This paper presents the results of forced and free horizontal vibration tests conducted on 9.0-m long and 324-mm shaft diameter single and double-helix large-capacity helical piles as well as a driven steel pipe pile of the same geometrical properties. The soil static and dynamic properties were determined from field and laboratory testing. Forced vibrations involved excitation forces with varying amplitudes. The experimental results provided insights into the dynamic pile–soil interaction for large-capacity helical piles installed in structured clayey soils. The dynamic behavior of helical piles was essentially similar to that of the driven pile, with insignificant effect from helices. The piles exhibited slight to moderate nonlinear behavior. An equivalent-linear analytical model of the pile–soil system was developed incorporating an annular zone around the pile with reduced shear modulus and accounting for pile–soil separation. The results from the model agreed well with the measured responses.