Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

Research on the sampling performance of a new bionic gravity sampler

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Cite this as: Yongqiang GE, Jiamin HE, Jin GUO, Peihao ZhANG, Hao WANG, Ziqiang REN, Xiaoling LE, Ying WANG, Yuhong WANG, Jiawang CHEN, 2023. Research on the sampling performance of a new bionic gravity sampler. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 24(8):692-709. https://doi.org/10.1631/jzus.A2200442

Analysis of the Mechanics of Gravity Sampler Tube

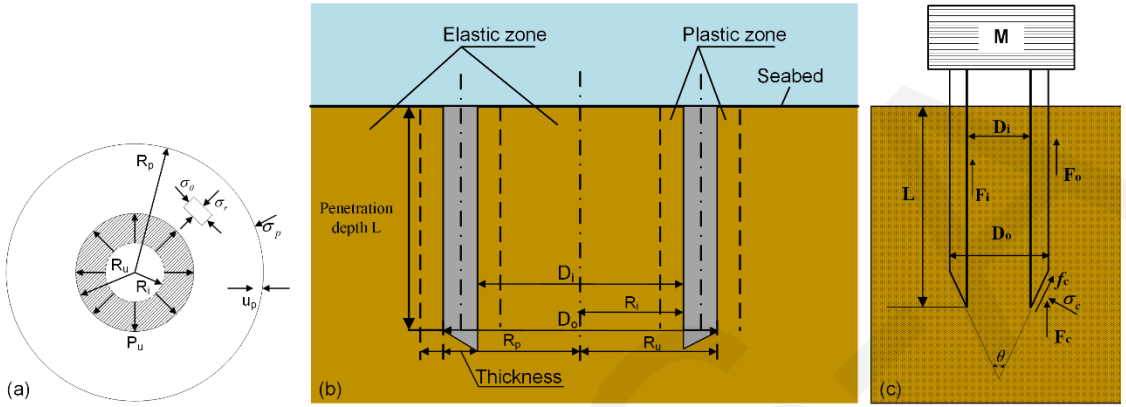


Fig. 1 (a-b) diagram of spherical cavity expansion model; (c) frictional resistance analysis of the sampler tube.

The radial dis-placement in the elastic-plastic interface can be expressed as:

$$u_p = \frac{(1+\mu)}{2E} R_p \left[P_u - 4c_u \ln \frac{R_p}{R_u} \right]$$

The ultimate reaming pressure can be expressed as:

$$P_u = \frac{4c_u}{3} \left(1 + \ln \frac{G}{c_u} \right)$$

The frictional resistance on the inner surface of a sampler tube can be expressed as:

$$F_i = 1000 \left(1 + J_s v_p \right) \pi D_i \int_0^L \alpha_{fi} \left(1 + 1.3L \right) dL$$

The frictional resistance on the outer surface of the sampler tube can be expressed as:

$$F_o = 1000 \left(1 + J_s v_p \right) \pi D_o \int_0^l \alpha_{fo} k_s \left(1 + 1.3l \right) dl$$

The resistance at the knife edge of the sampler tube can be expressed as:

$$F_c = 1000 \frac{\pi k_s}{4\alpha_{fc}} \left(1 + J_c v_p \right) D_o \left(D_o - D_i \right) \left[1 + \alpha_{fc} \cot \left(\frac{\theta}{2} \right) \right] (1 + 1.3l)$$

The effective factors on gravity sampling

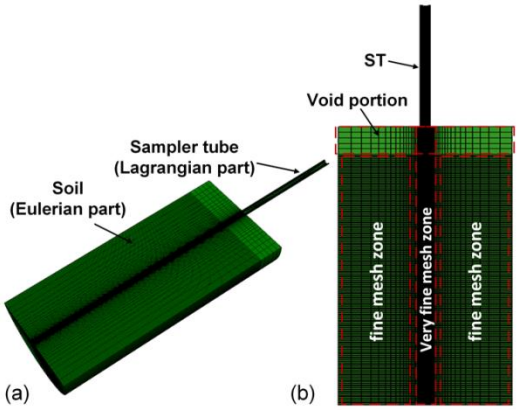
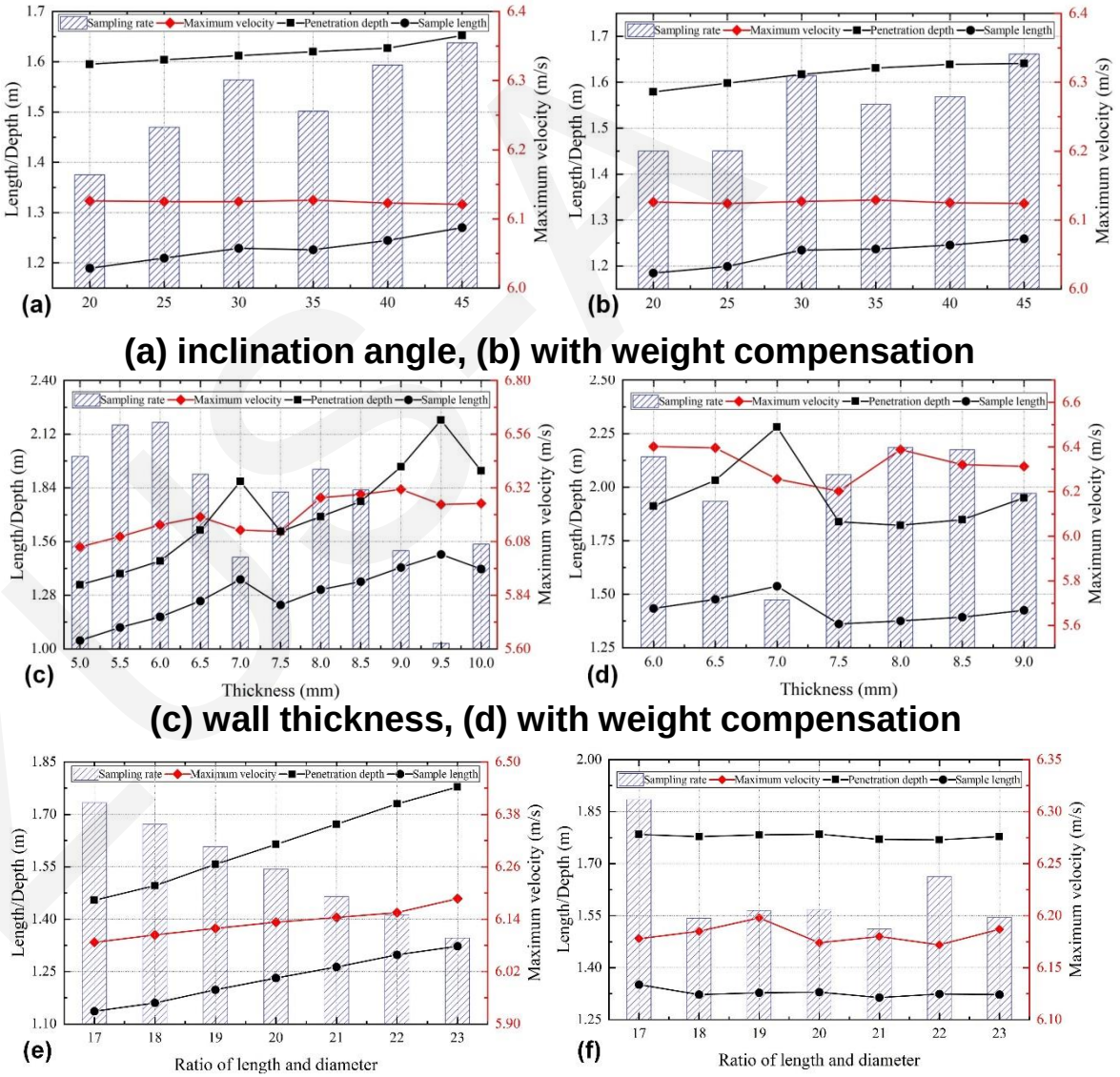


Fig.2. Typical mesh and geometry parameters used in CEL analysis

Table 1. Parameters of the sampler tube and soil used in CEL analysis

	Tube	Soil
ρ (kg/m^3)	7800	1260
E (kPa)	2.1e+8	1160
μ	0.3	0.32
L (m)	1.87	3.5
D (mm)	80	800
h (mm)	7.5	*
θ (°)	15-45	*
φ (°)	*	0
α (°)	*	0.1



(a) inclination angle, (b) with weight compensation

(c) wall thickness, (d) with weight compensation

(e) ratio of length and diameter, (f) with weight compensation

Fig.3. The sampling performances of the sampler tube with different factors.

The sampling performance of the BST with bionic non-smooth outer surface

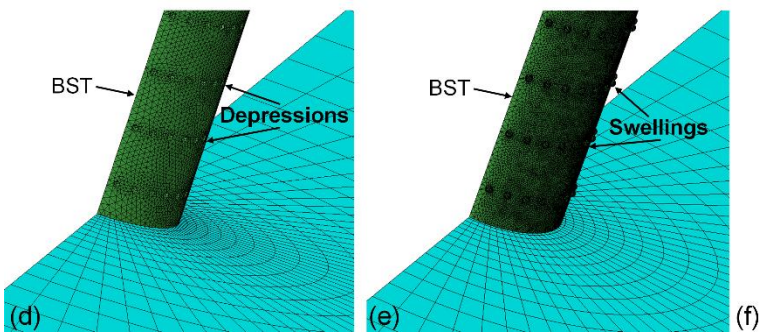


Fig.2. 3D mesh of bionic sampler tube.

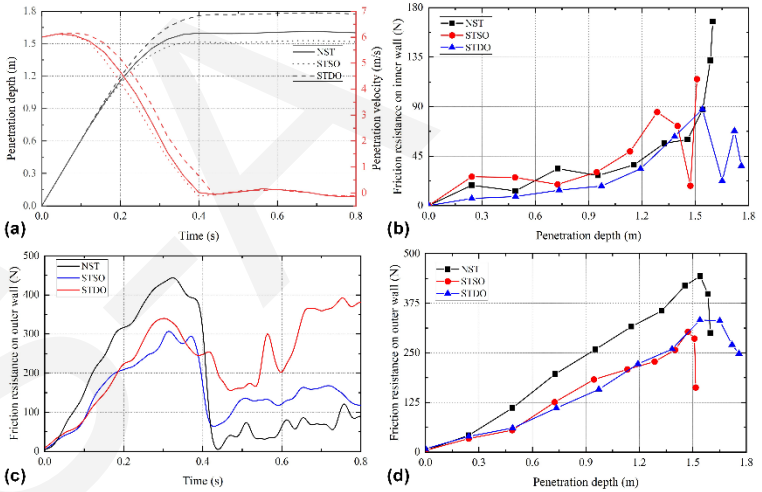


Fig. 4 (a) penetration depth and velocity, (b) friction resistance on inner wall, (c-d) friction resistance on outer wall.

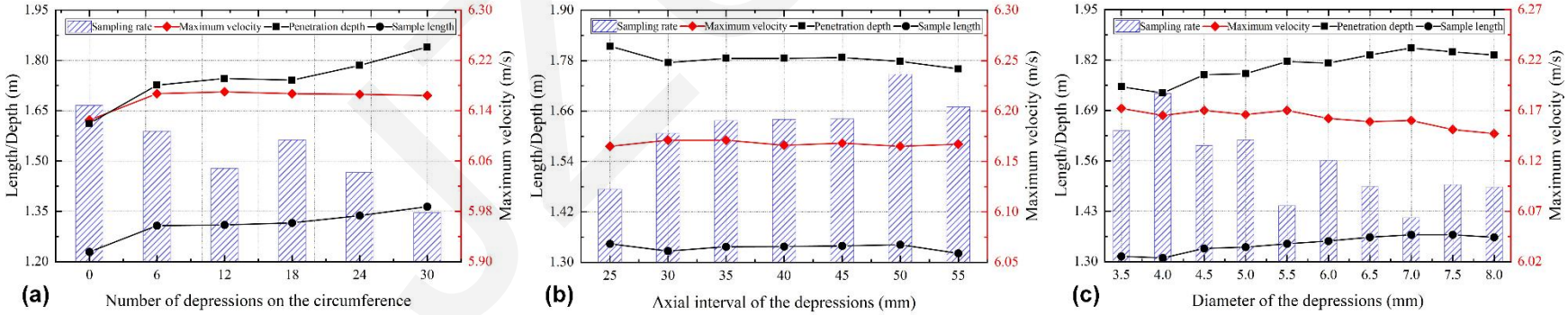


Fig. 5. The influence of different factors on sampling performance. (a) The circumferential distribution, (b) the axial interval, (c) the diameter.

The sampling performance of the BST with bionic non-smooth inner surface

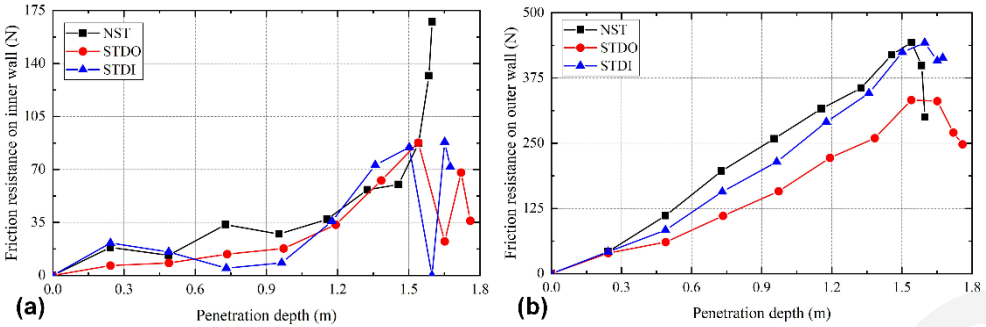


Fig. 6 Penetration resistance of sampler tube (a) on inner wall, (b) on outer wall.

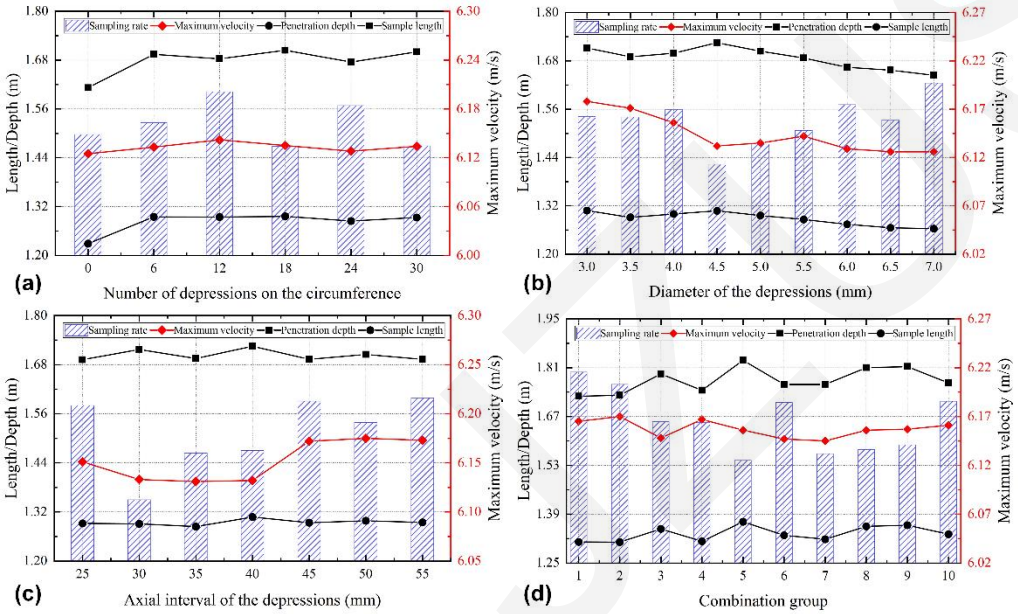


Fig. 6 The sampling performance of STDI. (a) the number of depressions on the circumference, (b) the diameter of the depressions, (c) the axial interval of the depressions, (d) combination group.

Table 3 Comparison of the sampling performance of STDI, STDO and NST

	NST	STDO	STDI
Penetration depth	1.612	1.785	1.675
Sample length	1.229	1.337	1.284
Maximum velocity	6.125	6.166	6.128
Sampling rate	76.2%	74.9%	76.7%

Table 4. The specifications of each combined bionic sampler tube.

	*d*1	*d*2	*n*	Δ*d*	Δ*h*
1	4.5	4.5	18	40	0
2	4.5	4.5	18	40	10
3	4.5	4.5	18	40	20
4	4.5	4.5	18	40	30
5	7	7	24	40	0
6	7	7	24	40	8
7	7	7	24	40	16
8	7	4.5	18	40	0
9	7	4.5	18	40	8
10	7	4.5	18	40	16

Indoor Experiment and Results

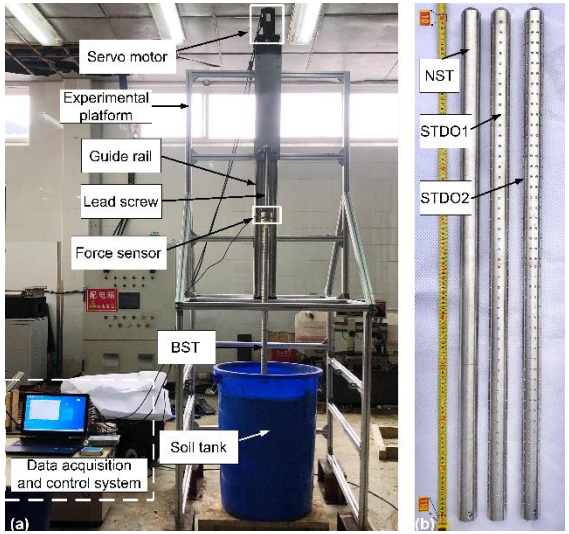


Fig. 7 Layout of the experiment setup

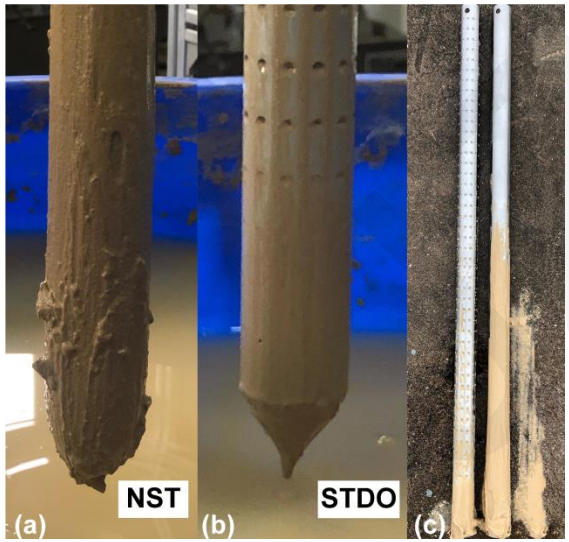


Fig. 7 The adhesion of soil on the sampler tube

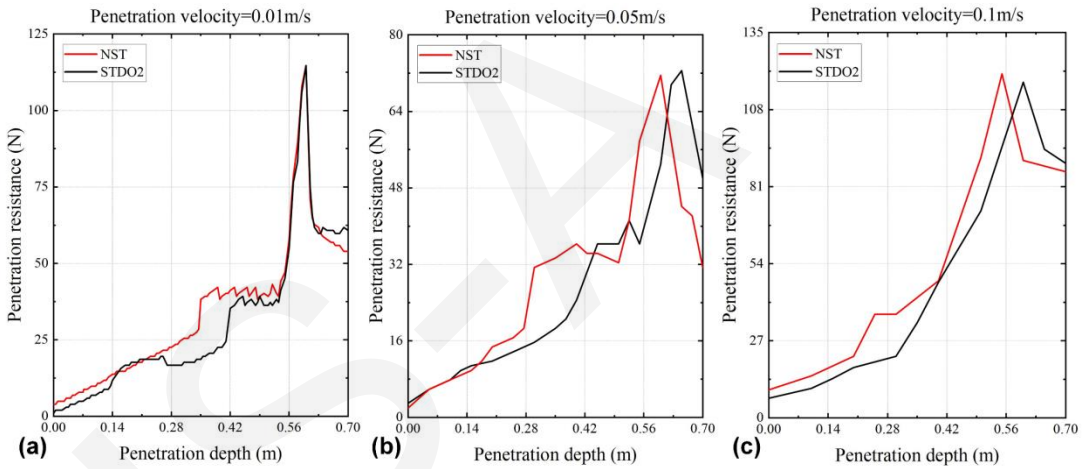


Fig.7 Penetrating test results. (a) velocity is 0.01 m/s, (b) velocity is 0.05 m/s, (c) velocity is 0.1 m/s.

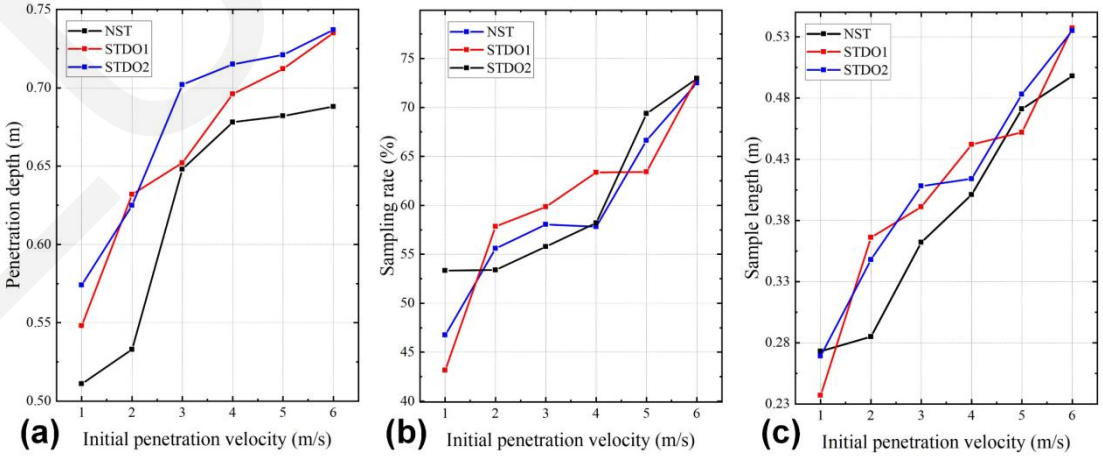


Fig. 9 The laboratory penetration test results of the NST and STDOs at different initial penetration velocity. (a) The penetration depth, (b) sampling rate, (c) sample length.

Tidal Flat Experiment and Results

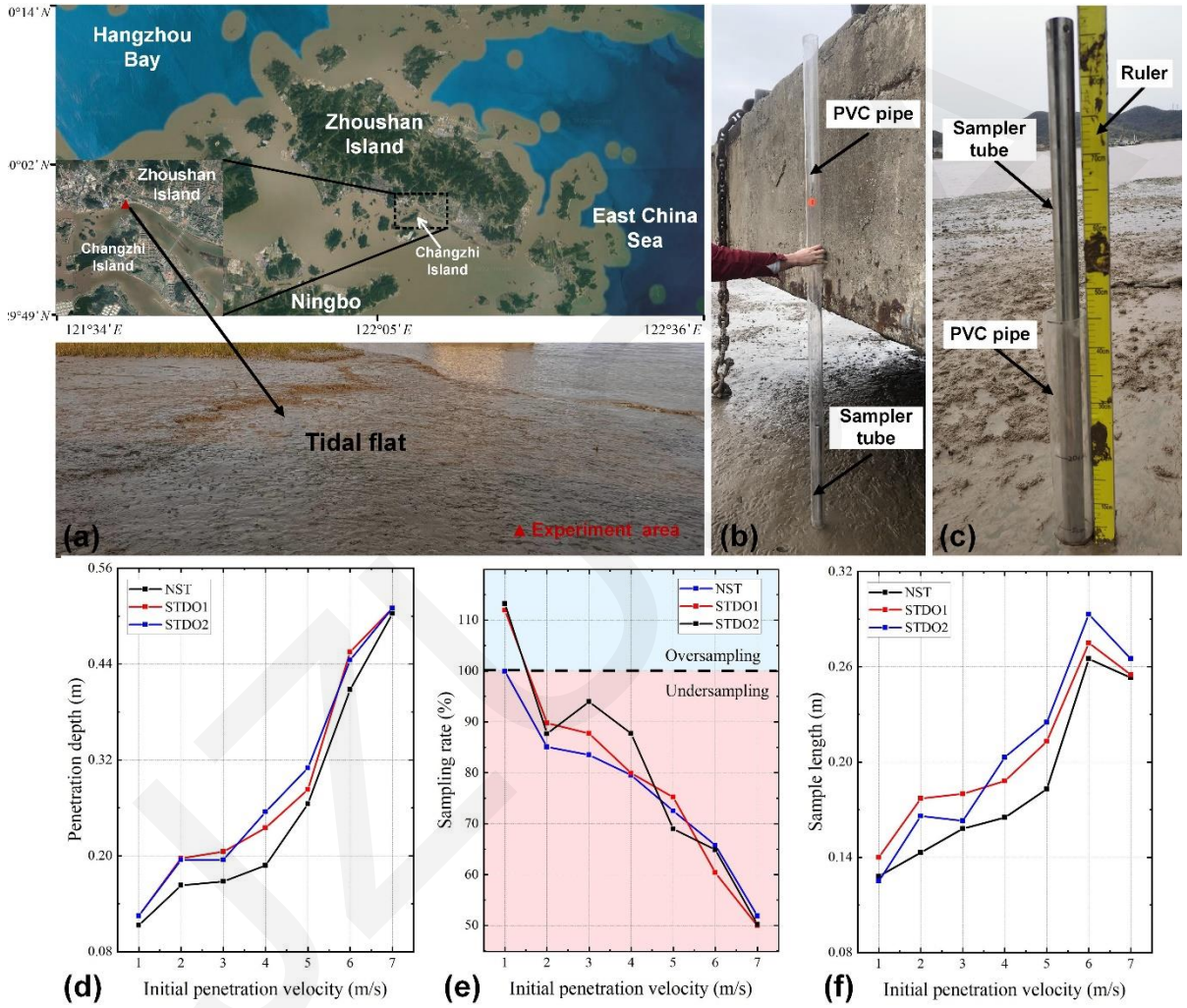


Fig. 8. Tidal flat sampling tests and results. (a) experiment area, (b) the sampler tube pass through the PVC pipe, (c) the penetration depth was measured by a ruler. (d-e) the penetration depth, sampling rate and sample length of the NST and STDOs.