## Supporting Information

# Modified Lignin-Based Cement Solidifying Material for Improving Engineering Residual Soil

**Xiang Yu [1,2], Hongbo Lu [1,*], Jie Peng [2], Jinming Ren [1], Yongmin Wang [1] and Junhao Chen [1]**

[1] Power China Huadong Engineering Corporation Limited, Hangzhou 311122, China; yu-xiang@hhu.edu.cn (X.Y.); ren_jm@hdec.com (J.R.); wang_ym2@hdec.com (Y.W.); chen_jh4@hdec.com (J.C.)

[2] College of Civil and Transportation Engineering, Hohai University, Nanjing 210098, China; peng-jie@hhu.edu.cn

* Correspondence: lu_hb2@hdec.com; Tel.: +86-13126859770

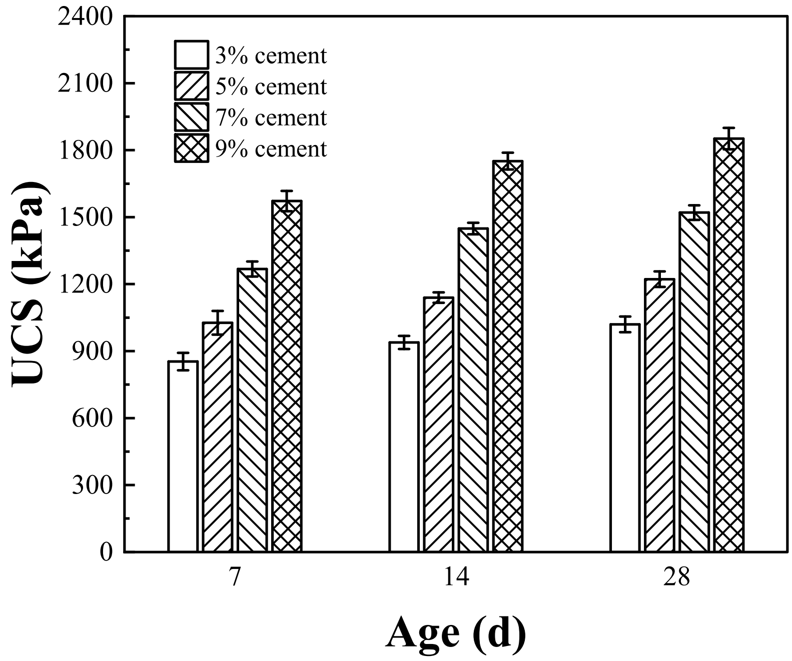



**Figure S1.** Influences of the cement content on the unconfined compressive strengths (UCSs) of cement-solidified soil at 7, 14, and 28 d.

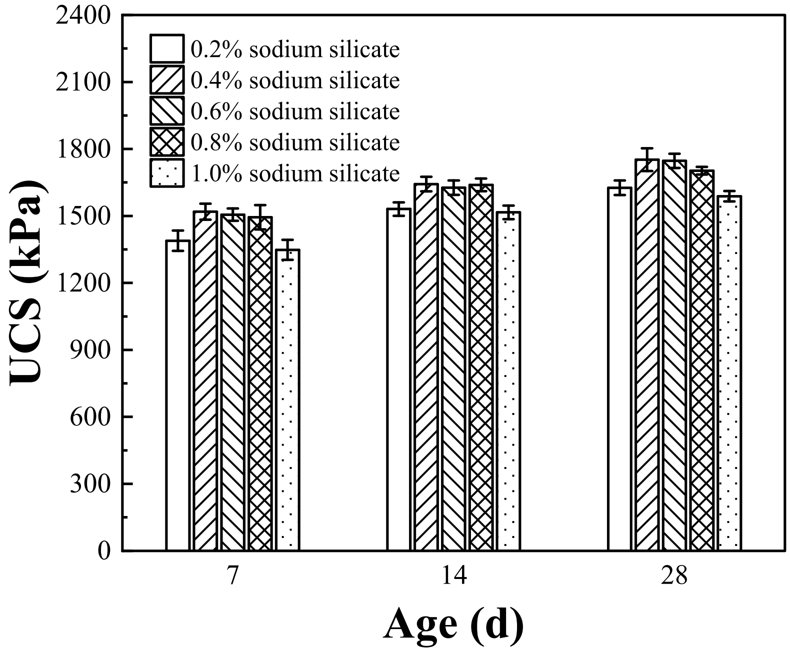



**Figure S2.** Influences of the dosage of sodium silicate on the UCSs of cement-solidified soil at 7, 14, and 28 d.

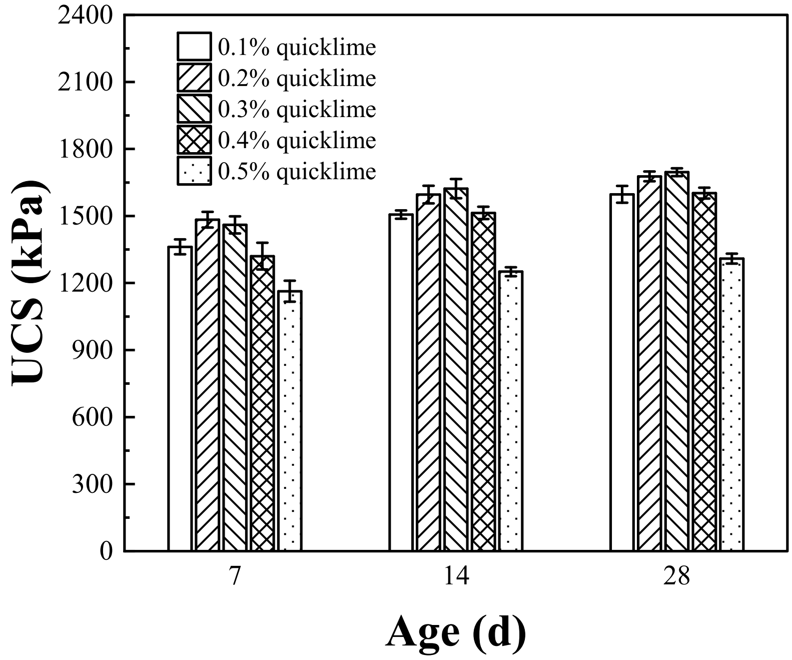



**Figure S3.** Influences of the quicklime content on the UCSs of cement-solidified soil at 7, 14, and 28 d.

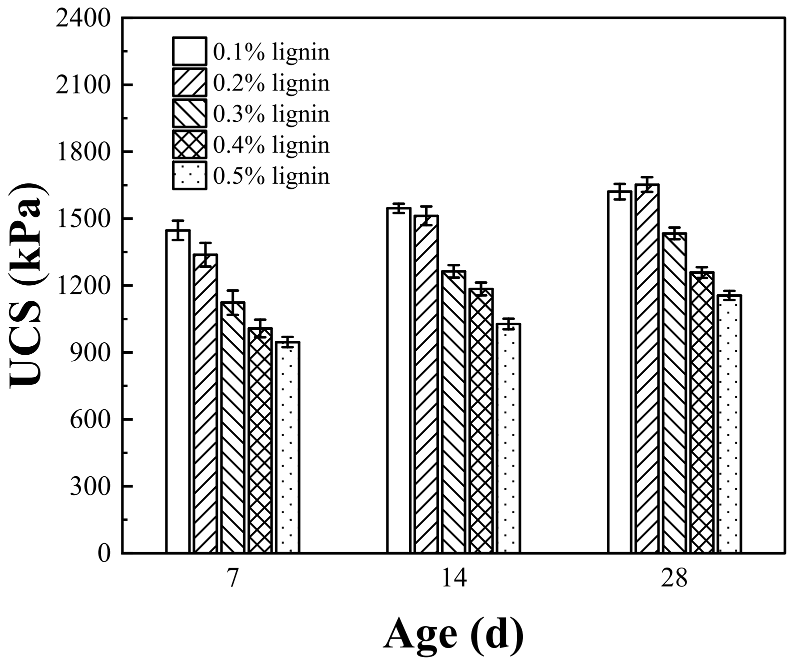



**Figure S4.** Influences of the lignin content on the UCSs of cement-solidified soil at 7, 14, and 28 d.

**Table S1.** Results of orthogonal experiments at different ages.

| Group | Sodium silicate (%) | Quicklime (%) | Lignin (%) | 7 d UCS (kPa) | 14 d UCS (kPa) | 28 d UCS (kPa) |
|---|---|---|---|---|---|---|
| 1 | 0.2 | 0.1 | 0.1 | 1387 | 1508 | 1583 |
| 2 | 0.2 | 0.2 | 0.15 | 1531 | 1654 | 1738 |
| 3 | 0.2 | 0.3 | 0.2 | 1432 | 1670 | 1746 |
| 4 | 0.4 | 0.1 | 0.15 | 1881 | 1980 | 2064 |
| 5 | 0.4 | 0.2 | 0.2 | 1924 | 2118 | 2209 |
| 6 | 0.4 | 0.3 | 0.1 | 1611 | 1834 | 1918 |
| 7 | 0.6 | 0.1 | 0.2 | 1728 | 1835 | 1893 |
| 8 | 0.6 | 0.2 | 0.1 | 1498 | 1668 | 1731 |
| 9 | 0.6 | 0.3 | 0.15 | 1561 | 1664 | 1820 |
| Optimal group | 0.4 | 0.2 | 0.2 | 1924 | 2118 | 2209 |

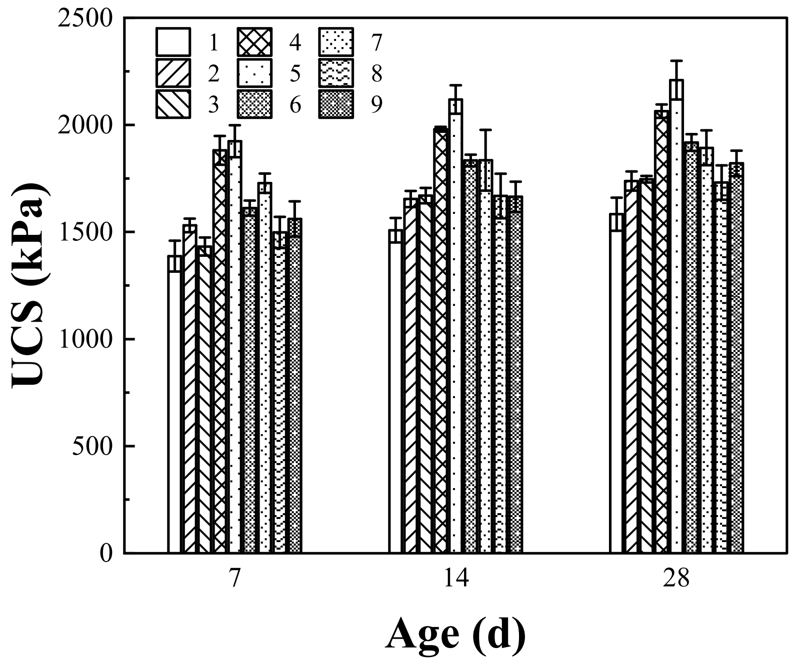
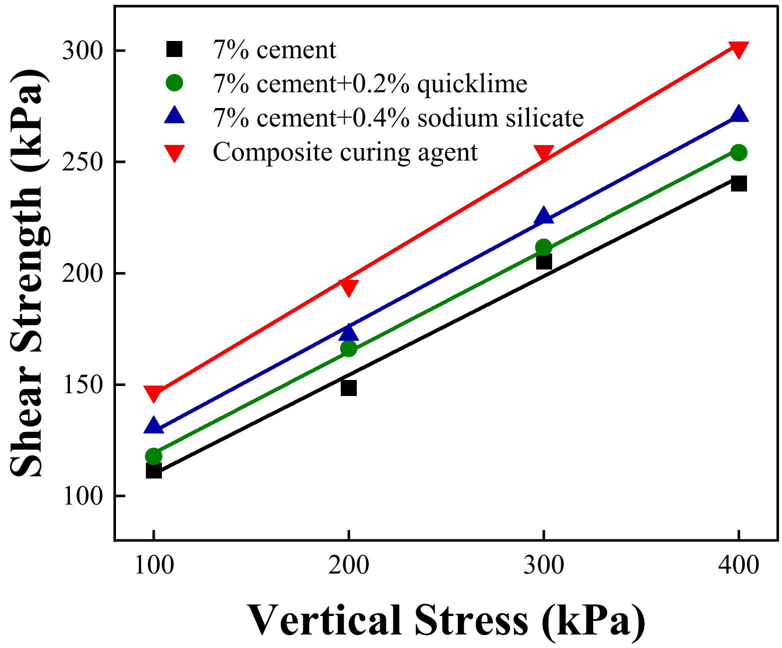
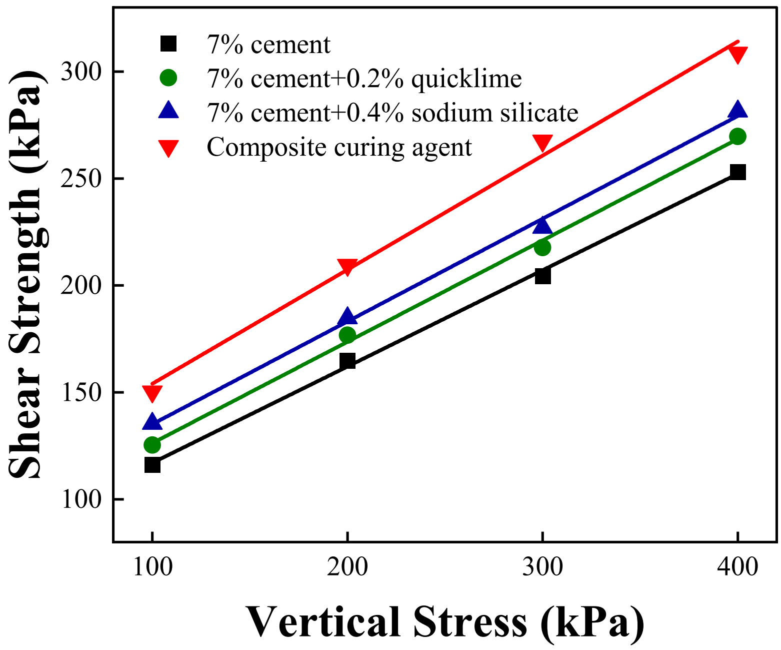



**Figure S5.** UCSs of the different groups used in the orthogonal study at 7, 14, and 28 d.




（a）**14 d**




（b）**28 d**

**Figure S6.** Relationships between the vertical stresses and shear strengths, as obtained via the 14 and 28 d direct shear studies.

**Table S2.** Levels of cohesion and the internal friction angles of different modifiers at ages of 7, 14, and 28 d.

| Curing agent | c （kPa） | | | φ (°) | | |
|---|---|---|---|---|---|---|
| | 7 d | 14 d | 28 d | 7 d | 14 d | 28 d |
| 7 % cement | 56.2 | 67.5 | 72.0 | 24.0 | 25.4 | 25.8 |
| 7 % cement + 0.2 % quicklime | 62.1 | 73.7 | 78.9 | 25.0 | 26.1 | 27.2 |
| 7 % cement + 0.4 % sodium silicate | 67.9 | 81.7 | 87.1 | 26.2 | 27.1 | 27.5 |
| Composite curing agent | 86.0 | 93.2 | 100.7 | 29.1 | 30.0 | 30.6 |

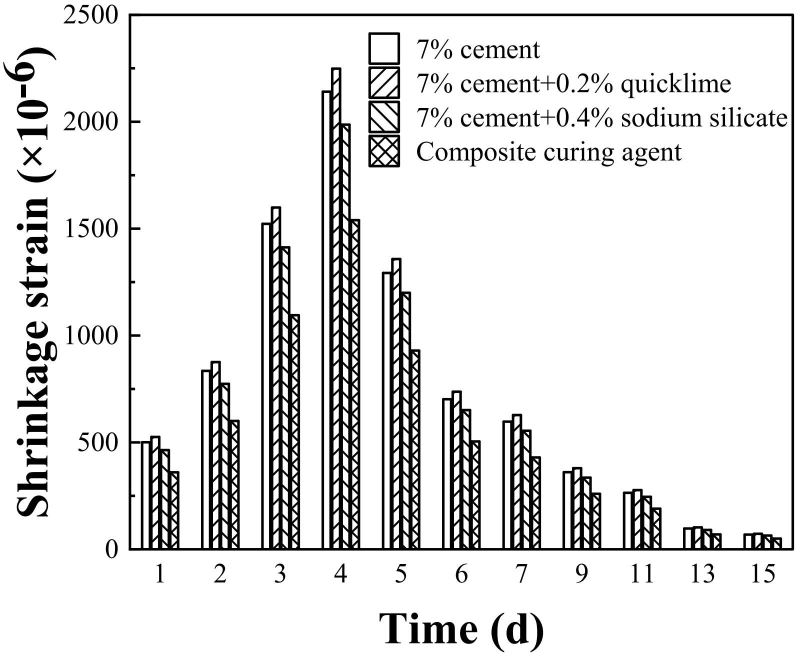



**Figure S7.** Variations in the dry shrinkage strains of cement-solidified soils under different curing agents in the first 15 d.

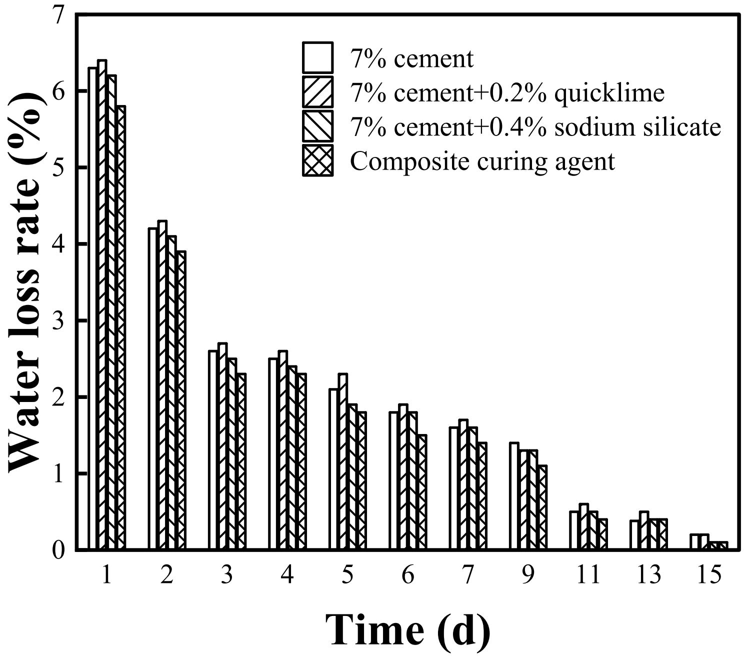
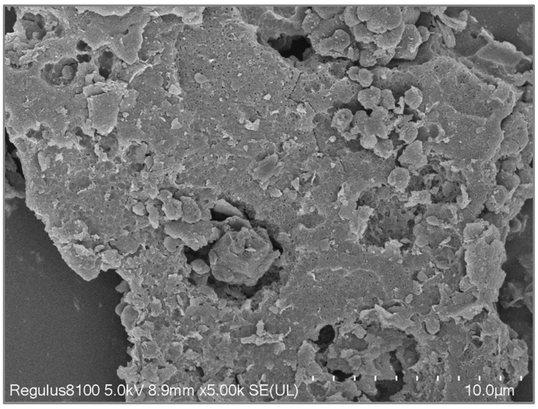
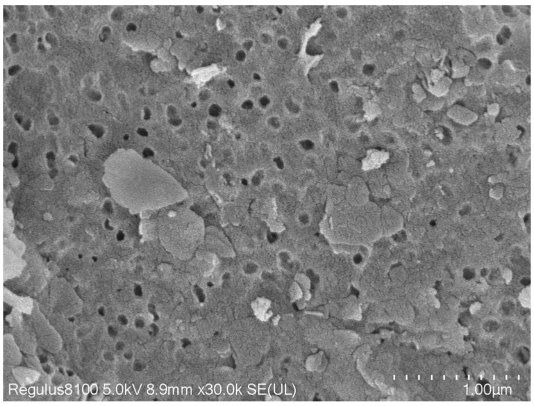



**Figure S8.** Variations in the rates of water loss of cement-solidified soils under different curing agents in the first 15 d.

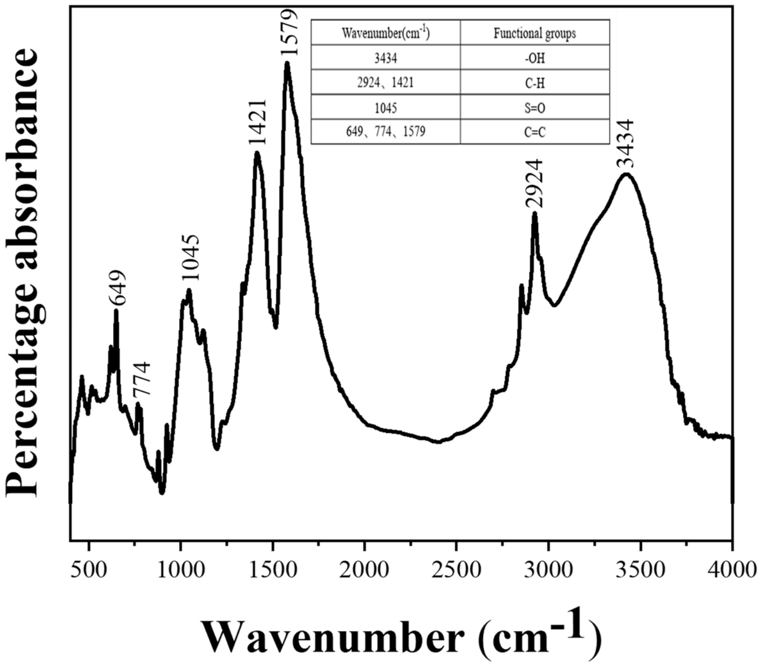



**(a) 5000**

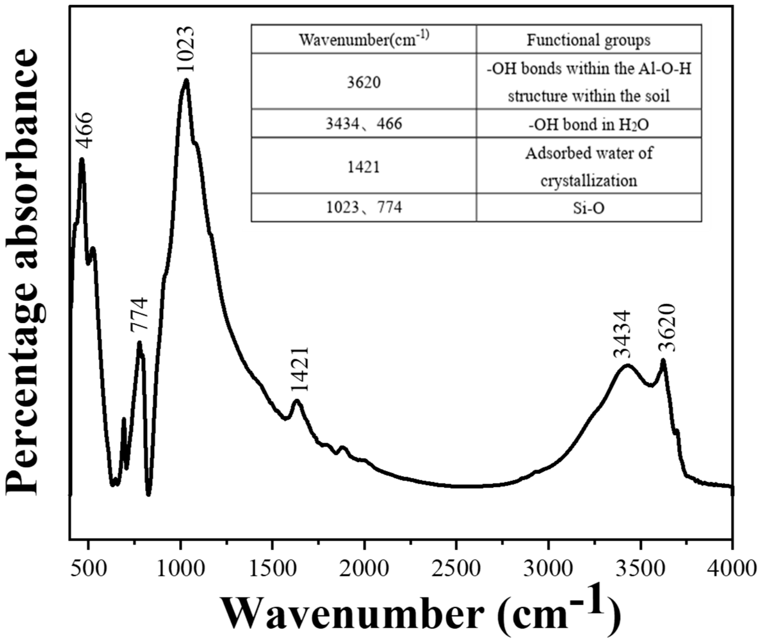



**(b) 30000**

**Figure S9.** Scanning electron microscopy images of plain soil at different magnifications.




**(a) Analysis of lignin functional groups**




**(b) Analysis of soil functional groups**

**Figure S10.** Analyses of the functional groups of soil and lignin based on Fourier transform infrared spectroscopy.