998 to 825,110 USD in 2004 and after the Aceh tsunami the cost suddenly increases 1,862,264 USD in 2005 to 3,099,815 USD in 2009 (Figure 7).

Figure 6. Annual total cost of shore protection in Indonesia.

Decentralization of coastal management in Indonesia is necessary to deal with diversity of geographical, social and cultural of 17,508 islands. To promote the decentralization of coastal zone management, a central government should provide trainings and technical assistance for all level government. In addition, the success of decentralized coastal management also requires the involvement of the public, environmental protection organizations (Ministry of Public Works and Ministry of Marine Affairs and Fisheries), NGOs (non government organizations), and the local community. The involved various stakeholders must share responsibility, too. Nevertheless, coastal erosions have been occurred in Indonesia that indicated under-quality of coastal management.

Background

It had been evident that coastal erosion and its effects were a serious problem in northern coast of Java Island by the 1970s, when the mangrove forest had been converted to shrimp
ponds, other aquaculture activities, and human settlement (Prasetya 2006). Coastal erosion also started in western coast of Kalimantan Island in 1970s and damaged private homes, commercial buildings, roads, and commercial agricultural (Ministry of Public Works Indonesia 2007). In 1972 emergency shore protection works was conducted by applying sand bags, but the erosion process is still undergoing. Adaptation and retreat with replaced homes and roads to hinterland started in 1974. Shore protection structures using revetment have been implemented starting from 1994. Furthermore, bulkhead structure by concrete cube with dimension 0.4-0.5 m and rubble mound located at 50-60 m from shoreline have been constructed. For instance in 2005, coastal condition in West Kalimantan Province has 225 km of shoreline, with badly damaged condition is 8,843 m (without action), slightly damaged condition is 1,650 km (without action), and only 1,480 m had been protected.

North Sulawesi Province with Manado as capital consists of a narrow peninsula and several small islands scattered along the 1,985 km of shoreline. The south Sulawesi is bordered by Tomini bay, north bordered by the Celebes Sea, and on the east bounded by the Molucca Sea. The beach materials composed of sand, gravel to rocks, and the beach shape is headland and bay-shaped. Coastal vegetation is very diverse from various species of mangrove trees, coconut trees and diverse of coral reefs. Results of field survey by the first author on North Sulawesi have been obtained the data of shore protection structures in several beaches such as;

1. Boulevard Beach in Manado
   In order to protect the beach, shore protection structures such as seawall made of pre-cast concrete and vertical seawall combined with rubble-mound breakwater had been used as shown in Figures 8 and 9. These structures built by directorate general of highways, Department of Public Works in order to protect the main highway along the beach in 1990. This beach has been reclaimed for commercial areas. However, every year in November and December the extreme wave attack in this area. The extreme wave overtopping the seawall and inundate the highway and destroy buildings along the coast.

   Figure 8. Vertical seawall in Boulevard Beach, Manado, Indonesia.

   Figure 9. Rubble-mound breakwater in Boulevard Beach, Manado, Indonesia.

2. Malayang Beach
   This beach is located 5 km from Manado. Beach erosion was occurred and shoreline retreat approached the highway along the beach. Shore protection structure consists of vertical sea wall combined with T-shaped groin made from concrete pipes as shows in Figures 10 and 11. Some of groin has damaged because did not installed of anchor joints between pipes. Many of pipe covers have been peeled off because did not use reinforcements. The space between groins is 100-150 m and length is 50-60 m. These structures built in 1993-1994 fiscal years. Head of groins near the bottom has
protected by toe from stone to increase the stability.

Figure 10. Groin in Malalayang Beach in Manado, North Sulawesi, Indonesia.

Figure 11. Vertical seawall in Malalayang Beach, North Sulawesi, Indonesia.

3. Ratatotok Beach

The beach is located 18 km from Belang city and borders with Bolaang Mongondow Regency with position facing to Maluku Sea. Its beach had been lost to erosion, replaced by pre-cast concrete pipe seawall with octagonal shape. The pipes are arranged to form a stair, so make easy access for the fishermen to go to coastal. Furthermore, the seawall has another function as the pear for fishermen boat. The outer layer with parallel to shoreline consists of rubble stone by slope1:2 (Figure 12). The structures were building for protected the settlement that is located very close to shoreline.

Figure 12. Concrete pipe seawall at Ratatotok Beach in Belang, North Sulawesi.

Awareness of coastal engineering problems was increased after a big tsunami attack in Nangroe Aceh Darussalam (NAD) Province and Nias Island, North Sumatera Province. A great earthquake (Richter Magnitude 9.0) occurred on 26 December 2004 in Indian Ocean with an epicenter in the west coast of Sumatera, Indonesia. It generated a very large tsunami in Aceh, Sumatera Island, approximately 230,000 people were killed and about 500,000 were left homeless. On July 17, 2006 an earthquake and tsunami struck Pangandaran, Java Island and killing more than 500 people. These above natural disasters raised strong interest of Indonesia government for maintaining the coastal land area with proper shore protection system.

Coastal engineer research activities in Indonesia are principally conducted by the researchers at universities and research institutes (e.g., Research and Development Agency (LIPI), Ministry of Public Works Indonesia; Agency for the Assessment and Application of Technology Indonesia; and Indonesian Institute of Sciences). Some collaborative research and education programs with various foreign research institutions, such as the Asian Living Coastal resources Program, cooperation between CSIRO (Commonwealth Scientific and industrial Research Organization)-LIPI, USAID (United States Agency for International Development), JICA (Japan International Agency), etc. However, still lack of budget for research on the coastal
problems causes of coastal management problem in Indonesia.

Marine Engineering education has been established at Institute Technology Surabaya (ITS) in March 1983 and developed into Offshore and Coastal Engineering in 1990’s. Coastal Engineering program study under Faculty of Civil and Environment in Institute Technology Bandung (ITB) established in 1994. However, at the university in Indonesia, the number of faculty of coastal engineering is quite small in general. In general, only one of subjects in faculty of civil engineering.

In addition, there are some research institutes in Indonesia for instance Tsunami Disaster Mitigation Research Center (TDMRC) in Syiah Kuala University, Banda Aceh, and was established in 2006.

Coastal Management

Since independence in the 1945, and particularly since the new order in 1964, Indonesia has operated under a centralized governance structure. Under the centralist approach, environmental policies were designed to be applied and implemented in all regions of Indonesia regardless of their local problems and the complex social, economic, and cultural diversity that exited across the archipelago.

Reformation and the rise of democracy in Indonesia in 1998, there has been a growing demand for autonomy from the central government. With the enactment of Act No. 22/1999 on regional autonomy and Act No. 25/1999 on financial relations in 1999, regional autonomy has become a fast reality. In new concept coastal management in Indonesia consists of central, provincial and district governments. The district has authority to arrange and organize coastal resources and environmental through their own decisions, based on their own aspirations, or it will have the option to work with provincial to developed a program or plan for submission to the central government (Figure 13). If approved, the central government will provide funding and

Figure 13. Coastal management flow in Indonesia.

Table 4. Allocation Funding in Ministry of Public Works Indonesia

<table>
<thead>
<tr>
<th>No</th>
<th>Division</th>
<th>2006 Cost (IDR)/(USD)</th>
<th>%</th>
<th>2007 Cost (IDR)/(USD)</th>
<th>%</th>
<th>2008 Cost (IDR)/(USD)</th>
<th>%</th>
<th>2009 Cost (IDR)/(USD)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>general secretariat</td>
<td>257,121,922,000</td>
<td>1.68</td>
<td>410,945,233,000</td>
<td>1.93</td>
<td>277,897,186,000</td>
<td>0.91</td>
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<td>3</td>
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<td>147,228,463,000</td>
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<td>200,520,745,000</td>
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<td>281,095,994,000</td>
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<td>directorate general of highways (bina marga)</td>
<td>8,181,396,795,000</td>
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<td>10,813,149,468,000</td>
<td>50.90</td>
<td>16,573,358,596,000</td>
<td>54.50</td>
<td>16,322,694,525,000</td>
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<td>5,786,082,405,000</td>
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<td>0.18</td>
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<td>development of drinking water supply system agency</td>
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<td>TOTAL</td>
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<td>21,245,256,521,000</td>
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<td>30,408,076,640,000</td>
<td>100.00</td>
<td>33,418,388,718,000</td>
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technical assistance for coastal management.

Funding for districts and provinces is comprised of a multitude of sources, a combination of original revenues from their own and the central government. Allocation funding from Indonesian government to Ministry of Public Works had been distributed to 10 divisions as shown in Table 4. Every year allocation funding in this department is increase. On the other hand, the budgets to construct shore protection structures were still insufficient and some critical coastal areas had to wait to be rescue.

**Shore Protection Methods**

There are many types of shore protection structures implemented in Indonesia (seawall, groin, breakwater, revetment, bulkhead, and jetty). Figures 14 and 15 shows type of shore protection commonly implemented in Indonesia and North Sulawesi, which seawall is primarily used. Seawalls are typically large and design to prevent inland flooding from storm events accompanied by large and full force waves. The main purpose is used to fix the shoreline. On an eroding coast, the beach in front of a seawall may narrow and eventually disappear if there is inadequate sediment supply. Thus, seawall can reduce the regional trend of coastal erosion, but it is constructed for protection of upland under extreme condition. Material for seawall construction such as boulder stone is easy to find around the Indonesia coastal area. The design construction of seawall is simple and inexpensive by comparison with another structure.

![Figure 15. Type of shore protection structures using in North Sulawesi, Indonesia.](image)

There are 3 types of seawall commonly used in Indonesia namely vertical sea wall, rubble-mound seawall, and concrete pipe seawall (precast concrete units) or combination of two types. Vertical seawall is used as pear for small boat when the sea is in calm condition (Figure 16).

![Figure 16. Vertical seawall in Bunaken Island, North Sulawesi, Indonesia.](image)

**Figure 14. Type of shore protection structures using in Indonesia.**

**Figure 17. Cross section of concrete pipe seawall.**
A rubble-mound seawall designed to prevent the area near shoreline. Furthermore, precast concrete unit seawall is only used for shallow water area and land base is relatively hard enough. Cross-section of precast pipe concrete seawall and combined with rubble-mound are shown in Figure 17.

The economics of a project is another important consideration especially for funding purpose which is a decision indicator in implementing shore protection project. Based on the collated data, the cost of seawall per unit volume are 4,573,496 IDR/m$^3$ (495 USD/m$^3$) for pipe seawall, 1,035,426 IDR/m$^3$ (112 USD/m$^3$) for vertical seawall, 539,158 IDR/m$^3$ (58.35 USD/m$^3$) for rubble-mound seawall, and 1,361,501 IDR/m$^3$ (147.35 USD/m$^3$) for vertical seawall combination with rubble-mound. Rubble-mound and vertical seawall appears to be most economic compare to another type.

Since 1997, Government of Indonesia and Japan entered a bilateral cooperation to rehabilitate Kuta, Sanur, Nusa Dua, and Tanah Lot beaches through Bali Beach Conservation Project. These beaches are the most famous tourist destination in Bali, but severe beach erosion has caused these areas lost their white sandy beach. A combination of hard engineering approaches of different shapes that fused functional design and aesthetic values, and soft engineering approaches (beach nourishment) were used. Beach nourishment is often used in combination with construction of a groin in general, but a few in Indonesia. By the end of the project in December 2003, groins, three offshore detached breakwaters, 16,000 m$^2$ submerged breakwater, and wide white sandy beach (volume 575,899 m$^3$) have been restored, along approximately 3.7 km of shorelines.

The average rate of sand loss in 16 months since the Bali Beach Conservation Project completed on December 2003 to September 2006 shows a loss percentage of 12.02% (44,747 m$^3$). The pocket beach formed between the two groins represent of the stable shoreline. The perpendicular groin that functions as an artificial headland has worked well; shown by the forming of a pocket beach that describes a stable shoreline (Siladharma 2009). In the other hand, monitoring results by Sulaiman, shows that 6 from 13 segments of entire Sanur Beach, or around 45% not yet reached its stability. This problem spread over north, middle and south of Sanur Beach. While for Nusa Dua Beach, 4 from 13 beach segments which have been conducted beach nourishment, or about 30% not yet reached its stability in north area.

Nipah Island is an Indonesia’s outer island and directly adjacent to Singapore. Continuous sand mining and erosion was resulting the almost sinking Nipah Island during high tide and extreme wave. This island was originally has about 7 ha area but in 2004 only 4 ha. Hence, reclamation project was required in order to keep the existence of Indonesia’s outer islands. That project was started in 2004 to 2008 fiscal year. The project was implemented by constructing 4.3 km length of seawall with 5.2 m height and armoured by using tetrapods at the outside, sand filling in 15 ha in northern zone, 12.28 ha mangrove zone, and 16.19 ha in southern zone as shown in Figure 18.

![Figure 18. Nipah Island after Reclamation Project in 2008. (source: Ministry of Marine Affairs and Fisheries)](image)

Vegetation is an effective and inexpensive way to stabilize coastal area. In 2002 area of mangrove forests in Indonesia was 9.2 million ha with 57.6% or 5.3 million ha in damaged condition (Ministry of Forestry Indonesia). In recent years it has been realized that mangroves may have a special role in supporting fisheries and in the stabilizing the coastal zone (Figure 19). Mangrove is used as an erosion control

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measure because roots and stems tend to trap fine sand and soil particles. Moreover, the mangrove’s massive root system is efficient at dissipating wave energy. In marshes, it also absorbs some of the water’s energy, slowing down potentially erosive currents. On the other hand, loss of mangrove forest and tidal marsh which support settlement, transport infrastructure, aquaculture and agriculture and human consumption (e.g., for food, household uses, medical applications).

Figure 19. Mangrove forest in Bunaken Island, North Sulawesi, Indonesia.

The activities related to mangrove development in Indonesia in the period of 2004-2008 (Ministry of Forestry Indonesia) consist of:

- establishment of 487 units of mangrove forest model,
- replanting/rehabilitation of 79,269 ha of mangrove forest,
- free distribution of seedling, 945,000 seedling for mangrove rehabilitation, and
- field training of 618 field officers, 3,753 farmers and NGOs.

CONCLUSIONS

Shore protection schemes in Indonesia are compiled and analysed in this research. The conclusions are as follows;

1. Main shore protection scheme is hard structures in Indonesia, except Bali Island (both hard structures and beach nourishment) and seawall structure is widely applied as much as other structures.
2. In the aspect of effective, efficient and inexpensive shore protection structure, seawall is the continuous implemented as a favored approach for developing country such as Indonesia.
3. A country as large and diverse as Indonesia, decentralized of coastal planning and management is appropriate to implemented.

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