The Important Role of Gravel and Rocky Beach as A Natural Stable Form of Shore Defense in Southern Garut, West Java

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Abstract. Tectonic processes and high energy waves, tidal phases, generally formed the coasts of southern Java. The grain size of the beach is generally gravel, and large stones. Some pristine beaches consist of pebbly, rocky, sandy beaches or a mixture of sand, gravel, and rocks / boulders. Steep gravel beaches are always associated with coastal erosion. On the other hand, a beach with pebbles and boulders can be a stable natural defense. This location is a preservation of various fossil markers of sea level change and also as a habitat for marine life. A study on geomorphology and sediment types was carried out around the coast of Pameungpeuk, South West Java in May 2016. The purpose of this study was to demonstrate the importance of gravel beaches as natural protection in maintaining stability of coastal habitats and as a barrier from high waves. On the other hand, sandy beaches are highly susceptible to erosion. Exposure to gravel and boulders in front of the beach can act as a barrier to erosion from the beating of waves. Pameumpeuk beach and its surroundings are also a habitat for lobsters because many rock structures are found with holes and their position behind the rock barrier as natural protection.

1. Introduction

The rocky coast is composed of hard material and is an interesting ecosystem, because very diverse marine life lives in this ecosystem [11]. Compared to sandy and muddy beaches, rocky beaches are the most macro-dense areas and have the greatest diversity of animal and plant species. This is because the rocky coast has a good oxygen content, an adequate supply of food and is a refuge for good organisms. Gravel and rocky beaches usually have steep beaches, the width of the shoreline is narrow no more than 20 meters, the coastline is sunken and has slopes or cliffs that display a beach profile. On the beach slopes there is usually a form of steep steps called berms, which are always associated with tidal periods. [10]. Gravel beaches have grains that are coarser than sand, namely gravel (2-4 mm) crust (4-8mm) and boulders (> 8mm). But the results of working on waves with energy that are not entirely the same and also the influence of the tidal phase, so on gravel and rocky beaches there is also sand and clay, and is called a mixed sand-gravel beach. Gravel beaches and rocky beaches are also usually associated with erosional processes. Gravel beaches are very common on beaches located at high and medium latitudes, or areas with glacial processes, where the main source of coarse glacial alluvial sediment is carried with considerable energy to the coast. The system that works in gravel sedimentation is usually associated with the erosion of alluvial fans, areas affected by glaciation, and the process of rock avalanches on islands located on plate edges. Gravel and rocky beaches in Indonesia are found in many areas because even though they are located at low latitudes and not glacial areas, they are tectonically complex at the
junction of three active plates and there are many volcanic islands, so there are many pebbles and rocky beaches in Indonesia, for example on the west coast of Sumatra and south of Java [7].

The response of gravel beaches and rocky beaches is slower to withstand changes in sea level so that the fossil preserved in the coastal rock can be recorded properly, and can be used as an indicator of global sea level change. On a longer scale, pebble beaches with sand barriers or rock cliffs can form lagoon complexes and act as potential hydrocarbon traps [4].

Research that has been conducted by Pamengpeuk beach in the South of West Java shows that pebble beach is associated with rocky beaches, sand beaches, and mixed beaches. The purpose of this research on gravel beaches is to demonstrate the importance of the existence of gravel beaches in the coastal ecosystem, for example as a form of stable and natural coastal defense that is conducive to the habitat of biotas [2]. To reduce wave energy and longshore current intensity due to wave induction, a breakwater building is needed. With the construction of this breakwater, it is expected that current behavior parallel to shore due to wave induction can be controlled so that the rates of sediment transport in the surf zone can be reduced. Rocks and gravel on the beach can act as natural breakwaters and provide protection for the coast.

2. Method

The main investigation rocky shore morphological was carried out on 2-11 May 2016 on the South Coast of Garut observing the landscape, measuring the slope of the slope and layering stance using a geological compass at a predetermined location (Figure 1). The classification of coast adapted from verstappen [9]. Sediment samples on the beach were taken by hand sampling method as deep as 10 centimeters from the surface. Furthermore, a granulometric analysis was carried out using a stratified sieve method with sizes 8, 4, 2, 1, 0.5, 0.250, 0.125, 0.063 mm [8]. Sediment grains smaller than 0.063 mm were collected in a measuring tub and analyzed using the pipette method. The sediment type was named according to the method of Shepard [6].
3. Result and Discussion

The characteristics of the earth's surface landscape or geomorphology that we see today on the South Coast of Java reflect the development of complex physical and chemical processes in the region since the beginning of the Paleogene Age (65-55 million years ago) is part of the Sunda Arc and is located on the edge of the Eurasian continental plate which is convergently subducted by the Indian Ocean Plate. The subduction of the Sunda Arc made the island of Java, which at that time was still a large land area (Sunda Land), experienced a decrease in a shallow sea (1).

Until the Late Miocene, the southern part of Java Island was the shallow sea, so that many coral and limestone formations intercalated with breccia, andesite, basaltic lava, crystalline tuffs, and dacite intrusion rocks. The tectonic process that forms the primary coast is followed by the process of working waves into the main configuration on the southern coasts of West Java.

Coastal morphological observations were carried out in several districts, namely Babujung Beach, Cipatujah District; KarangParanje Beach, Cibalon District; Santolo Indah Beach, Pameungpeuk District; KarangPapak Beach, Cicalobak Beach, and Manalusu Beach, Cikelet District; Karang Wangi Beach, Bungbulang District; RancaBuaya 2 Beach and RancaBuaya 1 Beach, Cisewu District (Table 1).

Beaches with the dominant size of gravel are found in 5 locations, namely beautiful Santolo beach, Parang Papak Beach, part of Taman Manalasu beach, Cicaloba Beach, RancaBuaya 1, and RancaBuaya 2. Apart from that, there is a beach with a dominant size of sand with boulders in its coastal area.

| No | Location               | Gravel (%) | Sand (%) | Silt (%) | Clay (%) | Sediment types | Coastal types       |
|----|------------------------|------------|----------|----------|----------|----------------|---------------------|
| 1  | Bubujung               | 0          | 97.6772  | 1.7614   | 0.5613   | Sand           | Secondary coast     |
| 2  | Bubujung               | 0          | 97.6206  | 0.8321   | 1.5474   | Sand           | Secondary coast     |
| 3  | KarangParanje          | 0          | 98.0879  | 0.2719   | 1.6402   | Sand           | Secondary coast     |
| 4  | KarangParanje          | 0          | 98.2611  | 0.2388   | 1.5001   | Sand           | Secondary coast     |
| 5  | Santolo Indah          | 0.8109     | 96.3186  | 0.7089   | 2.1615   | Sand           | Secondary coast     |
| 6  | Santolo Indah          | 3.5389     | 95.1663  | 0.0868   | 1.2080   | Sand           | Secondary coast     |
| 7  | Santolo Indah          | 87.8336    | 11.7650  | 0.0380   | 0.3634   | Gravel         | Primary and secondary |
| 8  | Parang Papak           | 51.8183    | 46.2937  | 0.7767   | 1.1112   | Sandy gravel   | Primary and secondary |
| 9  | Taman Manalusu         | 0          | 98.4396  | 0.1854   | 1.3750   | Gravelly sand  | Primary and secondary |
| 10 | Taman Manalusu         | 97.2325    | 2.5161   | 0.0396   | 0.2118   | Gravel         | Primary and secondary |
| 11 | Cicaloba               | 47.6666    | 49.9452  | 0.0371   | 2.3511   | Gravelly sand  | Primary and secondary |
| 12 | Karang Wangi           | 11.7689    | 86.2311  | 0.1736   | 1.8264   | Sand           | Primary and secondary |
| 13 | RancaBuaya 2           | 79.2573    | 20.0405  | 0.0449   | 0.6573   | Gravel         | Primary and secondary |
| 14 | RancaBuaya 1           | 90.845     | 8.2515   | 0.0373   | 0.8662   | Gravel         | Primary and secondary |
| 15 | RancaBuaya 1           | 6.232      | 92.6696  | 0.0242   | 1.0742   | Sand           | Primary and secondary |
Coastal type classification can be seen from the type of sediment and its formation process as seen from the relief structure and landscape. Primary beaches, in general, are seen from the formation of cliffs, bedrock, and coral reefs that are raised on the coast and at the mouth of a river due to tectonic processes. Meanwhile, the secondary coast is characterized by sediment deposits that are formed as a result of reworking or being destroyed by waves. The transported sediment on the beach due to waves is then used to determine the secondary beach type with the type of sand beach, gravel beach, or rocky beach [3].

The beach types in southern Garut described according to the classification are all secondary beaches, namely beaches formed by sedimentation and erosion processes after the formation of the previous beach by tectonic processes [6]. The secondary beaches in the Bubujung area are generally due to sea erosion and sedimentation, characterized by the presence of sand material transported by waves, the presence of berms and berms with gentle sand slopes (Figure 2). Based on the analysis of material content and mineral composition, the source of this sand is lava breccia rock originating from the coastal land around the coast of the area, which is eroded and transported by waves to the coast.

![Figure 2. Sandy Coast At Karang Paranje Beach, Garut 2016](image)

The slope of the beach which is obtained from measurements in the field, Bubujung Beach and Karang Paranje Beach are slopes of 0-3%, which means that this beach is very sloping. Sloping and sandy beaches have high vulnerability, however the presence of boulders of breccia spread across the Karang Paranje beachfront, protecting the coast behind it from coastal erosion (Figure 3).

![Figure 3. Lava breccia which acts as a natural barrier to the sand beach from erosion at Karang Paranje Beach](image)

Mixed beaches between Sand Beach and Rocky Beach are on Santolo Indah Beach, Karang Papak Beach, Manalusu, and Cicaloba Beach. This beach has a composition of marine sediment sediments such as shell fragments and carbonate rocks. The source of this sediment is from the sea and raised
ancient coral reefs that form coral reefs on the coast (Figure 4). Based on the irregular shoreline structure and the presence of raised reef flats due to tectonics, this beach is also a mixture of primary and secondary beaches. This type of beach can develop into a beach with an estuarine ecosystem, especially if there is a sunngai estuary and there is a flat reef in front of the beach which acts as a barrier to the waves (Figure 4).

![Santolo Indah Beach](image1)
![KarangPapak Beach](image2)

**Figure 4. Mixed/compound coast.** The type of beach is a mixture of sand and gravel, where the sand material comes from the sea/marine sediment and raised reef flats.

![Manalusu Beach](image3)
![Cicaloba Beach](image4)

The gravel beach is a beach with a dominant material size coarser than sand, namely gravel and gravel with a diameter of 2-8mm. There are gravel beaches on Santolo Indah beach, parang papak beach, some manalusu beaches, RancaBuaya 1 and RancaBuaya 2, and Karang Wangi beach (Figure 5). On the Karang Wangi beach, there is a primary beach type characterized by a raised riverbed consisting of metasedimentary rocks (Figure 6), and a combination with a secondary beach which is characterized by sedimentary sand deposits composed of carbonate rock and shells (Figure 7).

A sand beach with boulders and coral reef flats in front of the beach can be said to be a beach with natural protection [3]. The beaches in South Garut, West Java, generally consist of sloping beaches, but in some places, rock and sand cliffs are found as micro-topography with beach terraces in the form of coral reef flats, which have the potential to become estuarine beaches [4]. Estuary beach is a beach that is protected or has a protected area, because the barrier in the form of boulders and spit gravel in front of the beach will produce a rear beach that is protected from waves [2]. The weakening of this wave energy allows for the formation of finer sedimentary deposits in the form of sand and clay. It is known that in several places such as on the beaches of Bubujung, Cicaloba, Karangwangi and RancaBuaya, sand and a little clay sediment were also found. The shoreline sediment reflects the combination of the sediment source and the wave energy level. Complex variations in grain size form when gravel and...
coastal barrier rocks are eroded by waves and supply sedimentary deposits in various sedimentary fractions [2]. The sediments behind the rock tend to be smoother than those at the face of the rock.

**Figure 5.** Gravel beach with a mixed beach type of primary and secondary processes

**Figure 6.** River bed raised at Karang Wangi Beach
The interpretation of the value of gravel and rocky beaches for biota habitats requires knowledge of the velocity and energy levels of the waves related to the season period, sediment activity, exfiltration, and water infiltration to the beach surface [2]. Apart from that, the shape of the topography and the distance between the tides and the distance from the river mouth to the estuary also play an important role. However, in this study, the data obtained is only sufficient to describe the suitability of the type of beach with the biota habitat, one of which is crayfish/lobster. According to [5] in Garut Beach, three types of lobsters were found out of 6 species found in Indonesia. The three types of lobsters are P. homarus, P. longipes and P. versicolor. These lobsters are very dominant because they are a type of crayfish found in coral waters and coral reefs with tropical, fertile climates, and these lobsters are usually found hiding in holes, under or behind rocks with high and strong sea waves [5].

Figure 7. Sediment from sea sediment at Santolo beach and Karang Wangi beach

Table 2. Coastal type and Lobster habitat

| No          | Location          | Lobster name                  | Coastal type       | Sediment type | Topographic Characteristic |
|-------------|-------------------|-------------------------------|--------------------|---------------|---------------------------|
| Babujung    | -                 |                               | Secondary          | Sand          | Flat                      |
| Karang Paranje | -               |                               | Secondary          | Sand          | Flat                      |
| Karang Papak | P. homarus, P. longipes | Primary and Secondary | Gravel             | Sloping with Reef flat |
| Cicalobak   | P. versicolor     | Primary and Secondary         | Gravel             | Steepy with barrier |
| Karangwangi | P. versicolor, P. longipes | Primary and Secondary | Gravel             | Reef flats and rock barrier |
| Rancabuaya 1 and rancabuaya 2 | P. versicolor, P. longipes dan P. homarus | Primary and Secondary | Gravel             | Sloping with Reef flat    |

The lobsters with the highest number of individuals, namely P. vesicolor and P. homarus species were found on the coasts of Cicalobak, Rancawangi and Ranca Crocodile. This is because the suitable habitat for a mixed beach type is dominated by gravel, sand, with natural protection in the form of coral blocks in front of the beach and ancient reef flats, and has many holes for lobsters to hide from the onslaught of the waves (Table 2).
4. Conclusion
Based on the formation process, there are 2 types of beaches found on Garut Beach, namely secondary beaches and mixed beaches. Secondary beaches are generally in the form of sandy beaches and mixed beaches generally consist of sediment with various grain sizes of sand, gravel, and boulders. Sand beaches have a high susceptibility to erosion, but with the presence of gravel and boulders in front of the beach that functions as a barrier from the onslaught of waves, making this Garut beach a beach that has a high value for crayfish habitat because of its hollow rock structure and its position behind a barrier, rocks as natural protection.

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