

ROLE OF WAVE-INDUCED OSILLATORY MOTIONS IN DEVELOPPMENT OF SANDY-MUDDY TRANSITIONAL BEACHES ON SOUTH CHINA COASTS

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INTRODUCTION

Sandy-muddy transitional beaches (SMT-Beaches) consist of an upper sand shoreface and a lower mudflat, connected by a distinct sand-mud transition (SMT) boundary (Fig. 1). The formation and development of SMT-Beaches require unique geological and dynamical conditions. Therefore, SMT-Beaches receive less attention compared with sandy beaches or sand-gravel mixed beaches. SMT-Beaches are mainly supplied with the sediments originating from e.g., river mouths, and the mud finally deposits on the intertidal or subtidal zone (Anthony and Dolique, 2004). The position of SMT boundary depends on the hydrodynamically controlled non-deposition of mud and the intensity of the mud supply. On SMT-Beaches, the exchange of sediments between the upper beachface and the lower shoreface is still unclear. Unlike pure sandy beaches with sufficiently in-depth studies, it is found that the exchange between the upper and lower shoreface is dominated by waves (Anthony and Aagaard, 2020), e.g., sandbar offshore migration transporting sediments from the upper shoreface to the lower shoreface under energetic wave conditions (Li et al., 2021), and onshore migration and welding of sandbars transporting sediments from the lower shoreface to upper shoreface under mild wave conditions. So far, studies on sediment transport on SMT-Beaches are just starting up (Guo et al., 2021). More attention needs to be paid to the hydrodynamically-controlled mud deposition, to get comprehensive insights on the formation of the SMT-Boundary.



Fig. 1 Snapshots of a typical SMT-Beach at South China Coasts

METHODS

Field observations were conducted on 4 SMT-Beaches along the South China Coasts in April 2018 (Zhao et al., 2020). These 4 SMT-Beaches include Changshacun Beach (CC), GW Beach (GW), Lieyu Beach (LY) and Nantaiwu Beach (NT). During the survey, the beach profile was surveyed from the backshore above the high-water level to a typical offshore location with approximately 30 cm-thick mud on the mudflat. The real-time kinematic continuously operational reference station was used to measure beach profile variations. In this study, the shoreline ($x = 0$ m; $z = 0$

m) is set at the location (elevation) of the intersection of the mean sea level and the beach profile. Sediment samples from the top 5 cm surface sediments were collected. The analysis of grain size distribution of surface sediments was conducted using a laser particle size analyzer. Wave transformations are modelled using a parametric wave model (Zhang et al., 2021).

SEDIMENT CHARACTERISTICS

The probability distribution of particle size of the two types of sediments (i.e., sand-dominated and mud-dominated) on, shoreward and seaward of the SMT boundary are provided in Fig. 2. The probability distributions of sediments shoreward of the SMT boundary are generally unimodal, the primary peak locates at a particle size of 0.35 mm (16%), 0.18 mm (13%), 0.18 mm (10%) and 0.15 mm (15%) for CC, GW, LY and NT, respectively. Compared with sediments shoreward of the SMT boundary, the probability distribution becomes broader at the SMT boundary in CC, where the probability decreases at the peak and increases at both its larger and smaller particles. While in GW and NT, the probability distribution at the SMT boundary in GW and NT becomes narrower. In GW and LY, the probabilities of coarse particles are negligible at the SMT boundary. On the mudflat, the probability distribution differs in these four beaches, i.e., it is trimodal, bimodal, unimodal and bimodal in CC, GW, LY and NT, respectively. In CC, GW and NT, a peak grows at the small particle size between clay and silt.

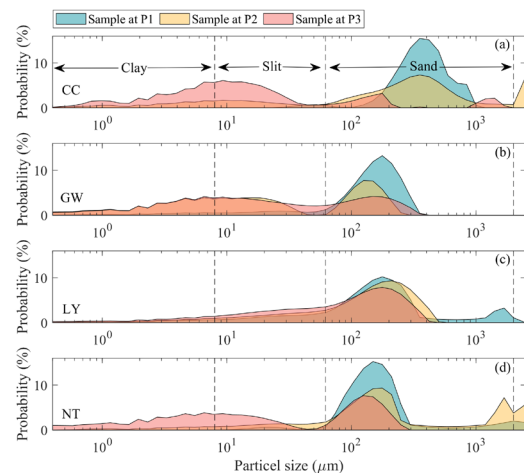


Fig. 2 Probability distributions of sediments shoreward, on and seaward of the SMT boundary in (a) CC; (b) GW; (c) LY and (d) NT

ROLE OF WAVE-INDUCED OSILLATORY MOTIONS
Waves tend to carry fine-grained sediment away from the shoreline mainly by the prevention of settlement of fine

sediments by wave-related oscillatory motions. To clarify the role of waves, an idealized analysis of the exceeded Shields parameter is provided. There are a few assumptions and simplifications before the analysis.

- (1) First, a representative grain size for fine sediments is selected as the grain size with a peak probability in the range of clay to silt at P3. The representative grain size d_m is 0.06 mm, 0.1 mm and 0.06 mm for CC, GW and NT, respectively.
- (2) Since it is difficult to determine the critical state for the deposition of fine sediments, they are pre-assumed to deposit on the whole beach profile. If it is not the case, they will be picked up by waves, i.e., with a positive exceeded Shields parameter.
- (3) Three tidal elevations are used to represent the low tide, middle tide and high tide. These three tidal elevations for CC, GW and NT are (-1, -0.5, 0) m, (-1.5, -1, -0.5) m and (-1, -0.5, 0) m, respectively. These tidal elevations are chosen to ensure the area (P1-P3) is submerged and seaward of the shore-breaker. Wave breakings are not considered.
- (4) Tidal modulations of offshore wave heights and cohesion of fine-grained sediments are neglected.

A positive exceeded Shields parameter (i.e., $\theta - \theta_c > 0$) means fine sediments (i.e., mud) cannot deposit on the beach profile, and vice versa. As can be seen in Fig. 3a, the critical position for fine sediment deposition ($\theta - \theta_c = 0$) migrates onshore as the tidal level increases. In CC, the critical positions at low-to-middle tides are generally close to the SMT boundary, implying the variations of sediment composition between these two boundaries are caused by the sediment suspension supported by wave-induced oscillatory motions. However, the wave-induced oscillatory motions cannot fully explain the sediment variations on both sides of the SMT boundary, since the critical positions are all further shoreward in CC, implying fine sediments with this representative diameter can deposit shoreward of the SMT boundary.

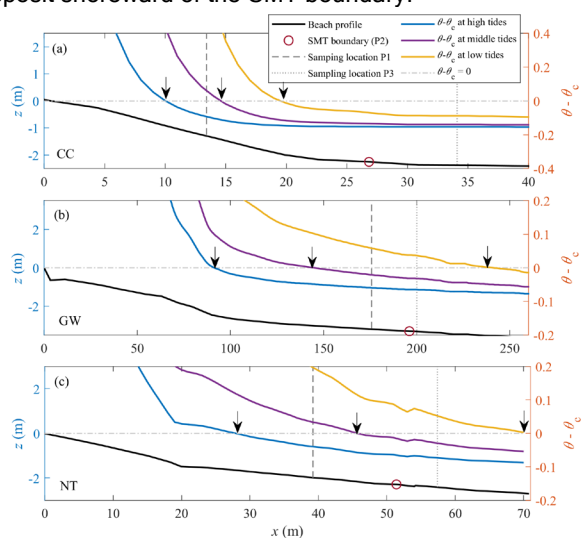


Fig. 17 Cross-shore distributions of exceeded Shields parameters at low-to-high tides in (a) CC; (b) GW and (c) NT. The critical position for mud deposition is denoted as the arrow.

The critical positions at low-to-middle tides present a broad cross-shore span of migration in GW and NT. This cross-shore span covers the SMT boundary, indicating that wave-related oscillatory motions play a dominant role in the formation of the SMT boundary. Fine sediments around the SMT boundary can experience a suspension-to-deposition cycle during a tidal period. According to Figs. 3b and c, fine sediments with this representative diameter can hardly deposit shoreward of the SMT boundary, it can be inferred that fine sediments deposited shoreward of the SMT boundary at high tides would be picked up at low tides.

CONCLUSIONS

To sum up, the critical position for the deposition of fine sediments with a representative diameter generally corresponds well with the SMT boundary, indicating that wave-related oscillatory motions play a dominant role in the formation of the SMT boundary. However, wave-related oscillatory motions cannot fully explain the formation of SMT boundary in the embayed beach (i.e., CC) since the critical position is more shoreward. This is because the beach exposure to waves is reduced and wave-related oscillatory motions cannot solely support the suspension of the mud particles. Besides, it can be found that the critical position in the embayed SMT-Beach is more shoreward than that in the estuarine SMT-Beach (i.e., GW and NT). This explains the more shoreward placement of SMT boundary in embayed beaches. Furthermore, the critical position for mud deposition migrates in a broad cross-shore span in estuarine SMT-Beaches, resulting in an unstable and ambiguous SMT boundary that exhibits large variations in the cross-shore direction.

REFERENCES

- Anthony, & Aagaard, (2020). The lower shoreface: Morphodynamics and sediment connectivity with the upper shoreface and beach. *Earth-Science Reviews*, 210, 103334.
- Anthony, & Dolique, (2004). The influence of Amazon-derived mud banks on the morphology of sandy headland-bound beaches in Cayenne, French Guiana: a short- to long-term perspective. *Marine Geology*, 208 (2-4), 249-264.
- Guo, Shi, Chen, Castelle, Chang, & Cheng, (2021). Sand-mud transition dynamics at embayed beaches during a typhoon season in eastern China. *Marine Geology*, 441, 106633.
- Li, Zhang, Chen, Zheng, Sun, & Wang, (2021). Barred beach profile equilibrium investigated with a process-based numerical model. *Continental Shelf Research*, 222, 104432.
- Zhao, Qi, Cai, Zhu, Zhou, & Lei, (2020). Morphological and sedimentary features of sandy-muddy transitional beaches in estuaries and bays along mesotidal to macrotidal coasts. *Earth Surface Processes and Landforms*, 45 (7), 1660-1676.
- Zhang, Li, Zheng, Xie, Shi, & Wang, (2021). Parametric modelling of nearshore wave reflection. *Coastal Engineering*, 169, 103978.