

# Deformation and stability of the seawall, considering the strength uncertainty of cement mixing piles

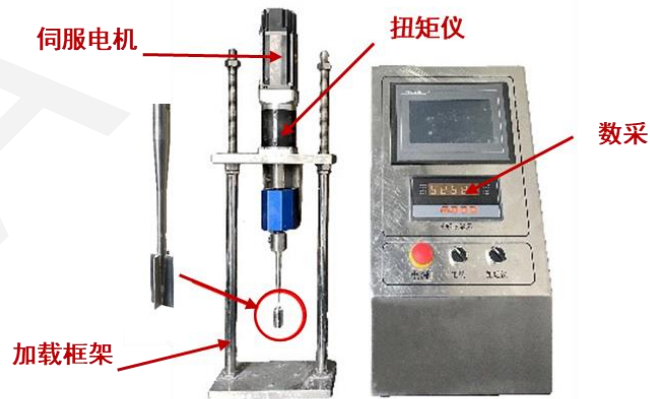
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### 试验方案

土体类别	浸泡环境	水泥掺量 $a_c/\%$	含水率 $w/\%$	时间 $t/h$
西店湾淤泥土	海水	8/11/14/17/20	55/60/65/70/75	2/4/7/10/24



### 试验步骤

按配合比称取实验材料



搅拌、填入模具并振捣均匀



海水浸泡

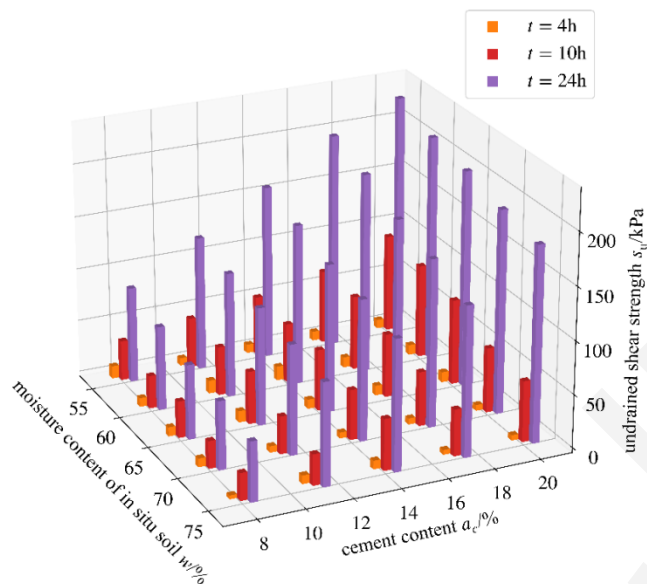


十字板剪切

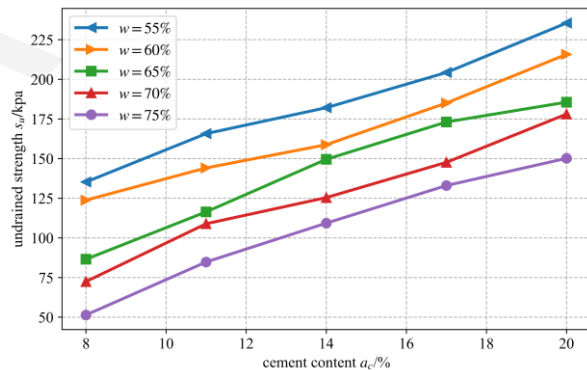
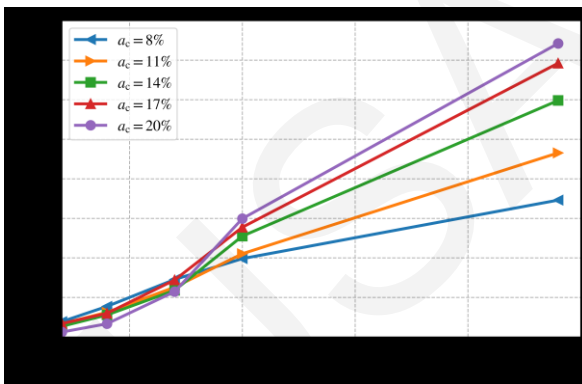
$$s_u = \frac{2M}{\pi d^2 (h + d/3)}$$

$$s_t = \frac{s_u}{s_{u,r}}$$

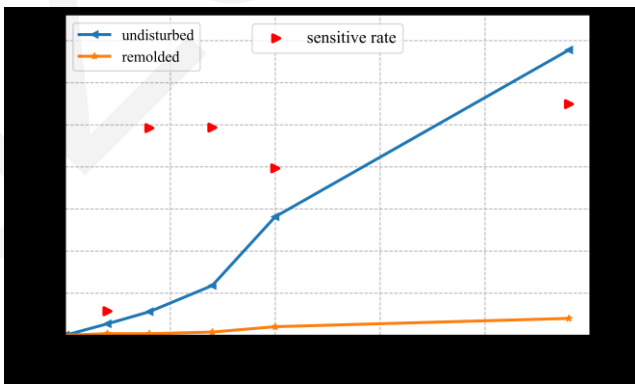
## 试验结果



## 含水率、水泥掺量影响



## 固化土体灵敏度

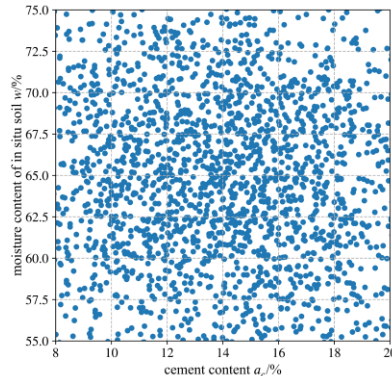
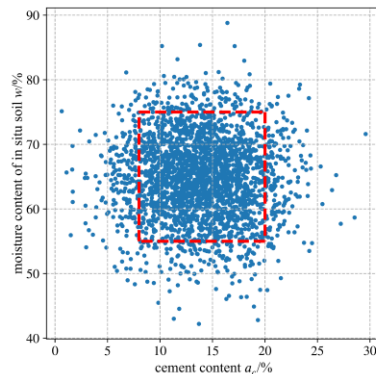
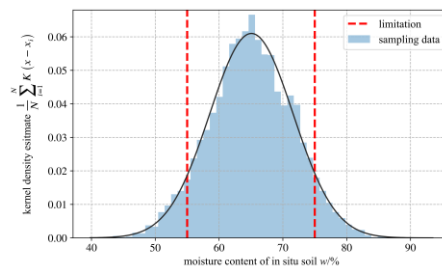
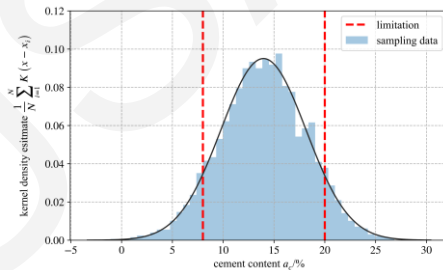
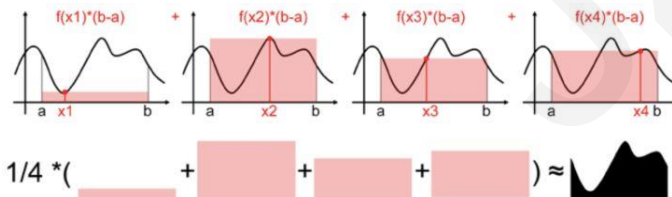
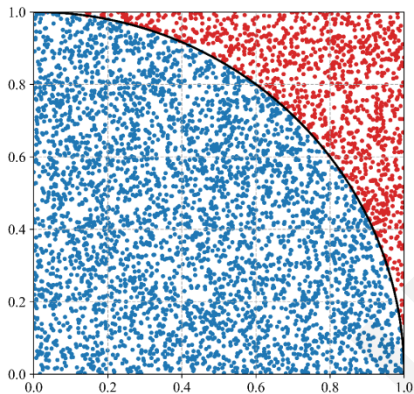


固化土体结构性显著，  
为高灵敏度土

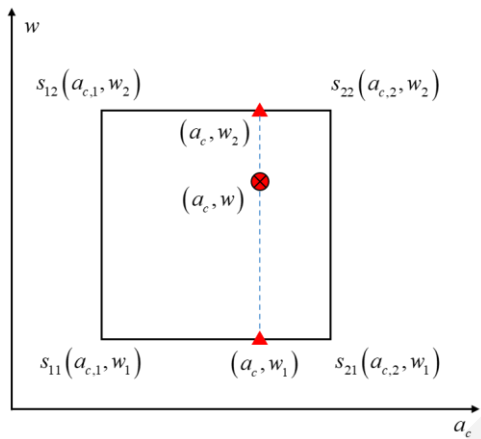
## 蒙特-卡罗方法

- ✓ 通过不断的**抽样**以逼近**真实的值或分布**
- ✓ 原位土体含水率与施工水泥掺量**相互独立**

随机变量	均值 $\mu$	标准差 $\sigma$	变异系数 COV
原状土含水率 $w$ /%	65	6.5	0.1
水泥掺量 $a_c$ /%	14	4.2	0.3



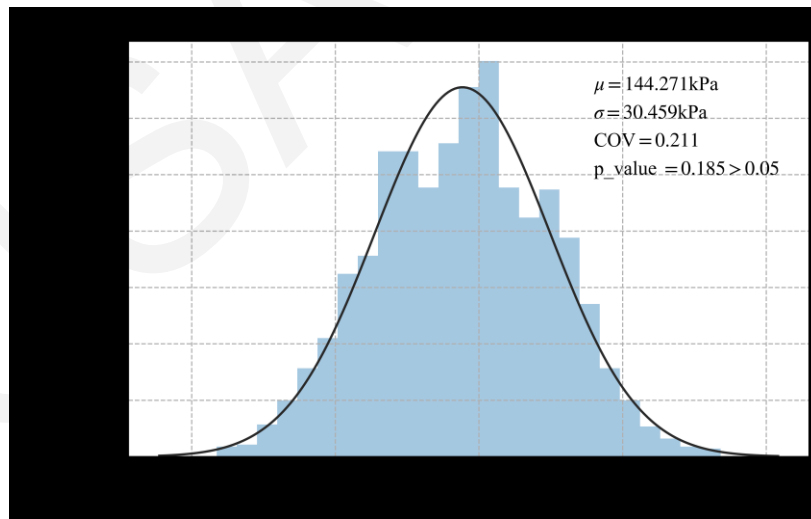
### □ 双线性插值



$$s(a_c, w_1) = \frac{a_{c,2} - a_c}{a_{c,2} - a_{c,1}} s_{11} + \frac{a_c - a_{c,1}}{a_{c,2} - a_{c,1}} s_{21}$$

$$s(a_c, w_2) = \frac{a_{c,2} - a_c}{a_{c,2} - a_{c,1}} s_{12} + \frac{a_c - a_{c,1}}{a_{c,2} - a_{c,1}} s_{22}$$

$$s(a_c, w) = \frac{w_2 - w}{w_2 - w_1} s(a_c, w_1) + \frac{w - w_1}{w_2 - w_1} s(a_c, w_2)$$



现场淤泥土固化24h抗剪强度服从均值为  
144.27kPa，变异系数为0.21的正态分布

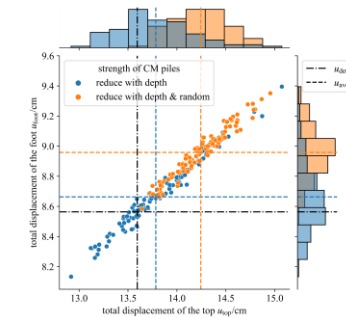
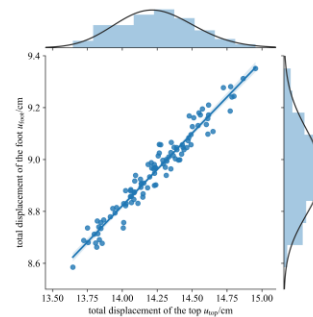
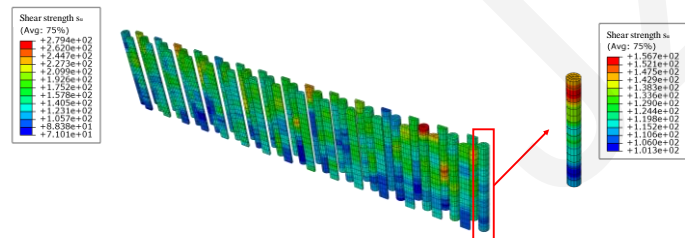
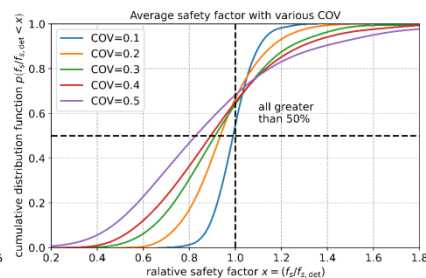
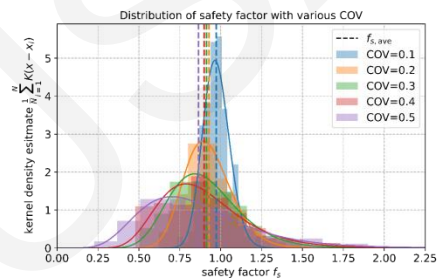
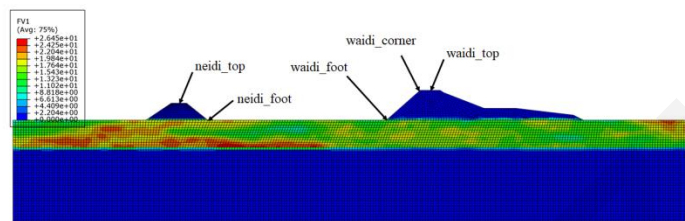
## □ 小结

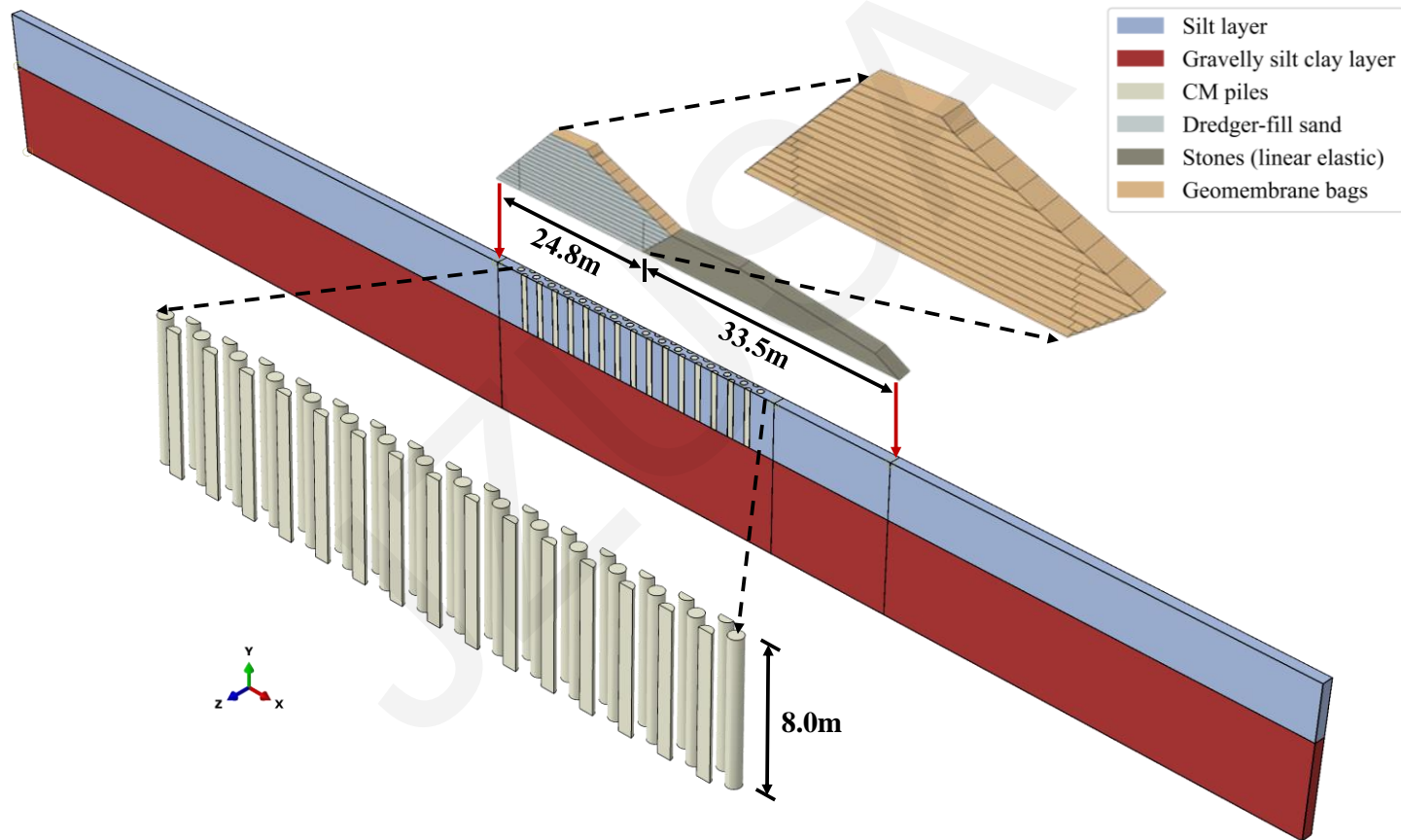
- ✓ 水泥固化土体表现出明显的**结构性**，为**高灵敏度土**；
- ✓ 水泥搅拌桩24h不排水抗剪强度服从均值为144.27kPa，变异系数为0.21的**正态分布**

# 4. 基于蒙特-卡罗模拟的海堤可靠度分析

## 引言

- ✓ 生成表达空间变异性和空间关联性的强度随机场
- ✓ 针对地基土和水泥搅拌桩强度空间变异性开展随机有限元计算与分析

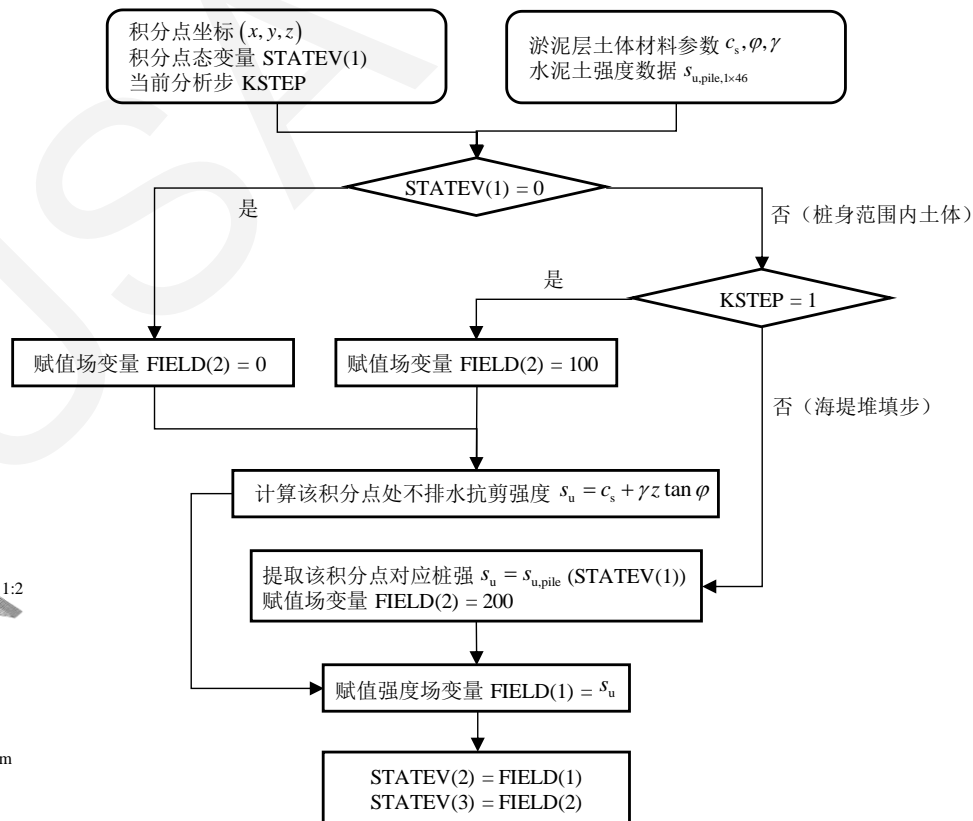
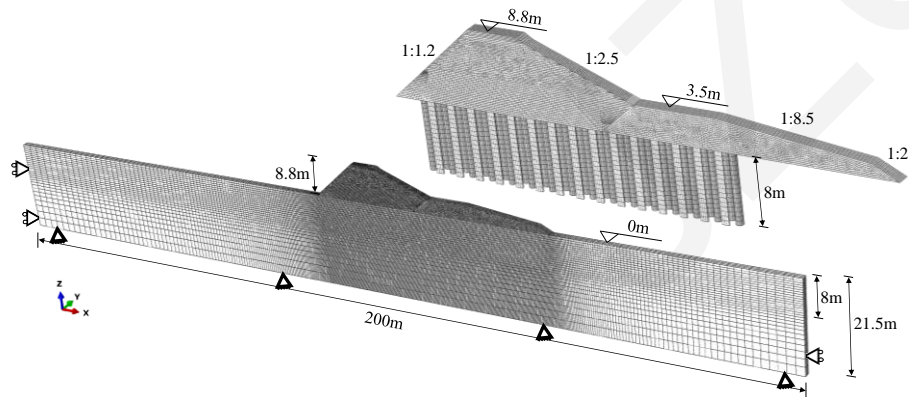




## 数值模型

### 对水泥搅拌桩和海堤膜袋精细化建模

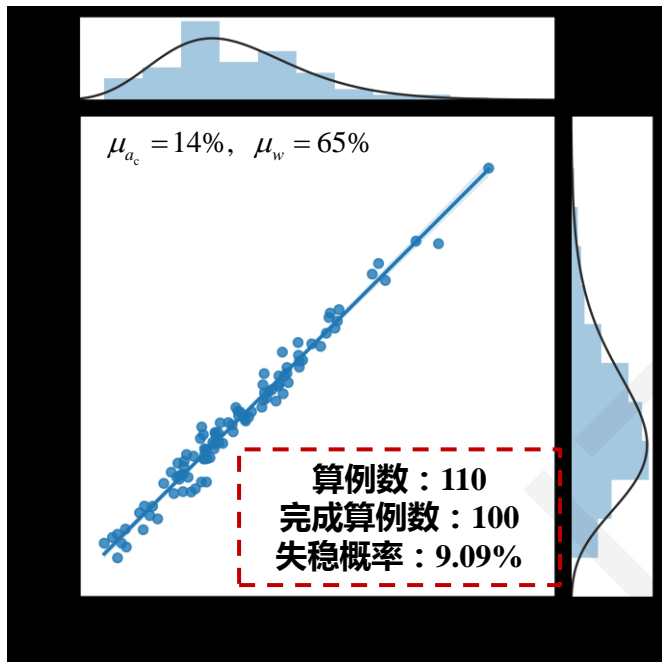
重度	弹性模量	泊松比	粘聚力	内摩擦角	不排水抗剪强度
$\gamma / (\text{kN/m}^3)$	$E / (\text{kN/m}^2)$	$\nu$	$c / \text{kPa}$	$\varphi / ^\circ$	$s_w / \text{kPa}$
淤泥土	16.70	3.32e3	—	—	$13.8 + \gamma z \cdot \tan \varphi$
含砾黏土	19.30	22.44e3	24.0	12.6	—
海堤吹填砂	20.00	14.86e3	4.0	28.0	—
水泥搅拌桩	18.00	$250s_u$	—	—	场变量决定



# 4. 基于蒙特-卡罗模拟的海堤可靠度分析

## 搅拌桩强度不确定性

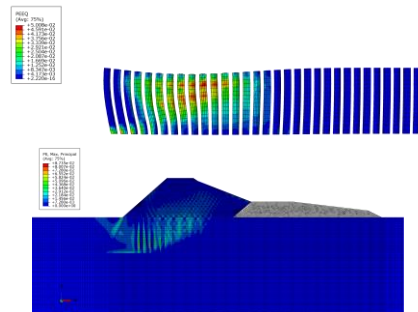
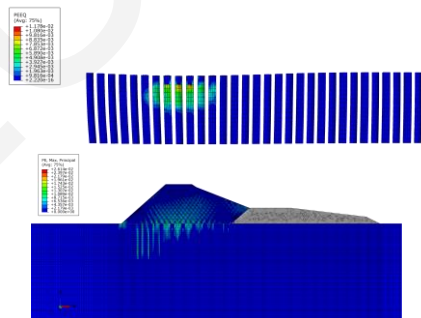
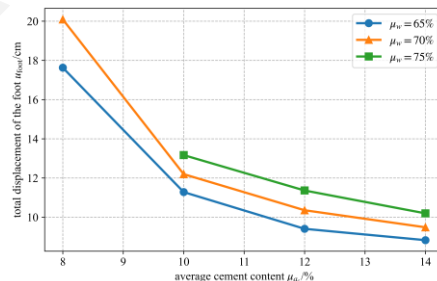
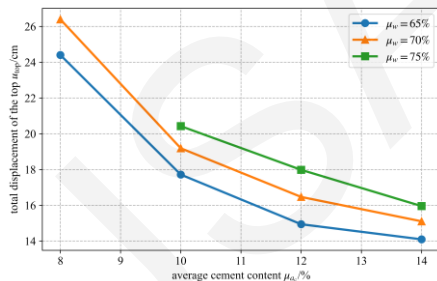
### 随机有限元计算结果



参数 水泥掺量均值  $\mu_{a_c}/\%$  原位土体含水率均值  $\mu_w/\%$

取值 8%, 10%, 12%, 14%

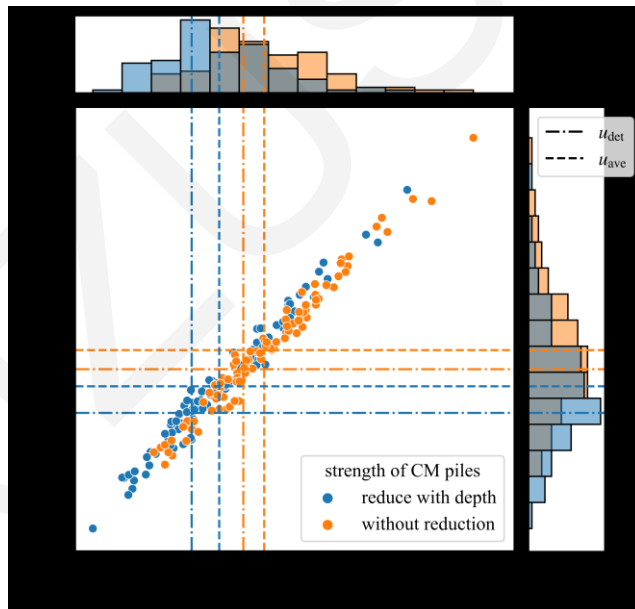
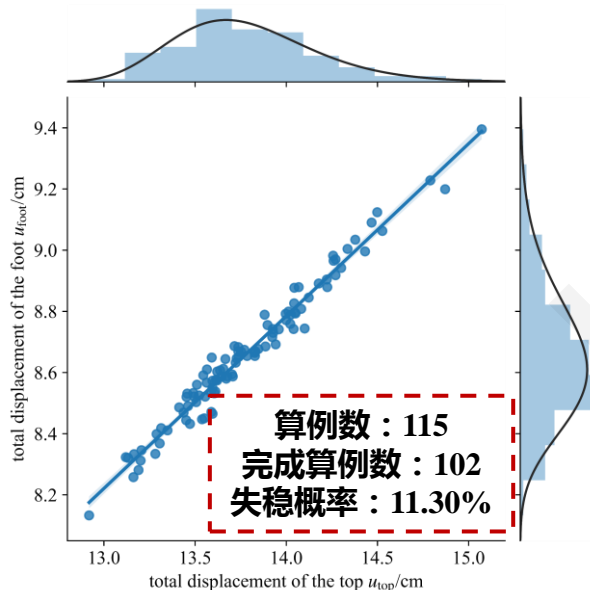
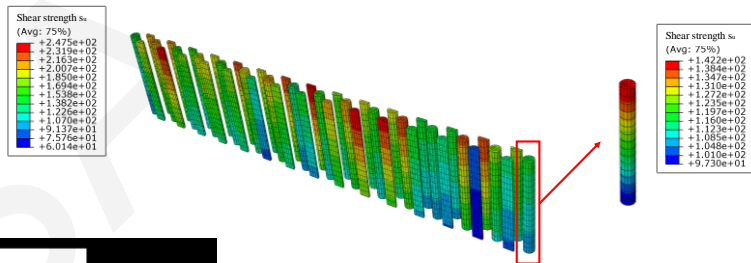
65%, 70%, 75%



水泥搅拌桩强度均值低于一定阈值时，海堤存在整体失稳风险

### 桩强随机表现形式的讨论

✓ 单桩内部土体强度沿深度方向均匀折减



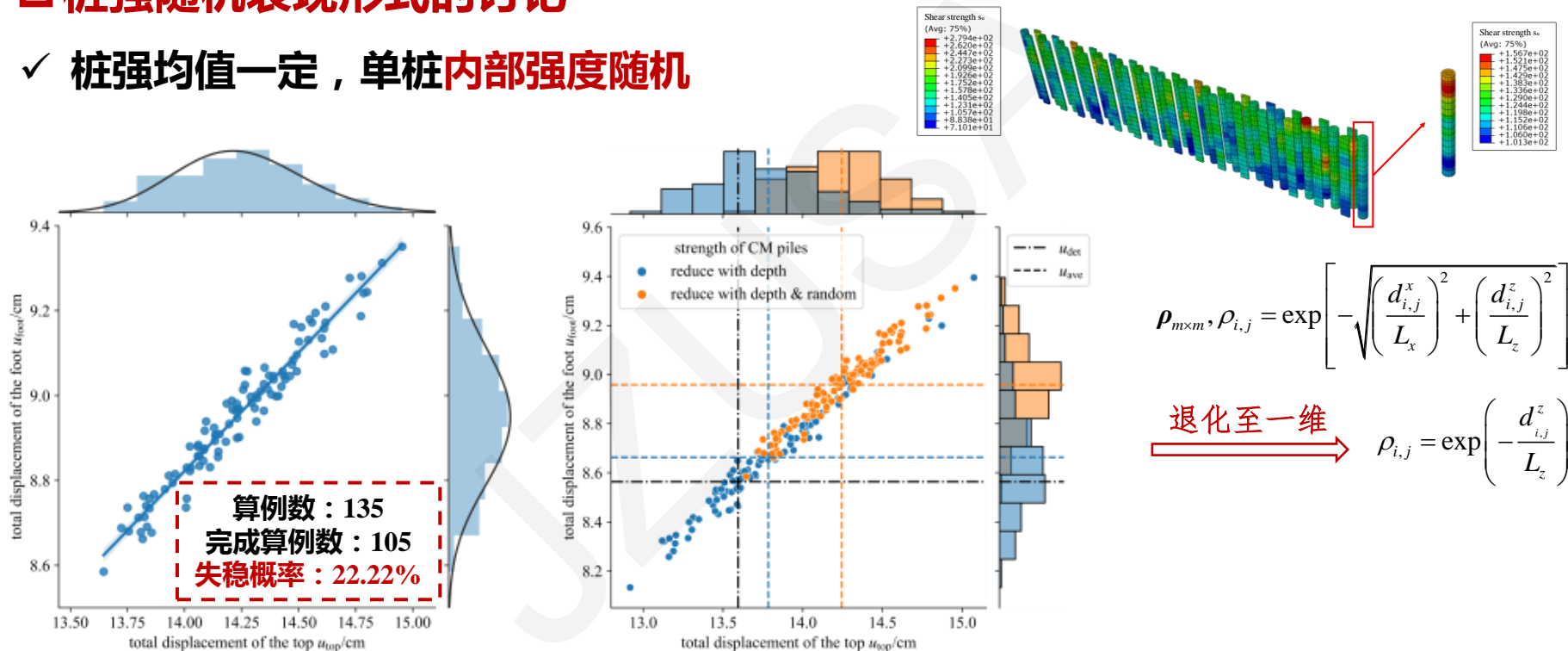
$$s_u(z) = \frac{6}{5} s_{u,mean} + \frac{1}{20} s_{u,mean} \cdot z$$

$$u_{ave} > u_{det}$$

按确定的土体强度参数进行设计和计算偏于危险

### 桩强随机表现形式的讨论

✓ 桩强均值一定，单桩内部强度随机



单桩内桩身强度的变异性对海堤稳定性有更为显著的影响

## 4.基于蒙特-卡罗模拟的海堤可靠度分析

### □ 小结

- ✓ 当水泥搅拌桩强度均值**低于一定阈值时**，海堤存在整体失稳风险。单桩内桩强的**随机分布**对海堤稳定性有更为显著的影响；
- ✓ 土体强度存在空间变异性条件下，按确定的土体强度参数进行设计和计算是**偏于危险的**，须**预留更多的安全系数裕度**