The beach slopes and grain size distribution at Anoi Itam and Pasir Putih Beaches, Sabang City

S Purnawan1*, N A Mailala1, S Karina1, Muhammad1, I Setiawan1, Y Ilhamsyah1,2
1Department of Marine Sciences, Faculty of Marine and Fishery Sciences, Syiah Kuala University, Banda Aceh 23111, Indonesia
2Applied Climatology, Graduate School of Bogor Agriculture University, Bogor, Indonesia
*e-mail: syahrulpurnawan@unsyiah.ac.id

Abstract. Since ocean and land greatly influence on coastal processes, and continually affected by these dynamics, the coastal zone become the most dynamical region of the ocean. Coastal geomorphological changes principally in a more specific of beach processes and made of are found from the characteristics of the sediments over certain coastal waters. This research examines the relationship between beach slope and mean grain size. The objective of the research is to explain the mechanisms of sediment distribution associated with different beach slopes. The sampling locations were situated at Anoi Itam and Pasir Putih Beaches of Sabang City on October 2016 and April 2017. Coring method was used in this research. There were six collection sites with two repetitions of treatment in each location. The distribution of sediment based on grain size was measured using wet sieving procedure extracted by stratified sieving. The results showed that medium sand are dominant at Anoi Itam and Pasir Putih Beaches while beach slopes vary from nearly flat to gently sloping.

1. Introduction
Hydrological processes play a major role in sediment transport. Coastal dynamics such as: waves, tidal currents, stream flow affect sediment contents greatly [1]. Grain size is one of the fundamental properties in sedimentology that provides information about depositional environment and transport processes [2]. The relationship between sediment and coastal morphodynamics have been examined by some studies [3,4,5]. The characteristics of sediment are associated with variations of beach profiles. Thus, variations in grain size are described by the changes of beach profiles [6,7].

Seasonal variability influences the composition of sediment over certain waters [8], where transport processes and sediment deposition from one to another location cause the water bottom to change [9,10]. One of the constraints in this study, however, is the availability of long-term field data. Sabang city is administratively located at Weh Island, far northern Sumatera Island, Indonesia. Hydrodynamics condition of Weh Island waters is influenced by such adjacent waters as the Andaman Sea, the Malacca Strait, and the Indian Ocean [11]. Two sampling locations are chosen for the study, i.e., Anoi Itam and Pasir Putih Beaches, situated in the eastern and southern part of the Weh Island, respectively.

The beach sediment characterizes environmental influences and abundant mineral composition from surrounding areas [12,13]. Based on their given names, Anoi Itam is associated with dark sand with magnetite content while Pasir Putih is named after bright white sand with carbonate-silicate contents. Sediment characteristics in these two locations are different marked by coarser sediments found at Pasir Putih.
Field measurements of beach profiles, in this case the beach slope and sediment properties are important to conduct to achieve a better description of beach dynamics. This study focused on the relationship between seasonal beach slopes and grain size at Anoi Itam and Pasir Putih. The objective of the study is to obtain advanced understanding on seasonal variability of sediment dynamics over Weh Island.

2. Methods
Data were collected at Pasir Putih and Anoi Itam on October 2016 and April 2017. Each location consists of 6 stations, separated by a distance of 200 meters covering sediment samples and beach profiles (Figure 1). Sediment samples were collected by coring method to a depth of 5 centimeters beneath the ground surface. The extraction was done using wet sieving method with the following The Krumbein phi (φ) scale: -1, 0, 1, 2, 3, 4, and 5φ. The graphic mean was calculated based on the formula of Folk and Ward. Folk triangle was used to describe the types of sediment.

The characteristics of the beach is represented by beach slopes with the following expression:

\[
\arctan \alpha (\degree) = \frac{y}{x} \quad (1)
\]

\[
\text{Slopes } \% = \frac{\alpha}{90} \times 100\% \quad (2)
\]

![Figure 1. Sampling location in Pasir Putih Beach and Anoi Itam Beach, Weh Island, Aceh Province.](image-url)
3. Result and discussion

3.1 Result
Seasonal variability during October (west season) and April (east season) lead sediment types to change at 10 of 12 stations, both Anoi Itam and Pasir Putih beaches. It is shown that sediment textures are coarser from October to April at Anoi Itam (Table 1). Anoi Itam’s grain size range from 0.59φ to 1.82φ and has averaged of 1.37φ and 1.23φ during west and east season, respectively. Several stations at Pasir Putih showed coarser types of the sediment, but the average of grain size is less during east than west season (Table 2). Pasir Putih has mean grain size (Mz) ranged from -0.09φ to 2.09φ and has averaged 1.19φ and 1.35φ for west and east season, respectively. This is consistent with the presence of increasing find sand fraction during east season at Pasir Putih. An overview of the the grain-size shift that has occurred on the Pasir Putih Beach and Anoi Itam Beach can be seen in Figure 2.

Anoi Itam and Pasir Putih have typical gently slopes. It is found that the beach slopes at Anoi Itam and Pasir Putih change in response to season. In general, the slope is steeper during east than west season (Figure 3). The slope averages change from 2.63 to 3.40 during west and east season at Anoi Itam, respectively and 1.01 to 2.48 during west and east season at Pasir Putih, respectively. The relationship between slope variations and grain size are depicted from seasonal linear relationship in each sampling locations. The pattern showed the changes of the grain size (Mz) which are coarser as the slope increase (Figure 4 and Figure 5).

Table 1. Sediment textures and beach slope at Anoi Itam.

| St | Sediment percentage of class (phi) | Mz | Sediment type | Beach Slope (%) |
|----|----------------------------------|----|---------------|-----------------|
|    |                                  |    |               | October         |
| 1  | 9.30 13.51 42.11 29.23 3.34 2.53 0.00 | 0.60 | gS | 2.50 |
| 2  | 0.00 0.08 12.45 51.03 35.17 1.08 0.19 | 1.79 | S  | 1.50 |
| 3  | 0.32 0.74 40.02 44.40 13.48 0.89 0.15 | 1.18 | (g)S | 4.60 |
| 4  | 0.39 1.60 0.22 82.17 15.46 0.15 0.00 | 1.58 | (g)S | 3.90 |
| 5  | 0.88 0.97 27.72 66.70 3.48 0.25 0.00 | 1.21 | (g)S | 2.20 |
| 6  | 3.71 0.41 5.73 52.18 37.48 0.47 0.02 | 1.82 | (g)S | 1.10 |
|    | average | 1.37 |     | 2.63 |
|    | April   |      |     |      |
| 1  | 0.07 0.42 18.78 44.09 31.79 4.39 0.45 | 1.72 | (g)S | 1.60 |
| 2  | 0.18 2.71 41.89 49.42 4.37 1.19 0.24 | 1.07 | (g)S | 3.00 |
| 3  | 5.89 12.63 56.45 22.61 1.80 0.52 0.10 | 0.59 | gS  | 5.00 |
| 4  | 0.32 1.54 34.13 61.06 2.45 0.44 0.07 | 1.14 | (g)S | 3.60 |
| 5  | 0.00 0.27 30.31 64.50 4.75 0.13 0.04 | 1.22 | S  | 4.80 |
| 6  | 5.78 0.19 8.01 62.89 22.91 0.19 0.03 | 1.64 | gS  | 2.40 |
|    | average | 1.23 |     | 3.40 |

References: Sediment types were determined based on “Folk triangle”. Gravelly sand (gS); Sand (S); Slightly gravelly sand ((g)S).
Table 2. Sediment textures and beach slope at Pasir Putih.

| St | Mz Sediment type | Beach Slope (%) |
|----|-----------------|-----------------|
|    | Sediment percentage of class (phi) |                 |
|    | -1 0 1 2 3 4 5 | Mz 1.19 1.01    |
|----|-----------------|-----------------|
| October |
| 7  | 3.82 3.37 26.00 40.22 24.98 1.26 0.35 | 1.39 (g)S 0.80 |
| 8  | 0.47 1.02 13.39 55.20 26.77 2.86 0.28 | 1.73 (g)S 0.70 |
| 9  | 11.57 12.41 30.59 23.67 18.45 3.32 0.00 | 0.84 gS 1.30 |
| 10 | 22.86 3.66 19.16 45.15 8.07 0.71 0.39 | 0.55 gS 0.95 |
| 11 | 9.66 2.61 13.74 63.29 9.31 1.02 0.36 | 1.19 gS 1.00 |
| 12 | 1.55 3.02 20.48 54.13 19.24 1.21 0.37 | 1.42 (g)S 1.30 |
| average | 1.19 | 1.01 |
| April |
| 7  | 5.46 4.63 25.81 31.33 31.23 1.54 0.00 | 1.41 gS 3.30 |
| 8  | 0.14 0.23 2.93 40.36 48.56 7.73 0.05 | 2.09 (g)S 1.20 |
| 9  | 1.69 0.06 1.33 40.16 53.36 3.16 0.24 | 2.07 (g)S 2.50 |
| 10 | 39.47 8.51 31.71 17.03 2.94 0.26 0.07 | -0.09 sG 3.10 |
| 11 | 36.12 2.03 7.98 34.19 18.12 1.50 0.06 | 0.59 sG 2.40 |
| 12 | 11.29 0.59 1.52 24.98 58.60 2.98 0.05 | 2.03 gS 2.40 |
| average | 1.35 | 2.48 |

References: Sediment types were determined based on “Folk triangle”. Slightly gravelly sand ((g)S); Gravelly sand (gS); Gravelly sand (gS)
Figure 2. Changes in sediment grain size: a) Anoi Itam Beach in October 2016; b) Anoi Itam Beach in April 2017; c) Pasir Putih Beach in October 2016; d) Pasir Putih Beach in April 2017.
Figure 3. Changes in Beach slope: a) Anoi Itam Beach in October 2016; b) Anoi Itam Beach in April 2017; c) Pasir Putih Beach in October 2016; d) Pasir Putih Beach in April 2017.
3.2 Discussion

The variations of grain size obtained at foreshore are associated with energy received from wave and tidal activity [1], where coarser grain size characterized by high intensity of energy exposure [14,15]. Seasonal variability affects to the changes of sediment size distribution. On October, sediment was highly distributed at medium sand fraction (phi=2), while in April the distribution of sediments was more evenly distributed on the other fractions. This condition leads the average value to change where coarser grain size is found on April instead of October.

**Figure 4.** The relationship between beach slope and mean grain size (Mz) at Anoi Itam.

**Figure 5.** The relationship between beach slope and mean grain size (Mz) at Pasir Putih.
Generally, changes of the beach slope to the steep profiles are associated with coastal erosion due to intensive energy in that season. It is shown that a steeper profile occurred on April as confirmed by the changes of sediment roughness, in particular at Anoi Itam where coarser than averages were found. Although the average grain sizes were finer on April at Pasir Putih, but the additional gravel fraction was found during east season which is consistent with earlier statement where the erosion occurred on April. Seasonal variability plays a major role on the changes of beach characteristics and sediment at two locations. Wind circulation at Weh Island is strongly influenced by monsoonal pattern, i.e., southwest and northeast monsoon during August and February, respectively. Based on NCEP long-term data, averages wind velocity of 4 m/s flow over Weh Island [11]. Meanwhile, the ocean current move to the west from the Andaman Sea and the Malacca Strait, during northeast or southwest monsoon as confirmed by advanced model study by Rizal et al. [11,16].

Based on wind and current profiles around Weh Island, it is concluded that strong current toward west occurred on April, driven by strong wind circulation from east as well as current from the Andaman Sea and the Malacca Strait. These conditions have an impact on sediment variations at Anoi Itam and Pasir Putih on April where beach slope increase and coarser grain size are found in many stations. High energy during east season is suspected to transport finer grain size leading the slope to become steeper [17]. On the other hand, steeper changes of the beach slope influence the beach hydraulic conductivity, swash mechanism, which also correlated to grain size [18].

The relationship between the slope and grain size show nearly similar pattern in every condition during east and west season at Anoi Itam and Pasir Putih. It is shown that the steeper the beach, the coarser the grain size. The R-value in each location is likely to be lower if October (west season) and April (east season) data are combined. Thus, seasonal changes give different pattern and these might be expected to be separated [6].

4. Conclusion
Seasonal variability affects on the changes of sediment roughness and beach slopes, specifically steeper profile is found during east season. Despite the correlation between beach slope and grain size in this study is not significant, yet a slight tendency that finer sediment established at a gentle beach slope.

References
[1] Curtiss G M, Osborne P D and Horner-Devine A R 2008 Seasonal patterns of coarse sediment transport on a mixed sand and gravel beach due to vessel wakes, wind waves, and tidal currents Marine Geology 259 73–85
[2] Wilson A M, Huettel M and Klein S 2008 Grain size and depositional environment as predictors of permeability in coastal marine sands Estuarine, Coastal and Shelf Scienc 80 193–199
[3] Marino-Tapia I J, Russel P E, O’Hare T J, Davidson M A and Huntley D A 2007 Cross-shore sediment transport on natural beaches and its relation to sandbar migration patterns: 1. Field observations and derivation of a transport parameterization Journal of Geophysical Research 112 C03001 doi:10.1029/2005JC002893
[4] Austin M J and Buscombe D 2008 Morphological change and sediment dynamics of the beach step on a macrotidal gravel beach Marine Geology 249 167-183
[5] Reis A H and Gama C 2010 Sand size versus beachface slope- An explanation based on the Constructal Law Geomorphology 114 276–283
[6] Sajeev R, Sankaranarayanan V N, Chandramohan P and Nampoothiripad K S N 1996 Seasonal changes of the sediment size distribution and stability along the beaches of Kerala, south west coast of India Indian Journal of Marine Sciences 25 216-220
[7] Stauble D K 2005 A review of the role of grain size in beach nourishment projects National Conference on Beach Preservation Technology February 2 - 4, 2005. Destin, Florida
[8] Staub J R, Among H L and Gastaldo R A 2000 Seasonal sediment transport and deposition in the Rajang River delta, Sarawak, East Malaysia Sedimentary Geology 133 249–264

[9] Charkin A N, Dudarev O V, Semiletov I P, Kruhmalev A V, Vonk J E, Sanchez-Garcia L, Karlsson E and Gustafsson O 2011 Seasonal and interannual variability of sedimentation and organic matter distribution in the Buor-Khaya Gulf: the primary recipient of input from Lena River and coastal erosion in the southeast Laptev Sea Biogeosciences 8 2581-2594

[10] Mao Z, Pan D, Tang C L, Tao B, Chen J, Bai Y, Chen P, He X, Hao Z, Huang H and Zhu Q 2016 Dynamic sediment model based on satellite-measured concentration of the surface suspended matter in the East China Sea Journal of Geophysical Research Oceans 121 2755–68 doi:10.1002/2015JC011466

[11] Rizal S, Damn P, Wahid M A, Sundermann J, Ilhamsyah Y, Iskandar T and Muhammad 2012 General circulation in the Malacca Strait and Andaman Sea: a numerical model study American Journal of Environmental Science 8(5) 479-488

[12] Saniah, Purnawan S and Karina S 2014 Karakteristik dan kandungan mineral pasir pantai Lhok Mee, Beureunut dan Leungah, Kabupaten Aceh Besar Depik 3(3) 263-270

[13] Purnawan S, Alamsyah T P F, Setiawan I, Rizwan 2016 Sediment distribution analysis in Balohan Bay, Sabang Jurnal Ilmu dan Teknologi Kelautan Tropis 8(2) 531-538

[14] Purnawan S, Setiawan I, Haridhi H A, and Irham M 2018 Granulometric analysis at Lampulo Fishing Port (LFP) substrate, Banda Aceh, Indonesia IOP Conf. Ser.: Earth Environ. Sci. 106 012070

[15] Purnawan S, Setiawan I and Muchlisin Z A 2015 Sediment grain-size distribution in the Lake Laut Tawar, Aceh Province, Indonesia AACL Bioflux 8(3) 404-410

[16] Rizal S, Setiawan I, Iskandar T, Ilhamsyah Y, Wahid M A and Musman M 2010 Currents simulation in the Malacca Straits by Using three-dimensional numerical model Sains Malaysiana 39(4) 519–524

[17] Buscombe D and Masselink G 2006 Concepts in gravel beach dynamics Earth Science Reviews 79:33-52

[18] Kulkarni D C, Levoy F, Monfort O and Miles J R 2004 Morphological variations of a mixed sediment beachface (Teignmouth, UK) Continental Shelf Research 24 1203–18