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EPR-RCGA-based modelling of compression index and RMSE-AIC-BIC-based model selection for Chinese marine clays and their engineering application

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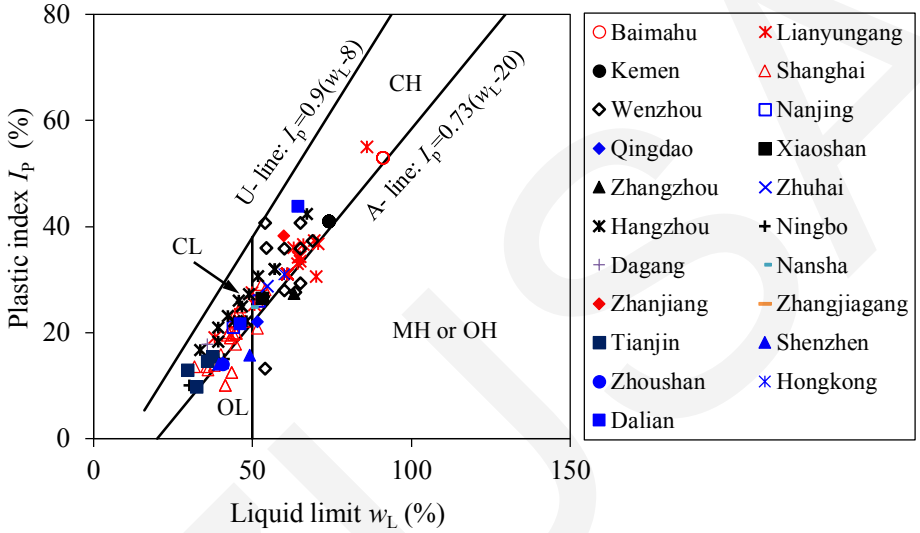
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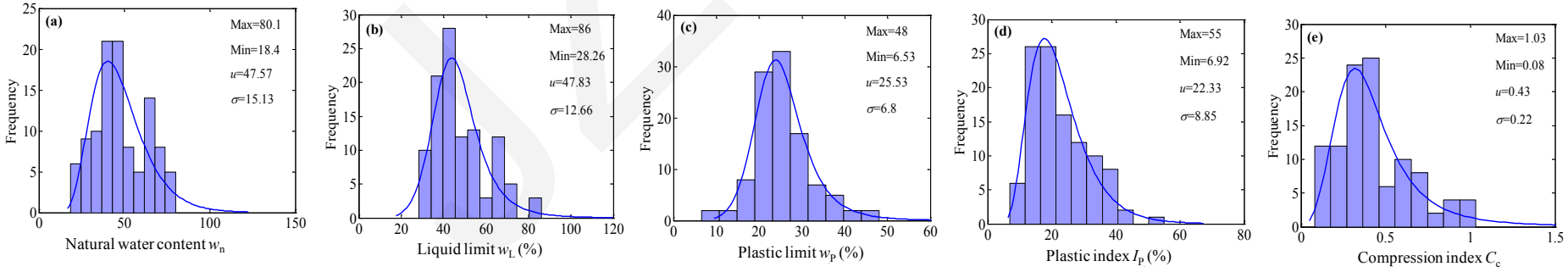
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1.
Physical properties of clays 21 regions along the Chinese coast

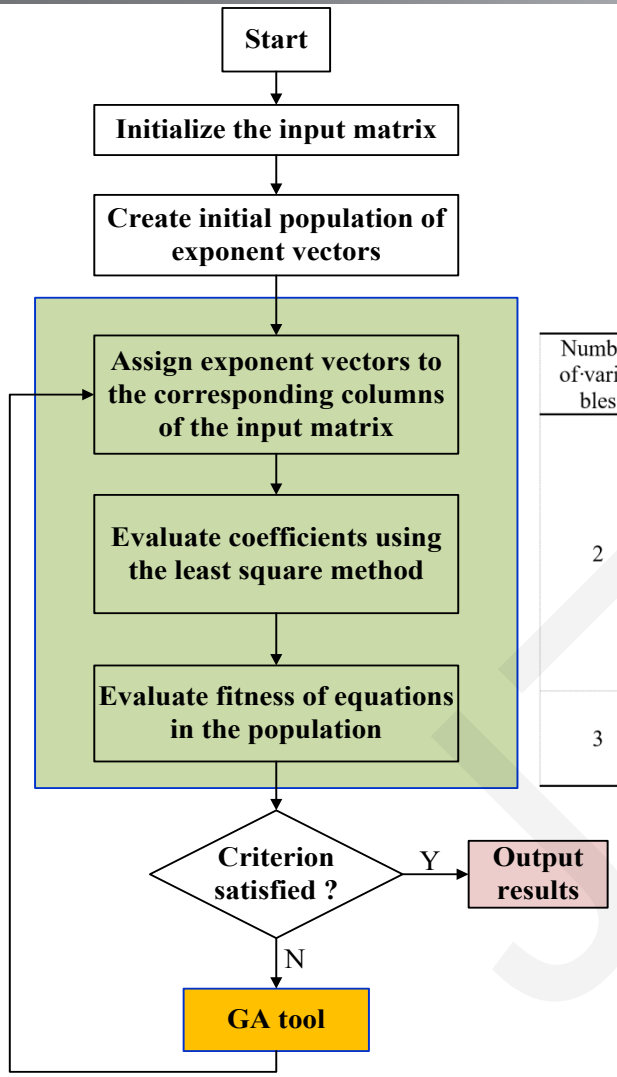


Plasticity of the selected Chinese marine clays



Histograms of selected physical properties

2.
A real coded genetic algorithm (RCGA) combined technique



Flow chart of the proposed optimization based EPR process

Optimal correlation equations with correlation coefficient values for Chinese marine clays

Number of variables	Combination of variable	Correlation expression	R^2
2	w_n, w_L	$C_c = -0.366 - 4.9\frac{(w_n)^2}{w_L} + 5.53(w_n)^2 w_L + 10.2 w_n w_L + 1.36\left(\frac{w_n}{w_L}\right)^2 - 10.66 w_n (w_L)^2$	0.872
	w_n, I_p	$C_c = -0.13 - 12.1(I_p)^2 + 0.027\left(\frac{w_n}{I_p}\right)^2 + 10.85 w_n I_p - 1.48(w_n)^2 + 2.01\frac{(I_p)^2}{w_n}$	0.861
	w_L, I_p	$C_c = -0.714 - 0.26\frac{w_L}{I_p} + 0.33\frac{I_p}{(w_L)^2} + 0.08\left(\frac{w_L}{I_p}\right)^2 + 9.11 I_p - 9.9\frac{(I_p)^2}{w_L}$	0.657
3	w_n, w_L, I_p	$C_c = -0.218 + 1.34 w_n\left(\frac{I_p}{w_L}\right)^2 + 1.86(w_L)^2 - 8.67(w_L I_p)^2 + 0.028\frac{(w_n)^2}{(w_L)^2 I_p} + 6.92(w_n I_p)^2 w_L$	0.876

3.
An optimal correlation according to (RMSE), (AIC), and (BIC).

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\boldsymbol{Y}_{\mathrm{a}} - \boldsymbol{Y}_{\mathrm{p}}\right)^2}$$

$$\mathrm{AIC} = n \cdot \log\left(\mathrm{RSS}\right) + 2k,$$

$$\mathrm{BIC} = n \cdot \log\left(\mathrm{RSS}/n\right) + k \cdot \log\left(n\right).$$

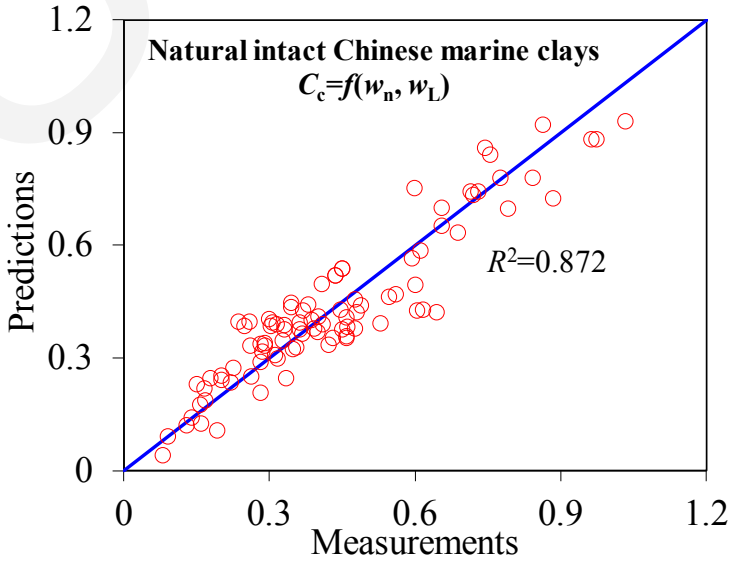
Error index, u and σ of Ya/Yp, AIC, and BIC when using different optimal correlations for Chinese marine

Variables	RMSE	u	σ	AIC	BIC
w_{n}, w_{L}	0.0777	1.0393	0.2332	-48.0	-486.6
w_{n}, I_{p}	0.0809	1.0576	0.2590	-40.2	-478.8
w_{L}, I_{p}	0.1218	1.1481	0.5297	39.3	-399.3
w_{n}, w_{L}, I_{p}	0.0764	1.0481	0.2391	-49.24	-485.3

Best correlation of compression index for natural intact Chinese marine clays:

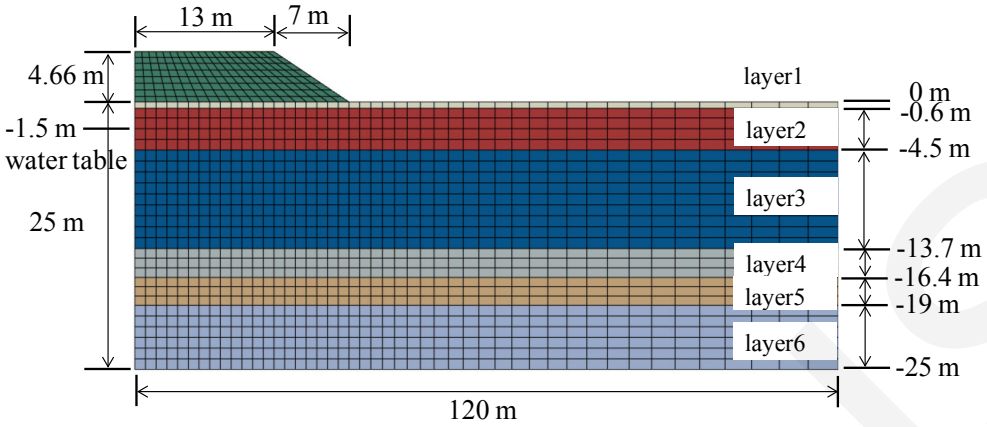
$$C_{\mathrm{c}} = -0.366 - 4.9\frac{\left(w_{\mathrm{n}}\right)^2}{w_{\mathrm{L}}} + 5.53\left(w_{\mathrm{n}}\right)^2 w_{\mathrm{L}} + 10.2 w_{\mathrm{n}} w_{\mathrm{L}}$$

$$+1.36\left(\frac{w_{\mathrm{n}}}{w_{\mathrm{L}}}\right)^2 - 10.66 w_{\mathrm{n}}\left(w_{\mathrm{L}}\right)^2.$$

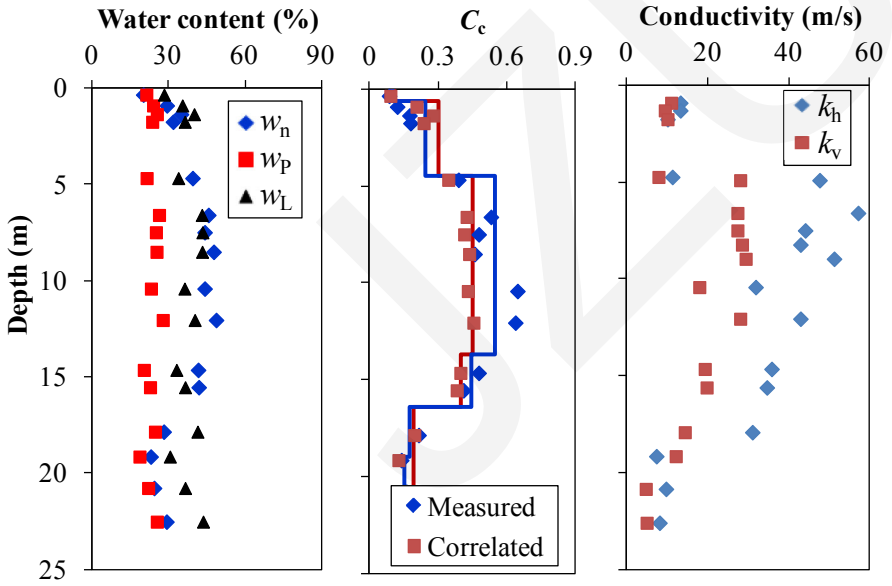


Box plot of the ratio Yp/Ya of the compression index of different optimized correlations for Chinese marine clays

4.
Validation (an embankment on the southeast coast of China)

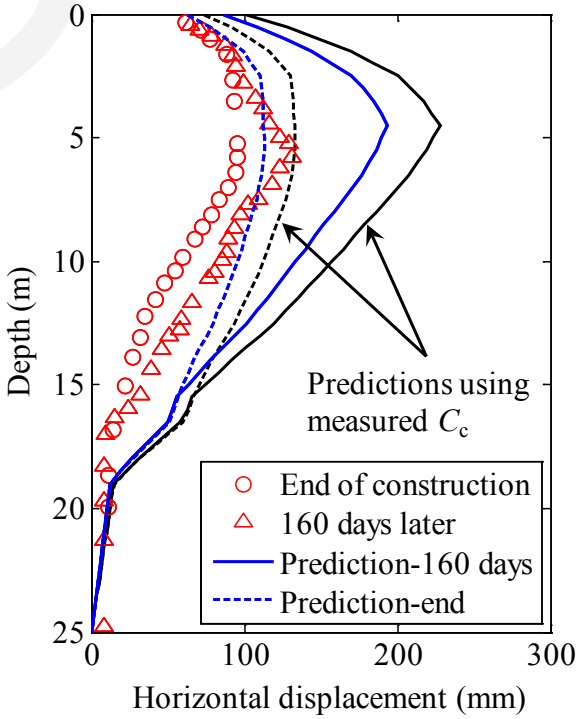


Finite element model of the embankment



Soil properties throughout the depth of the embankment

Measured and calculated values of horizontal dis-placements at different time points



Conclusions

1. The correlation of the compression index with the physical properties of Chinese marine clays was investigated through an EPR-RCGA-RMSE-AIC-BIC combined technique. A database containing the compression index and soil physical properties of Chinese marine clays from 21 regions along China coast was established.
2. The correlations between the compression index and different combinations of w_n, w_L, and I_p were then investigated using the EPR procedure. The results indicate that the performance of EPR-RCGA based correlations is slightly improved by increasing the number of variables involved, and that correlations involving w_n and w_L may give a better performance than others.
3. For selecting the most EPR-RCGA based correlation, the performance of each correlation was first evaluated using the RMSE index, the mean value and the standard deviation value of Y_p/Y_a. Then the performance was estimated using two evaluation criteria (AIC and BIC). Based on these, the EPR-RCGA based correlation involving only w_n and w_L was selected as the most "appropriate"correlation of C_c for Chinese marine clays.
4. The reliability of the suggested correlation was tested by comparing it with existing empirical correlations for Chinese marine clays. The correlated compression index was used to simulate an embankment on the southeast coast of China. Compared to field measurements and simulation results based on compression index measurements, good agreement was achieved for surface settlement of the embankment, horizontal displacement of subsoils, and excess water pore pressure in soils. This demonstrates that the suggested correlation of C_c for Chinese marine clays is reliable and applicable.