ALLEGATO 4

SCHEDA DI SINTESI DELLA TESI

La domanda mondiale di energia è soddisfatta principalmente da fonti non rinnovabili, che hanno un impatto negativo sull'ambiente poiché contribuiscono all'aumento delle emissioni di CO2, all'effetto serra e al riscaldamento globale. Per promuovere lo sfruttamento di energie pulite alternative sono necessarie strategie efficaci. A tal fine, un'interessante applicazione per gli edifici di nuova costruzione è rappresentata dai pali energetici. I pali energetici sono pali di fondazione che, interagendo con il terreno a profondità utili per lo sfruttamento della risorsa geotermica a bassa entalpia, sono in grado di provvedere anche al fabbisogno energetico dell'edificio. Lo scambio termico è possibile in quanto il palo è equipaggiato medianti tubicini, collegati direttamente alla gabbia di armatura, all'interno dei quali, tramite l'impiego di una pompa di calore, scorre un fluido termovettore. Tale fluido, essendo in grado di scambiare calore con il terreno circostante, consente di riscaldare l'edificio durante l'inverno e di raffreddarlo durante l'estate, in modo da ridurre, ed in alcuni casi eliminare, l'impiego di combustibile fossile. I pali energetici assolvono, pertanto, al duplice compito di trasferire i carichi strutturali (dalla struttura al terreno) ed il calore (dal terreno alla struttura e viceversa). Negli ultimi anni, grazie ai vantaggi ottenibili in termini di sostenibilità energetica, l'impiego di tali sistemi ha subito un forte impulso sia nel settore pubblico che in quello privato ed è attualissimo.

La tesi è suddivisa in sette Capitoli e due Appendici.

Nel **Capitolo 1** è riportata una panoramica relativa alle principali caratteristiche delle strutture geo-energetiche. Successivamente, l'attenzione è focalizzata sui pali energetici. Il capitolo riporta lo stato dell'arte con riferimento alle principali caratteristiche del comportamento dei pali, isolati ed in gruppo, dedotte mediante prove in sito ed in laboratorio, analisi numeriche ed approccio analitico.

Nel **Capitolo 2** sono ricavate le soluzioni analitiche per la progettazione allo Stato Limite Ultimo dei pali energetici. Tali soluzioni rappresentano un'assoluta novità nel campo dei pali energetici ed hanno ricevuto l'attenzione di diversi ricercatori illustri in materia. Dopo aver descritto il modello proposto, è presentata la formulazione matematica del profilo di spostamenti, in forma di equazione differenziale del secondo ordine, per i casi di terreno omogeneo, bistrato e Gibson. Sono ricavate, poi, le soluzioni esatte relative allo sforzo assiale indotto dalla variazione di temperatura e quelle approssimate per condizione di sottosuolo generalizzata. Infine, sono presentati la calibrazione delle molle ed i confronti con i dati sperimentali e le analisi numeriche.

Nel **Capitolo 3** è descritta la struttura matematica dei modelli costitutivi utilizzati nelle analisi numeriche. In particolare, è riportata la formulazione dei modelli Lineare-Elastico, Mohr-Coulomb, Cam-Clay Modificato e Ipoplastico, con e senza la parte termica. Quest'ultima è stata implementata dalla scrivente e, pertanto, nel capitolo è riportata anche la validazione di tale implementazione attraverso confronti con prove triassiali in condizioni drenate e non drenate. Nell'ultima sezione del capitolo è illustrata la formulazione termo-idro-meccanica accoppiata utilizzata nelle successive analisi numeriche.

Nel **Capitolo 4** è descritto il modello 2D assialsimmetrico adoperato nelle analisi agli elementi finiti. In particolare, sono illustrate le condizioni al contorno, la tipologia e le dimensioni degli elementi utilizzati per palo e terreno. Inoltre, sono riportate le caratteristiche geometriche, meccaniche e termiche del palo oltre che quelle meccaniche e termiche del terreno. Infine, è presentata la calibrazione dei modelli costitutivi impiegati, tenendo presente che il modello Ipoplastico è scelto come modello di riferimento sul quale calibrare i parametri degli altri modelli.

I risultati delle analisi numeriche termo-idro-meccaniche accoppiate sono presentati nel **Capitolo 5**. Riguardo la fase meccanica, è riportata la curva carico-cedimento ottenuta con i diversi modelli costitutivi oltre che il calcolo relativo alla capacità portante del palo tramite le formule statiche; sono, inoltre, riportati i livelli di carico meccanico scelti da applicare alla testa del palo contemporaneamente alla variazione di temperatura. Successivamente, oltre a chiarire la scelta delle condizioni di vincolo alla testa, sono presentati anche i profili di temperatura nel palo e nel terreno. Per la condizione di palo libero, i risultati sono discussi, per ciascun modello costitutivo, con riferimento a sforzo assiale, cedimenti, deformazioni medie e posizione del punto di nullo. Inoltre, per 4 elementi all'interfaccia palo-terreno posizionati a diverse profondità, la risposta è riportata anche in termini di deformazioni volumetriche e di taglio, pressione interstiziale, cedimenti locali, stato di sforzo nel piano deviatorico e percorsi di carico nel piano q-p'. Riguardo il palo vincolato, il comportamento globale è descritto in termini di sforzo assiale e deformazione media. La fine del capitolo è dedicata ad una sintesi dei principali risultati.

Nel **Capitolo 6** sono presentati i confronti tra l'approccio analitico e quello numerico in condizioni di carico termico monotono. Infine, è riportata una procedura iterativa innovativa per la stima del modulo di taglio efficace da utilizzare nella definizione della rigidezza delle molle.

La tesi è conclusa con il **Capitolo 7** che è dedicato alla sintesi dei principali risultati ottenuti. Infine, sono discussi possibili scenari di ricerca nel campo dei pali energetici.

In **Appendice I** sono riportati i passaggi utilizzati per derivare sia le soluzioni analitiche esatte che quelle approssimate. Inoltre, per alcune tipologie di terreno sono presentate le espressioni del profilo di spostamento lungo il fusto del palo, della profondità a cui tale profilo si annulla, dello sforzo di taglio e dello sforzo assiale lungo il fusto.

Nell'**Appendice II** è descritta l'implementazione della parte termica del modello Ipoplastico.

BIBLIOGRAFIA

1. Abaqus 6.14 Online Documentation
2. Abuel-Naga, H. M., Bergado, D. T., Ramana, G. V., Grino, L., Rujivipat, P. and Thet, Y. (2006a). Experimental evaluation of engineering behavior of soft Bangkok clay under elevated temperature. Journal of Geotechnical and Geoenvironmental Engineering, 132(7), 902-910.
3. Abuel-Naga, H. M., Bergado, D. T. and Chaiprakaikeow, S. (2006b). Innovative thermal technique for enhancing the performance of prefabricated vertical drain system. Geotextiles and Geomembranes 24(6): 359–370.
4. Abuel-Naga, H., Bergado, D. T., Bouazza, A. and Ramana, G. (2007). Volume change behaviour of saturated clays under drained heating conditions: experimental and constitutive modelling. Canadian Geotechnical Journal, 44, 942-956.
5. Adam, D., and Markiewicz, R. (2009). Energy from earth-coupled structures, foundations, tunnels and sewers. Géotechnique, 59(3), 229-236.
6. Akrouch, G. A., Sánchez, M., and Briaud, J. L. (2014). Thermo-mechanical behavior of energy piles in high plasticity clays. Acta Geotechnica, 9(3), 399-412.
7. Adinolfi, M., Maiorano, R. M. S., Mauro, A., Massarotti, N. and Aversa, S. (2018). On the influence of thermal cycles on the yearly performance of an energy pile. Geomechanics for Energy and the Environment, 16, 32–44.
8. Allani, M., Van Lysebetten, G., and Huybrechts, N. (2017). Experimental and numerical study of the thermo-mechanical behaviour of energy piles for Belgian practice. In Advances in laboratory Testing and modelling of soils and Shales (pp. 405-412). Springer, Cham.
9. Amatya, B. L., Soga, K., Bourne-Webb, P. J., Amis, T. and Laloui, L. (2012). Thermo-mechanical behaviour of energy piles. Géotechnique, 62(6), 503–519.
10. Aversa, S., and Evangelista, A. (1993). Thermal expansion of Neapolitan yellow tuff. Rock Mechanics and Rock Engineering, 26(4), 281-306.
11. Baldi, G., Hueckel, T., and Pellegrini, R. (1988). Thermal volume changes of the mineral–water system in low-porosity clay soils. Canadian geotechnical journal, 25(4), 807-825.
12. Baldi, G., Hueckel, T., Peano, A., and Pellegrini, R. (1991). Developments in modelling of thermohydro-geomechanical behaviour of Boom clay and clay-based buffer materials. Volume 1. Commission of the European Communities.
13. Batini, N., Loria, A. F. R., Conti, P., Testi, D., Grassi, W., and Laloui, L. (2015). Energy and geotechnical behaviour of energy piles for different design solutions. Applied Thermal Engineering, 86, 199-213.
14. Berezantzev, V. G. (1961). Load bearing capacity and deformation of piled foundations. In Proceedings of the 5th international conference on soil mechanics and foundation engineering (Vol. 2, pp. 11-15).
15. Bourne-Webb, P. J., Amatya, B., Soga, K., Amis, T., Davidson, C. and Payne, P. (2009). Energy pile test at Lambeth College, London: geotechnical and thermodynamic aspects of pile response to heat cycles. Géotechnique, 59(3), 237–248.
16. Bourne-Webb, P. J., Amatya, B., and Soga, K. (2013). A framework for understanding energy pile behaviour. Proceedings of the Institution of Civil Engineers-Geotechnical Engineering, 166(2), 170-177.
17. Bourne-Webb, P., Burlon, S., Javed, S., Kürten, S., and Loveridge, F. (2016). Analysis and design methods for energy geostructures. Renewable and Sustainable Energy Reviews, 65, 402-419.
18. Brandl, H. (2006). Energy foundation and other thermo-active ground structures. Géotechnique, 56(2), 81–122.
19. Brandl, H. (2008). Energy piles concepts. In Deep Foundations on Bored and Auger Piles-BAP V (pp. 89-108). CRC Press.
20. Burghignoli, A., Desideri, A., and Miliziano, S. (2000). A laboratory study on the thermomechanical behaviour of clayey soils. Canadian Geotechnical Journal, 37(4), 764-780.

21. Butterfield, R. and Douglas, R. A. (1981). "Flexibility coefficients for the design of piles and pile groups", Construction Industry Research and Information Association, Technical Note, 108.
22. Campanella, R. G., and Mitchell, J. K. (1968). Influence of temperature variations on soil behaviour. Journal of Soil Mechanics and Foundations Div. Vol. 94(3), pp. 709–734, 1968.
23. Caulk, R., Ghazanfari, E., and McCartney, J. S. (2016). Parameterization of a calibrated geothermal energy pile model. Geomechanics for Energy and the Environment, 5, 1-15.
24. Cecinato, F., and Loveridge, F. A. (2015). Influences on the thermal efficiency of energy piles. Energy, 82, 1021-1033.
25. Cekerevac, C., and Laloui, L. (2004). Experimental study of thermal effects on the mechanical behaviour of a clay. International journal for numerical and analytical methods in geomechanics, 28(3), 209-228.
26. Chen, D. and McCartney, J.S. (2016). Parameters for load transfer analysis of energy piles in uniform soils. International Journal of Geomechanics, ASCE, 1-17. 10.1061/(ASCE) GM.1943-5622.0000873. 04016159.
27. Chen, Y., Xu, J., Li, H., Chen, L., Ng, C. W., and Liu, H. (2017). Performance of a prestressed concrete pipe energy pile during heating and cooling. Journal of Performance of Constructed Facilities, 31(3), 06017001.
28. Clancy, P., and Randolph, M. F. (1993). An approximate analysis procedure for piled raft foundations. International Journal for Numerical and Analytical Methods Geomechanics, 17(12), 849-869
29. Coyle, H. M. and Reese, L. C. (1966). Load transfer for axially loaded piles in clay. Journal of the Soil Mechanics and Foundations Division, 92(2), 1–26.
30. Crispin, J., Su, H., Round, K. and Mylonakis, G. (2019). Energy Formulation for Axial Pile Head Stiffness in Inhomogeneous Soil. El-Naggar H., Abdel-Rahman K., Fellenius B., Shehata H. (eds) Sustainability Issues for the Deep Foundations. GeoMEast 2018. Sustainable Civil Infrastructures. Cairo, 181–190.
31. Di Donna, A. and Laloui, L. (2014). Numerical analysis of the geotechnical behaviour of energy piles. International journal for numerical and analytical methods in geomechanics, 39(8), 861–888.
32. Di Donna, A. and Laloui, L. (2015a). Response of soil subjected to thermal cyclic loading: experimental and constitutive study. Engineering Geology, 190, 65–76.
33. Di Donna, A., Ferrari, A., and Laloui, L. (2015b). Experimental investigations of the soil–concrete interface: physical mechanisms, cyclic mobilization, and behaviour at different temperatures. Canadian Geotechnical Journal, 53(4), 659-672.
34. Di Donna, A., Loria, A. F. R. and Laloui, L. (2016). Numerical study of the response of a group of energy piles under different combinations of thermo-mechanical loads. Computers and Geotechnics, 72, 126–142.
35. Dupray, F., Laloui, L., and Kazangba, A. (2014). Numerical analysis of seasonal heat storage in an energy pile foundation. Computers and Geotechnics, 55, 67-77.
36. Ennigkeit, A., and Katzenbach, R. (2001). The double use of piles as foundation and heat exchanging elements. In Proceedings of the international conference on soil mechanics and geothecnical engineering. Vol. 2, pp. 893-896.
37. Fadejev, J., Simson, R., Kurnitski, J., and Haghighat, F. (2017). A review on energy piles design, sizing and modelling. Energy, 122, 390-407.
38. Frank, R., and Zhao, S. R. (1982). "Estimation par les paramètres pressiométriques de l'enfoncement sous charge axiale de pieux forés dans des sols fins." Bull. Liaison Lab. Ponts Chaussees, 119, 17–24.
39. Fuentes, R., Pinyol, N., and Alonso, E. (2016). Effect of temperature induced excess porewater pressures on the shaft bearing capacity of geothermal piles. Geomechanics for Energy and the Environment, 8, 30-37.
40. Goode III, J. C. and McCartney, J. S. (2015). Centrifuge modeling of end-restraint effects in energy foundations. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 141(8), 04015034-1–04015034-13.
41. Gudehus, G. (1996). A comprehensive constitutive equation for granular materials. Soils and foundations, 36(1), 1-12.
42. Haenel, R., Rybach, L., and Stegena, L. (Eds.). (1988). Handbook of terrestrial heat-flow density determination. Kluwer Academic, Dordrecht, Netherlands, 9-57.
43. Hirschberg, S., Wiemer, S., and Burgherr, P. (Eds.). (2014). Energy from the Earth: Deep Geothermal as a Resource for the Future? (Vol. 62). vdf Hochschulverlag AG.
44. Hueckel, T. and Pellegrini, R. (1989). Modelling of thermal failure of saturated clays. International symposium on numerical models in geomechanics - NUMOG, 81-90.

45. Hueckel, T. and Baldi, M. (1990). Thermoplastic of saturated clays: an experimental constitutive study. Journal of Geotechnical Engineering, ASCE 116: 1778–1796.
46. Hueckel, T., Pellegrini, R. and Del Olmo, C. (1998). A constitutive study of thermo-elasto-plasticity of deep carbonatic clays. International Journal for Numerical and Analytical Methods in Geomechanics, 22(7), 549-574.
47. Iodice, C., Di Laora, R. and Mandolini A. (2020). Analytical solutions for Ultimate Limit State design of thermal piles. Journal of Geotechnical and Geoenvironmental Engineering, ASCE. 146(5), 04020016.
48. Karatzia, X. and Mylonakis, G. (2016). Horizontal stiffness and damping of piles in inhomogeneous soil. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 143(4), 04016113-1–04016113-19.
49. Katzenbach, R., Ramm, H., and Waberseck, T. (2008). Economic and eniviroment-friendly ways of designing and-using deep foundations. In Proceedings of the Eighth International Conference on the Application of Stress Wave Theory to Piles 2008 (pp. 77-84).
50. Khalili, N., Uchaipichat, A., and Javadi, A. A. (2010). Skeletal thermal expansion coefficient and thermo-hydro-mechanical constitutive relations for saturated homogeneous porous media. Mechanics of materials, 42(6), 593-598.
51. Knellwolf, C., Peron, H. and Laloui, L. (2011). Geotechnical analysis of heat exchanger piles. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 137(10), 890–902.
52. Kolymbas, D. (1991). An outline of hypoplasticity. Archive of applied mechanics, 61(3), 143-151.
53. Laloui, L., Moreni, M., Fromentin, A., Pahud, D. and Steinmann, G. (1999). Heat exchanger pile: effect of the thermal solicitations on its mechanical properties. Bulletin d'Hydrogéologie, 17(1), 331–340.
54. Laloui, L., Moreni, M. and Vulliet, L. (2003). Comportement d'un pieu bi-fonction, fondation et échangeur de chaleur. Canadian Geotechnical Journal, 40(2), 388–402.
55. Laloui, L., Nuth, M. and Vulliet, L. (2006). Experimental and numerical investigations of the behaviour of a heat exchanger pile. International Journal for Numerical and Analytical Methods in Geomechanics, 30(8), 763–781.
56. Luo, J., Zhao, H., Gui, S., Xiang, W., and Rohn, J. (2017). Study of thermal migration and induced mechanical effects in double U-tube energy piles. Computers and Geotechnics, 91, 1-11.
57. Ma, Q. J., Ng, C. W. W., Mašín, D. and Zhou, C. (2017). An approach for modelling volume change of fine-grained soil subjected to thermal cycles. Canadian Geotechnical Journal, 54(6), 896–901.
58. Mašín, D. (2005). A hypoplastic constitutive model for clays. International Journal for Numerical and Analytical Methods in Geomechanics, 29(4), 311-336. Mašín, D.: Hypoplastic Cam-clay model. Géotechnique 62(6), 549–553 (2012)
59. Mašín, D., and Khalili, N. (2012). A thermo-mechanical model for variably saturated soils based on hypoplasticity. International journal for numerical and analytical methods in geomechanics, 36(12), 1461-1485.
60. Mašín, D. (2013). Clay hypoplasticity with explicitly defined asymptotic states. Acta Geotechnica, 8(5), 481-496
61. Mašín, D. (2014). Clay hypoplasticity model including stiffness anisotropy. Géotechnique, 64(3), 232-238.
62. Mašín, D. (2019). Modelling of Soil Behaviour with Hypoplasticity: Another Approach to Soil Constitutive Modelling. Springer.
63. McCartney, J. S. and Murphy, K. D. (2012). Strain distributions in full-scale energy foundations (DFI Young Professor Paper Competition 2012). DFI Journal-The Journal of the Deep Foundations Institute, 6(2), 26–38.
64. Mimouni, T., and Laloui, L. (2015). Behaviour of a group of energy piles. Canadian Geotechnical Journal, 52(12), 1913-1929.
65. Murphy, K. D. and McCartney, J. S. (2015). Seasonal response of energy foundations during building operation. Geotechnical and Geological Engineering, 33(2), 343–356.
66. Mylonakis, G. (2001). Winkler modulus for axially loaded piles. Geotechnique, 51(5), 455–462.
67. Niemunis, A., and Herle, I. (1997). Hypoplastic model for cohesionless soils with elastic strain range. Mechanics of Cohesive-frictional Materials: An International Journal on Experiments, Modelling and Computation of Materials and Structures, 2(4), 279-299.
68. Ng, C. W. W., Shi, C., Gunawan, A. and Laloui, L. (2014a). Centrifuge modelling of energy piles subjected to heating and cooling cycles in clay. Geotechnique letters, 4(4), 310–316.
69. Ng, C. W. W., Shi, C., Gunawan, A. and Laloui, L., and Liu, H. L. (2014b). Centrifuge modelling of heating effects on energy pile performance in saturated sand. Canadian Geotechnical Journal, 52(8), 1045–1057.

70. Ng, C. W. W., Wang, S. H., and Zhou, C. (2016a). Volume change behaviour of saturated sand under thermal cycles. Géotechnique Letters, 6(2), 124-131.
71. Ng, C. W. W., Ma, Q. J., and Gunawan, A. (2016b). Horizontal stress change of energy piles subjected to thermal cycles in sand. Computers and Geotechnics, 78, 54-61.
72. Ng, C. W. W., Gunawan, A., Shi, C., Ma, Q. J. and Liu, H. L. (2016c). Centrifuge modelling of displacement and replacement energy piles constructed in saturated sand: a comparative study. Géotechnique Letters, 6(1), 34–38.
73. Ng, C. W. W., and Ma, Q. J. (2019). Energy pile group subjected to non-symmetrical cyclic thermal loading in centrifuge. Géotechnique Letters, 1-5.
74. Nguyen, V. T., Tang, A. M., and Pereira, J. M. (2017). Long-term thermo-mechanical behavior of energy pile in dry sand. Acta Geotechnica, 12(4), 729-737.
75. Nguyen, V. T., Wu, N., Gan, Y., Pereira, J. M., and Tang, A. M. (2019). Long-term thermo-mechanical behaviour of energy piles in clay. Environmental Geotechnics, 1-12.
76. Pasten, C., and Santamarina, J. (2014). Thermally induced long-term displacement of thermoactive piles. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 140(5), 06014003.
77. Pahud, D., and Hubbuch, M. (2007). Measured thermal performances of the energy pile system of the dock midfield at Zürich Airport.
78. Plum R. L. and Esrig M.I. (1969) Some temperature effects on soil compressibility and pore water pressure. In Effects of Temperature and Heat on Engineering Behavior of Soils. Highway Research Board, Washington, DC, USA, Special Report No. 103, 231–242.
79. Rammal, D., Mroueh, H. and Burlon, S. (2018). Impact of thermal solicitations on the design of energy piles. Renewable and Sustainable Energy Reviews, 92, 111–120.
80. Randolph, M.F. and Wroth, C.P. (1978). Analysis of vertical deformation of vertically loaded piles. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 104(12), 1465–1488.
81. Roscoe, K. H., Schofield, A., and Wroth, A. P. (1958). On the yielding of soils. Geotechnique, 8(1), 22-53.
82. Roscoe K.H. and Burland J.B. (1968). On the generalised stress-strain behaviour of 'wet' clay. Eng. plasticity, Cambridge Univ. Press, 535-609
83. Rotta Loria, A. F. R., Gunawan, A., Shi, C., Laloui, L., and Ng, C. W. (2015). Numerical modelling of energy piles in saturated sand subjected to thermo-mechanical loads. Geomechanics for Energy and the Environment, 1, 1-15.
84. Rotta Loria, A. F. and Laloui, L. (2016a). Thermally induced group effects among energy piles. Géotechnique, 67(5), 374–393.
85. Rotta Loria, A. F., and Laloui, L. (2016b). The interaction factor method for energy pile groups. Computers and Geotechnics, 80, 121-137.
86. Rotta Loria, A. F., and Laloui, L. (2017a). Thermally induced group effects among energy piles. Géotechnique, 67(5), 374-393.
87. Rotta Loria, A. F., and Laloui, L. (2017b). The equivalent pier method for energy pile groups. Géotechnique, 67(8), 691-702.
88. Rotta Loria, A. F., and Laloui, L. (2017c). Displacement interaction among energy piles bearing on stiff soil strata. Computers and Geotechnics, 90, 144-154.
89. Rotta Loria, A. F., and Laloui, L. (2018a). Group action effects caused by various operating energy piles. Géotechnique, 68(9), 834-841.
90. Rotta Loria, A. F. R., Vadrot, A. and Laloui, L. (2018b). Analysis of the vertical displacement of energy pile groups. Geomechanics for Energy and the Environment, 16, 1–14.
91. Rui, Y., and Yin, M. (2017). Investigations of pile–soil interaction under thermo-mechanical loading. Canadian Geotechnical Journal, 55(7), 1016-1028.
92. Rui, Y., and Soga, K. (2019). Thermo-hydro-mechanical coupling analysis of a thermal pile. Proceedings of the Institution of Civil Engineers-Geotechnical Engineering, 172(2), 155-173.
93. Salciarini, D., Ronchi, F., Cattoni, E., and Tamagnini, C. (2014). Thermomechanical effects induced by energy piles operation in a small piled raft. International journal of Geomechanics, 15(2), 04014042.
94. Salciarini, D., Ronchi, F., and Tamagnini, C. (2017). Thermo-hydro-mechanical response of a large piled raft equipped with energy piles: a parametric study. Acta Geotechnica, 12(4), 703-728.
95. Sani, A. K., Singh, R. M., Amis, T., and Cavarretta, I. (2019). A review on the performance of geothermal energy pile foundation, its design process and applications. Renewable and Sustainable Energy Reviews, 106, 54-78.
96. Schofield, A., and Wroth, P. (1968). Critical state soil mechanics (Vol. 310). London: McGraw-Hill.

97. Seed, H. B., and Reese, L. C. (1957). The action of soft clay along friction piles. Transactions of the American Society of Civil Engineers 122: 731–754
98. Skempton, A. W. (1951). The bearing capacity of clays. Selected Papers on Soil Mechanics, 50-59.
99. Sloan, S. W., 1987. Substepping schemes for the numerical integration of elastoplastic stress-strain relations. International Journal of Numerical Methods in Engineering, 24, 893-911.
100. Stewart, M. A. and McCartney, J. S. (2013). Centrifuge modeling of soil-structure interaction in energy foundations. Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 140(4), 04013044-1–04013044-11.
101. Sultan, N., Delage, P., and Cui, Y. J. (2002). Temperature effects on the volume change behaviour of Boom clay. Engineering Geology, 64(2-3), 135-145.
102. Suryatriyastuti, M. E., Mroueh, H. and Burlon, S. (2012). Understanding the temperature-induced mechanical behaviour of energy pile foundations. Renewable and sustainable energy reviews, 16(5), 3344–3354.
103. Suryatriyastuti, M. E., Mroueh, H. and Burlon, S. (2014). A load transfer approach for studying the cyclic behavior of thermo-active piles. Computers and Geotechnics, 55, 378–391.
104. Suryatriyastuti, M. E., Burlon, S., and Mroueh, H. (2015). On the understanding of cyclic interaction mechanisms in an energy pile group. International journal for numerical and analytical methods in geomechanics, 40(1), 3-24.
105. Sutman, M., Olgun, C. G., and Brettmann, T. (2015). Full-scale field testing of energy piles. In IFCEE 2015 (pp. 1638-1647).
106. Sutman, M., Olgun, C. G., and Laloui, L. (2019). Cyclic load–transfer approach for the analysis of energy piles. Journal of Geotechnical and Geoenvironmental Engineering, 145(1), 04018101.
107. Tamagnini, C., Viggiani, G., Chambon, R., and Desrues, J. (2000). Evaluation of different strategies for the integration of hypoplastic constitutive equations: Application to the CLoE model. Mechanics of Cohesive‐frictional Materials: An International Journal on Experiments, Modelling and Computation of Materials and Structures, 5(4), 263-289.
108. Tamagnini, C., and Viggiani, G. (2002). Constitutive modelling for rate-independent soils: a review. Revue française de génie civil, 6(6), 933-974.
109. Terzaghi, K. V. (1923). Die berechnung der durchlassigkeitsziffer des tones aus dem verlauf der hydrodynamischen spannungserscheinungen. Sitzungsberichte der Akademie der Wissenschaften in Wien, Mathematisch-Naturwissenschaftliche Klasse, Abteilung IIa, 132(3–4), 125-138.
110. Thomas, H. R. and King, S. D. (1994). A nonlinear, 2-dimensional, potential-based analysis of coupled heat and mass-transfer in a porous-medium. International Journal for Numerical Methods in Engineering, 37(21), 3707-3722, doi: 10.1002/nme.1620372108.
111. Towhata, I., Kuntiwattanakul, P., Seko, I., and Ohishi, K. (1993). Volume change of clays induced by heating as observed in consolidation tests. Soils Foundations 334: 170–183
112. Truesdell, C. (1956). Hypo‐elastic shear. Journal of Applied Physics, 27(5), 441-447.
113. Vardanega, P. J. and Bolton M. D. (2011). Predicting shear strength mobilization of London clay. Proc. 15th Eur. Conf. on Soil Mech. and Geoth. Eng., Athens, 1, 487–492.
114. Vega, A., and McCartney, J. S. (2014). Cyclic heating effects on thermal volume change of silt. Environmental Geotechnics, 2(5), 257-268.
115. Viggiani, G., and Atkinson, J. H. (1995). Stiffness of fine-grained soil at very small strains. Géotechnique, 45(2), 249-265.
116. Vieira, A., and Maranha, J. R. (2016). Thermoplastic analysis of a thermoactive pile in a normally consolidated clay. International journal of Geomechanics, 17(1), 04016030.
117. Wegener, D., and Herle, I. (2014). Prediction of permanent soil deformations due to cyclic shearing with a hypoplastic constitutive model. Geotechnik, 37(2), 113-122.
118. Wu, D., Liu, H. L., Kong, G. Q., Ng, C. W. W., and Cheng, X. H. (2018). Displacement response of an energy pile in saturated clay. Proceedings of the Institution of Civil Engineers-Geotechnical Engineering, 171(4), 285-294.
119. Yavari, N., Tang, A. M. and Pereira, J. M. (2014). A simple method for numerical modelling of mechanical behaviour of an energy pile. Geotechnique letters, 4(2), 119–124.
120. You, S., Cheng, X., Guo, H., and Yao, Z. (2016). Experimental study on structural response of CFG energy piles. Applied Thermal Engineering, 96, 640-651.
121. Zienkiewicz, O. C., Chan, A. H. C., Pastor, M., Schrefler, B. A., and Shiomi, T. (1999). Computational geomechanics (pp. 105-110). Chichester: Wiley.