SEDIMENT PROPERTIES OF PANTAI PUNGGUR

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Abstract- Pantai Punggur or Punggur beach is one of the critically eroded locations identified along the south-west coast of Peninsular Malaysia. Before erosion mitigation is proposed, initial investigations including the determination of sediment properties along the shore should be made. In this study, pantai Punggur has been found to be a very mild-sloped mud flat with slope between 1:400 and 1:1000. From the soil samples collected along the shoreline in 2012 and 2013, Punggur beach is classified as having marine-clay sand with 75.83% to 122.63% moisture content and 2.2% to 11.2% organic content. Along the landward limit of the nearshore zone, the sediment consisted of well-graded sand while along the seaward limit, the sediment consisted of marine clay. Specific gravity for the sand is found to be between 1.1 and 1.85, while for the marine clay is 2.62. Based on Stokes' equation, the settling velocities obtained for sand samples are between 0.020 m/s and 1.197 m/s, and for clay samples are between $7.15 \cdot 10^{-7}$ m/s to $3.23 \cdot 10^{-5}$ m/s.

Keywords- Erosion; marine clay sand; Punggur; sediment properties

I. INTRODUCTION

Malaysia coastline faces problems of over-fishing, pollution, coral reef destruction, deforestation, and erosion, among others. According to Lim (2005), Malaysia loses at least 1,000 km2 of mangrove area due to land development and aquaculture activities. Approximately 6.1 million mangrove trees were planted on 23.93 km2 of Malaysia shore between year 2005 and 2012 to mitigate erosion problem (BERNAMA, 2013).

The National Coastal Erosion Study 1984 reported that nearly 30% (1,380km) of Malaysia coastline are facing erosion in 1980s (DID, 2005). Since the last two decades, coastal erosion problem continues consistently with variability in climate change, sea level rise and human activities as reported by Md Ali and Tan (2012).

According to Lee and Mohamed (2010), 55% of Peninsular Malaysia shorelines has shoreline vulnerability index (SVI) between high and extreme. The 3% extreme erosion vulnerability shoreline stretches from Tanjung Piadang, Perak to Port Klang, Selangor, Senggarang to Tanjung Piai, Johor, and Pekan, Pahang.

The study also estimated that the erosion rate ranged between 3 m/year to 5 m/year, and even exceeded 5 m/year at some locations.

In 2009, 9 locations on the south-west coast of Johor have been identified as critically-eroded, i.e. Punggur, Minyak Beku, Tanjung Laboh, Koris, Parit Balau, Sungai Lurus, Sungai Ayam, Sungai Suloh and Tampok (Ahmad, 2009).

Due to the wind shield by the Sumatera, the west coast of Peninsular Malaysia is characterized by mud flat with mangroves vegetation on a very mild slope between 1:400 and 1:1000 (Abdullah, 1992).

According to Prasetya (2007), the site-specific rate of erosion does depend on the local water depth, sediment properties, vegetation and exposure time to the tidal cycle.

Due to the importance of site specific sediment properties, the aim of the paper is to report on the characteristics of sediment along the critically eroded pantai Punggur as input for sediment transport process study.

Study area

Pantai Punggur is located on the west coast of Johor as shown in Fig. 1(a)-(c). Punggur beach serves as one of the local recreation spots.

The beach faces the shallow and narrow Malacca Strait (approx. 87 m deep and 120 km wide) (Awang, 2010).

The beach experiences south-west monsoon (late May to September) and semi-diurnal mixed tide. According to Lee and Mohamed (2010), sediments along the Straits of Malacca shoreline is mostly muddy.

Pantai Punggur is listed as one of the critically-eroded sites on the south-west coast of Johor (Ahmad, 2009), and the problem continues with the sea level rise and

global warming (Abdullah and Kumar, 2011).

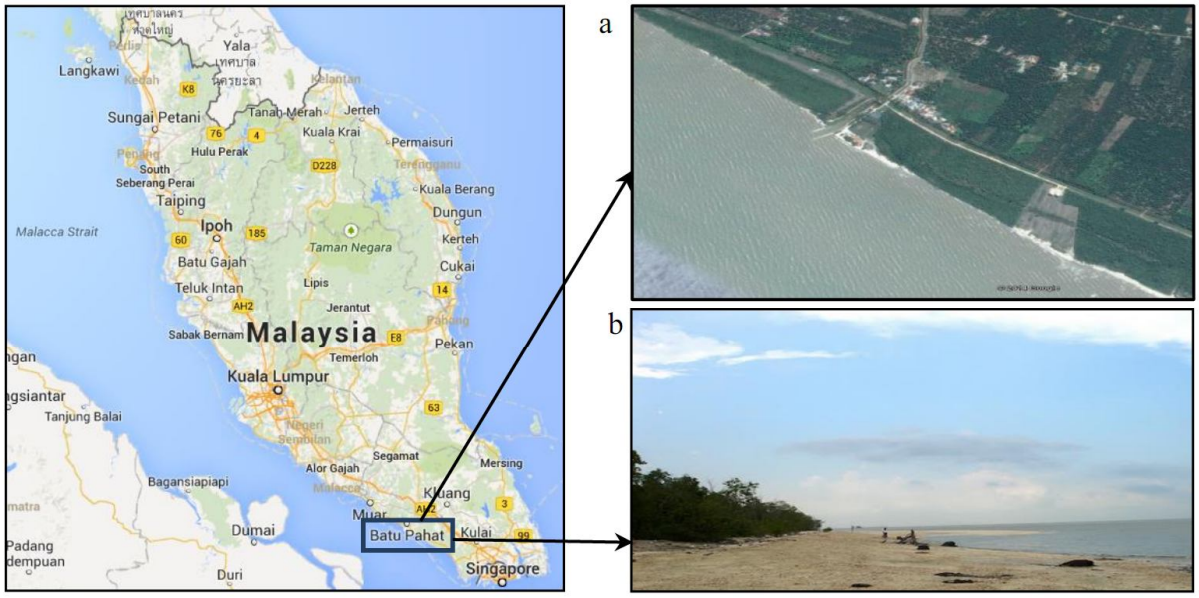


Fig. 1. (a) Location of pantai Punggur, (b) study area from google map (2014) and (c) condition of the beach in 2011

II. MATERIALS AND METHODS

Sampling points

Sediment samplings were carried out along 1.2 km of Pantai Punggur in two phases with a 1-year gap, that are on September 28 and 29, 2012 and September 26, 2013 as shown in Fig. 2. The location of sampling points are between latitude 1 • 40 • 53 • • N to 1 • 41 • 15 • • N and longitude 103 • 06 • 12 • • E to 103°5 • 46 • • E. During the first sampling in 2012, 15 sampling points were set-up along the shoreline, and divided into several zones based on level of tides, which are zone 1 (low tide level), zone 3 (high tide level) and zone 2 (in-between zones), which covered 600-m stretch along the beach and 600-m width between the low tide level and the high tide level. In 2013, investigation of soil properties were carried out again to strengthen the previous findings (of 2012) by establishing another 10 sampling points (5 points along shore on seaward limit and 5 points on landward limit) along a 1-km stretch of Pantai Punggur.

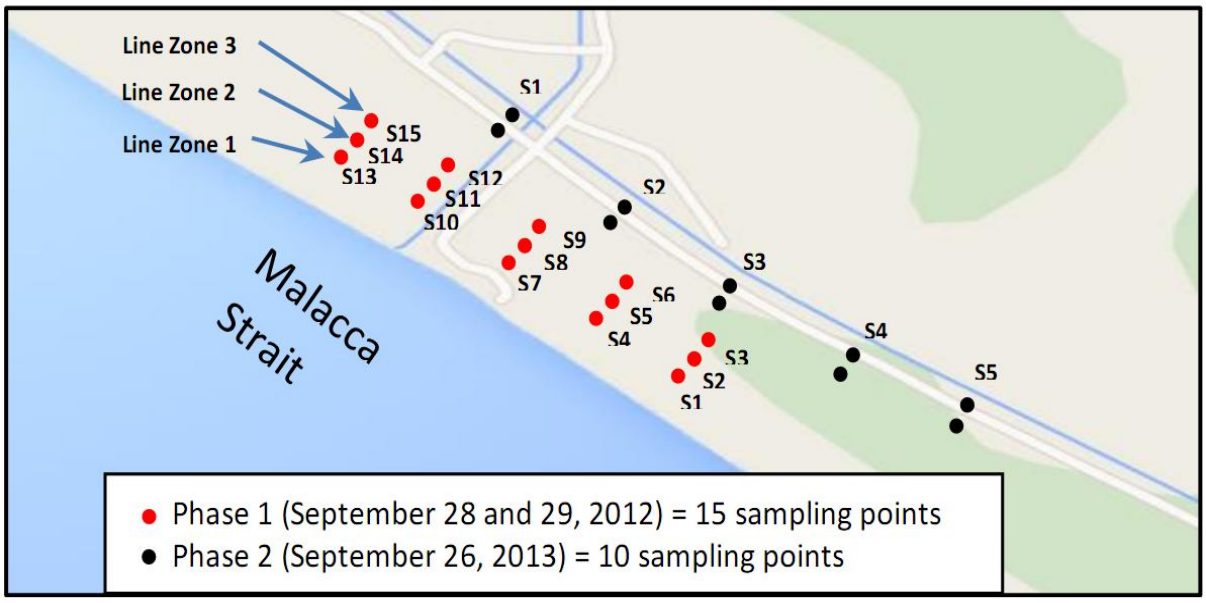


Fig. 2. Sketch map of 25 sampling points along 1.2 km of Pantai Punggur. Inlet: legend of phase 1 and 2 location (modified from goggle map 2014)

III. WIND SPEED AND WAVE HEIGHT

The wind speed for both years (2012 and 2013) along the southern Strait of Malacca is observed to be between 10 km/hr and 20 km/hr. Wave heights are from 1.0 m to 1.5 m in 2012 and 0.5 m to 1.0 m in 2013, obtained by interpolating recorded data at anjung Keling station (north) and Kukup station (south). The range of high and low tides for both stations are between 1.82 m and 2.77 m, and 0.78 m and 1.31 m, respectively. Laboratory tests Samples of sediment were collected at the sampling points using the peat sampler up to 1-m depth. In September 2012, the 15 samples collected were ran through Atterberg limit test, dry sieve analysis (using 0.075 mm to 10 mm sieve size) (BS1377: Part 2: 1990) and loss on ignition (LOI) test. In September 2013, 5 samples collected from the landward zone were dry sieved (0.063 mm to 5 mm sieve) while the 5 samples on the seaward zone were used in wet sieve analysis and analysed using CILAS 1180 Laser Particle Analyzer (since grain size are smaller than 0.01 mm). Small pycnometer was also used to determine specific gravity for coarse grain size.

Sieve analysis is used to determine the grain size at 60%, 30%, and 10% passing based on the Unified Soil Classification System (USCS), coefficient of uniformity Cu, and coefficient of curvature Cc. Sediment which has a very good uniformity, has Cu = 15 or greater. For gravel and sand, Cu must exceed 4 and 6, respectively. Sediment which has Cc between 1 and 3 are considered well graded (Das, 2010).

Sediment settling velocity (in m/s) estimated based on Stokes' equation is applicable for particles less than 2 mm, given as

$$V_s = \frac{D^2 g(\rho_s - \rho_w)}{18\mu}$$

where, D = grain diameter (m), g = gravitational acceleration (= 9.81 m/s2), ・s = density of settling particle (kg/m3), ・w = density of water (kg/m3), and ・ = dynamic viscosity of water at 20・C (= 0.001 kg/m.s).

IV. SEDIMENT PROPERTIES

Marine clay was found as the main type of sediment along the muddy coast of west coast Johor (Sieh et al., 1988; Tjahjanto and Sriyana, 2010) and usually is associated with coastal mangrove forests. As Punggur beach located in this range of area, marine clay is expected in this finding, but properties composition of each area usually slightly different and need to be determined. The sediment properties of Punggur beach are discussed in the following sections.

First Sampling
As preliminary study, 15 samples collected within tides level were carried out for plasticity index, distribution of size grain and percentage of organic content and discussed as below. Atterberg limit

Atterberg limits results are summarized in Table 1. Moisture content of samples at zone 1 and zone 3 ranges from 89.49% to 122.63% and 75.83 to 100.58%, respectively. The liquid limit at both zones is consistent with the moisture content. According to Chen et al. (2000), moisture content of soft clay is normally very high and closer or may exceed liquid limit. Another study on moisture content of soft marine clay in central west coast of Peninsular Malaysia was recorded as high as 125% (Ramamoorthy, 2007). As for plastic limit, samples from zone 3 are excluded due to existence of large particles between 0.06 mm and 5 mm.

Table 1 Summarize of Atterberg limit analysis for soil samples taken in September 2012

Parameter	Minimum (%)	Maximum (%)	Average (%)
Moisture content	75.8	122.6	99.2
Liquid limit LL	84.0	119.6	101.8
Plastic limit PL	40.1	52.5	46.3
Plasticity index PI	35.7	70.2	53.0

V. 1ORGANIC CONTENT

Organic content in soil samples ranges from 2.2% to 11.2% and samples at zone 3 mostly higher than other zones, which is above 6.5%. It shows that organic matter has been transported from seaward to the landward during tidal and wave flow, and deposited. A study conducted by Rahman et al. (2013) found that organic content is between 1.83% and 2.13% for marine clay coast of Kuala Muda, Kedah. It is show why this coast suitable for mangrove habitat.

Size distribution
The grain size distribution of collected sediment samples (between 300 g and 600 g each) are shown in Fig. 3(a)-(c) for zones 1, 2, and 3, respectively. Zone 1 shows a large range of percentage between the samples with sediment passing the size of 0.212 mm to 0.6 mm, while at zone 3 is no more than 10%. Grain size distribution shows that zone 1 is mostly sandy silt, zone 2 consists of fine sand, and zone 3 is dominated by gravelly sand. Percentage of sand is between 68% and 99% and gravel is between 21% and 30% in samples mostly from zone 3. Silt-clay reached a maximum 8.5% at S13, but is not more than 4% at other sampling points. Unfortunately, results for

distribution of grain size less than 2 mm cannot plot due to technical problem. This result can be seen as marine clay type.

Table 2 shows D60, D30, D10, Cu, and Cc for all 15 samples. The averaged grain size for all samples are D60 = 0.81 mm, D30 = 0.30 mm, and D10 = 0.16 mm. Averaged Cu and Cc are 4.68 and 0.81, respectively. The samples are classified as poorly-graded sand, although three of the five samples in zone 3 are well-graded sand.

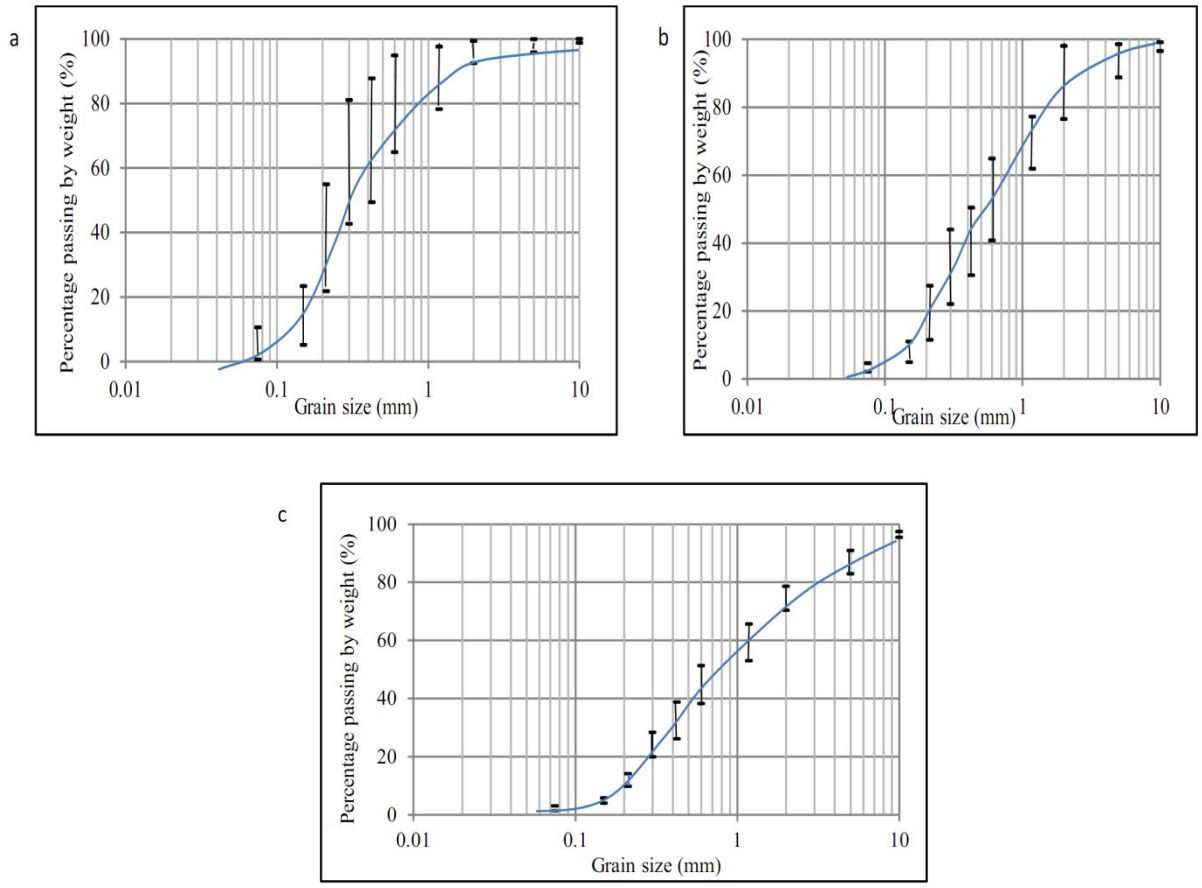


Fig. 3. Disibution of grain size (a) at zone 1; (b) at zone 2; and (c) at zone 3

Zone	Point	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c
1	S1	0.23	0.18	0.13	1.77	1.08
	S4	0.50	0.25	0.17	2.94	0.74
	S7	0.53	0.23	0.12	4.42	0.83
	S10	0.25	0.17	0.08	3.13	1.45
	S13	0.28	0.17	0.07	3.84	1.41
2	S2	0.58	0.25	0.17	3.41	0.63
	S5	0.95	0.40	0.20	4.75	0.84
	S8	1.20	0.37	0.19	6.32	0.60
	S11	0.57	0.25	0.17	3.35	0.64
	S14	0.54	0.23	0.14	3.86	0.70
3	S3	1.50	0.46	0.19	7.89	0.74
	S6	0.90	0.31	0.18	5.00	0.59
	S9	1.13	0.35	0.19	5.95	0.57
	S12	1.40	0.44	0.21	6.67	0.66
	S15	1.60	0.47	0.23	6.96	0.60

Second Sampling

After a year, 10 samples were taken again, however at different location due to tidal level changes. The results show the distribution of grain size and settling velocities between seaward and landward.

Size distribution

Fig. 4 shows the grain size distribution of the five samples (between 200g and 500g each) collected along the landward side of Punggur shoreline in 2013. The marker shows the range of percentage passing by weight for the five samples. Sediments collected consist of 0.8% fines and approximately 99.2% sand, which indicates coarse-grained soil. The averaged grain size at 60%, 30%, and 10% passing are D60 = 2.0 mm, D30 = 0.9 mm, and D10 = 0.3 mm, respectively.

Fig. 5 also shows the distribution of grain size for 5 samples collected along the seaward zone during low tide obtained from CILAS 1180. Distribution of marine clay shows the averaged size are D60 = 5.73 ・ m, D30 = 2.35 ・ m, and D10 = 0.92 ・ m.

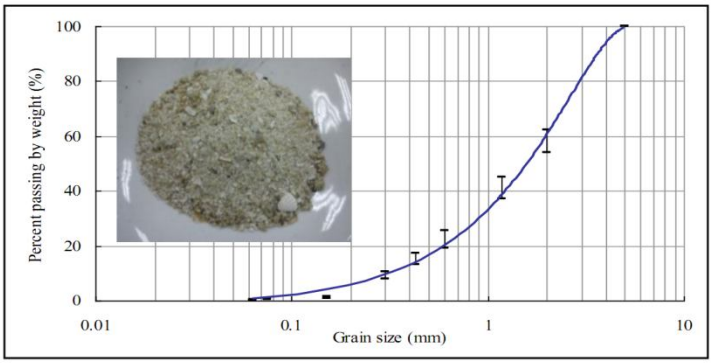


Fig. 4. Distribution of grain size for samples collected along the landward side of Punggur shoreline. Inset: Samples consist of sand and shells

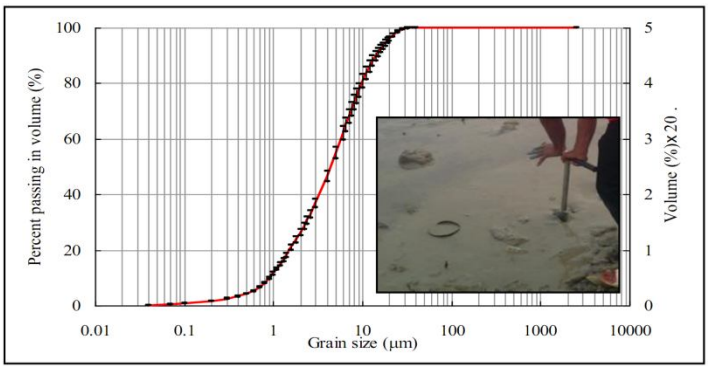


Fig. 5. Distribution of the marine clay samples collected along Punggur. Inset: Sampling of the clay

Continuing from Fig. 5, averaged Cu and Cc are 6.67 and 13.5, respectively, which classify the samples as well-graded sand. The details of landward and seaward sample analysis are shown in Table 3.

Table 3. Grain size at 60%, 30%, and 10% passing for sand and marine clay sample collected in 2013

Sampling point	Sand samples					Marine clay samples		
	D_{60} (mm)	D_{30} (mm)	D_{10} (mm)	C_u	C_c	D_{60} (μm)	D_{30} (μm)	D_{10} (μm)
S1	2.15	0.85	0.31	6.94	1.08	6.05	2.46	0.94
S2	2.12	0.77	0.28	7.57	1.00	5.46	2.28	0.90
S3	1.85	0.72	0.30	6.17	0.93	5.87	2.39	0.92
S4	2.15	0.90	0.34	6.32	1.11	5.38	2.23	0.91
S5	1.85	0.70	0.28	6.61	0.95	5.87	2.39	0.92

Specific gravity Gs

The specific gravity Gs for soil samples also determined. For coarser grain samples, the pycnometer was used and specific gravity was found to vary between 1.1 and 1.85. CILAS 1180 gave specific gravity Gs of the clay samples as 2.62. Rahman et al. (2013) stated that Gs for marine clay range between 2.4 and 2.6, and Ramamoorthy (2007) found the average specific gravity Gs that signifies marine clay is 2.6. In addition, Das (2010) states that specific gravity for silt and clay are between 2.6 hingga 2.9.

Settling velocity VS

Based on the grain size (Table 3), the settling velocities were obtained using Stokes' equation (Eq. 3), as shown in Table 4. According to Ramamoorthy (2007), the settling velocity for foreshore-inshore surface grain with diameter between 0.15 mm and 0.20 mm is less than 0.06 m/s. This verifies the settling velocities obtained for sand samples. The settling velocity for mud is typically between $1 \cdot 10^{-3}$ m/s and $1 \cdot 10^{-5}$ m/s (Odd, 1982).

Table 4. Settling velocities corresponding to the marine clay and sand samples in Table 3

Sampling point	Sand samples V_S (m/s)			Marine clay V_S ($\times 10^{-5}$ m/s)		
	D_{60}	D_{30}	D_{10}	D_{60}	D_{30}	D_{10}
S1	1.197	0.1870	0.0249	3.232	0.5343	0.0780
S2	1.163	0.1535	0.0203	2.632	0.4590	0.0715
S3	0.886	0.1342	0.0233	3.042	0.5043	0.0747
S4	1.197	0.2097	0.0299	2.556	0.4391	0.0731
S5	0.886	0.1268	0.0203	3.042	0.5043	0.0747

CONCLUSIONS

The sediment properties, i.e. the grain size distribution, organic and moisture content, specific gravity Gs, and settling velocity VS for pantai Punggur are reported. The sediment properties are important information in managing the shoreline. Future work should consider the sediment characteristics reported in the paper for further studies related to pantai Punggur.

ACKNOWLEDGEMENTS

The authors would like to thank Universiti Tun Hussein Onn Malaysia and other agencies which have contributed and support this study.

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