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

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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:

$$\arctan \alpha\ (°) = \frac{y}{x} \tag{1}$$

$$\text{Slopes } \% = \frac{\alpha}{90°} \times 100\% \tag{2}$$

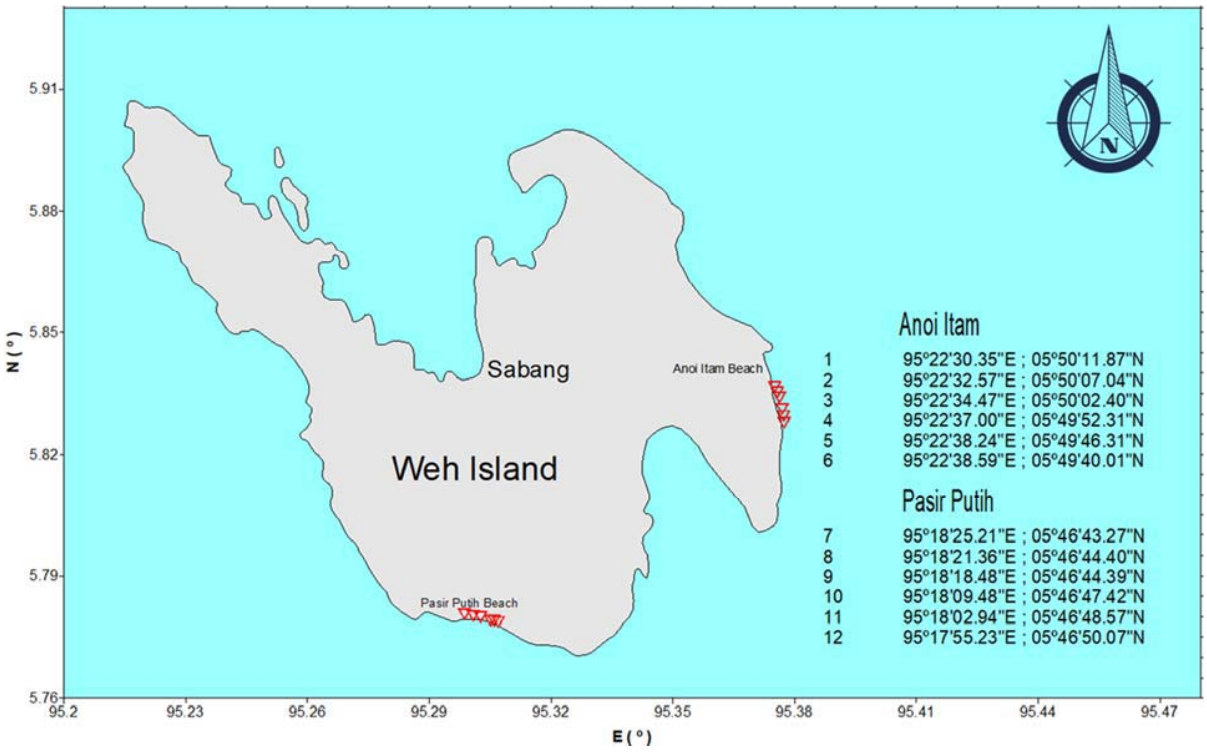

Figure 1. Sampling location in Pasir Putih Beach and Anoi Itam Beach, Weh Island, Aceh Province.

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 betweeen 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 (%)
	-1	0	1	2	3	4	5			
				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	Sediment percentage of class (phi)							Mz	Sediment type	Beach Slope (%)
	-1	0	1	2	3	4	5			
	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)

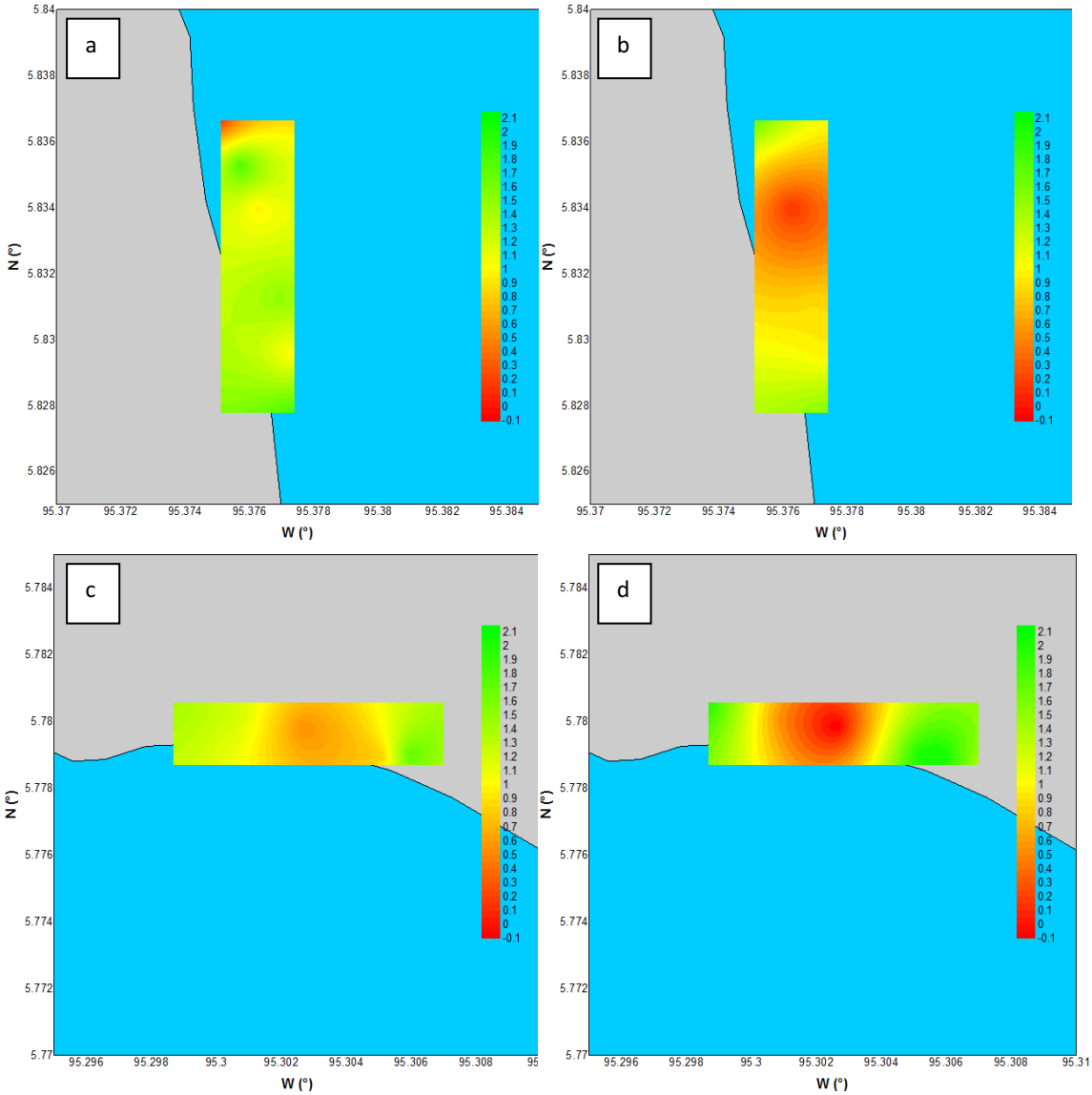

Figure 2. Changes in sediment grain size: a) Anoi Itam Beach in October 2016; b) Anoi Itam Beach in April 2017; c) Pasir Putih Beach in October 2016; d) Pasir Putih Beach in April 2017.

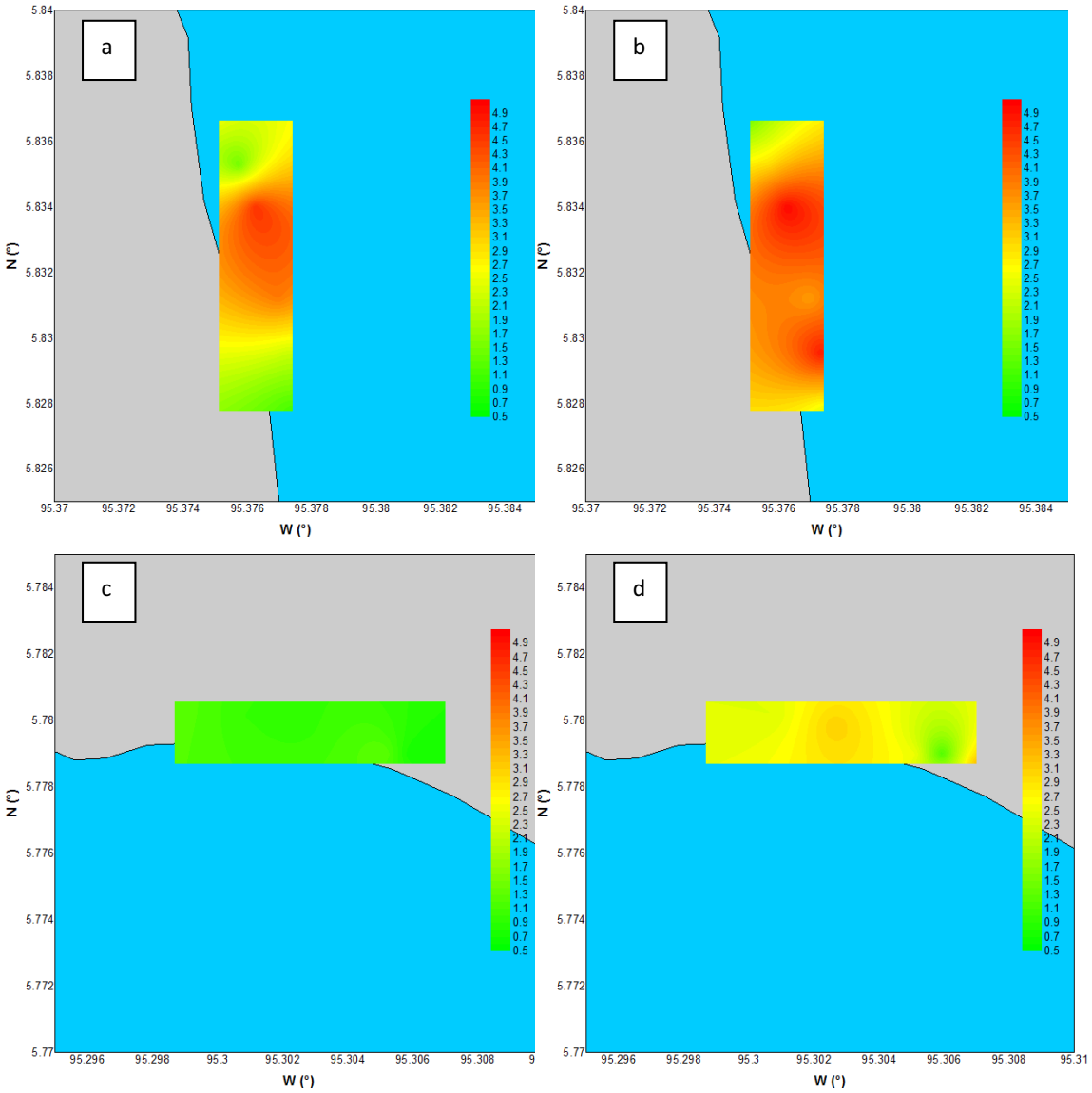

Figure 3. Changes in Beach slope: a) Anoi Itam Beach in October 2016; b) Anoi Itam Beach in April 2017; c) Pasir Putih Beach in October 2016; d) Pasir Putih Beach in April 2017.

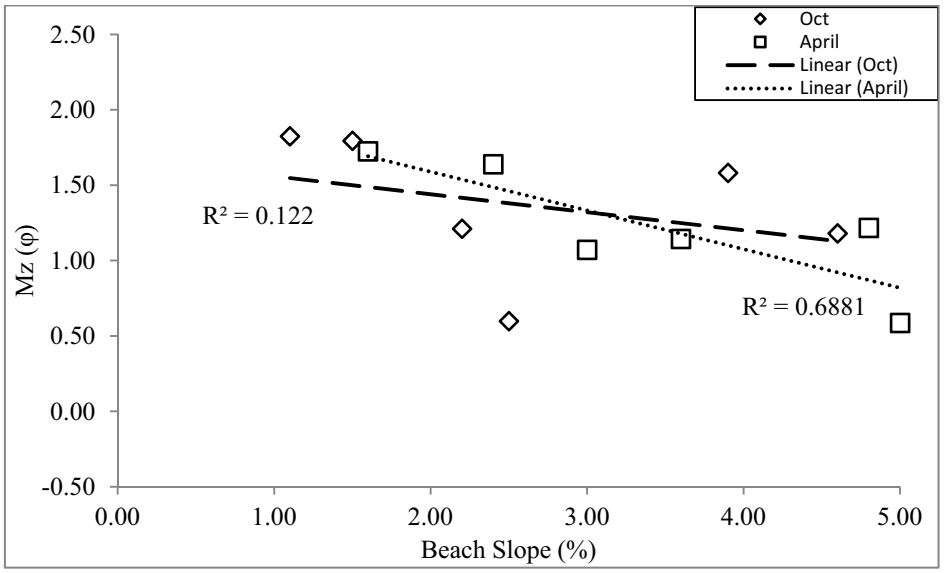

Figure 4. The relationship between beach slope and mean grain size (Mz) at Anoi Itam.

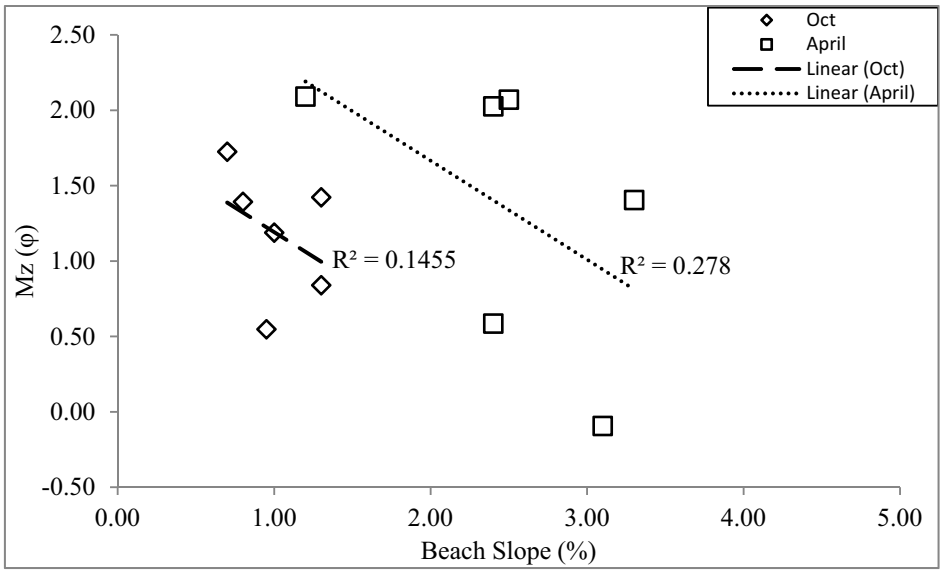

Figure 5. The relationship between beach slope and mean grain size (Mz) at Pasir Putih.

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.

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.

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