The impact of the abutment wall height, the bridge span length range, and the roadway profile grade on the moment profile and lateral displacement profile of HP or W piles under thermal expansion in integral abutment bridges (IABs)

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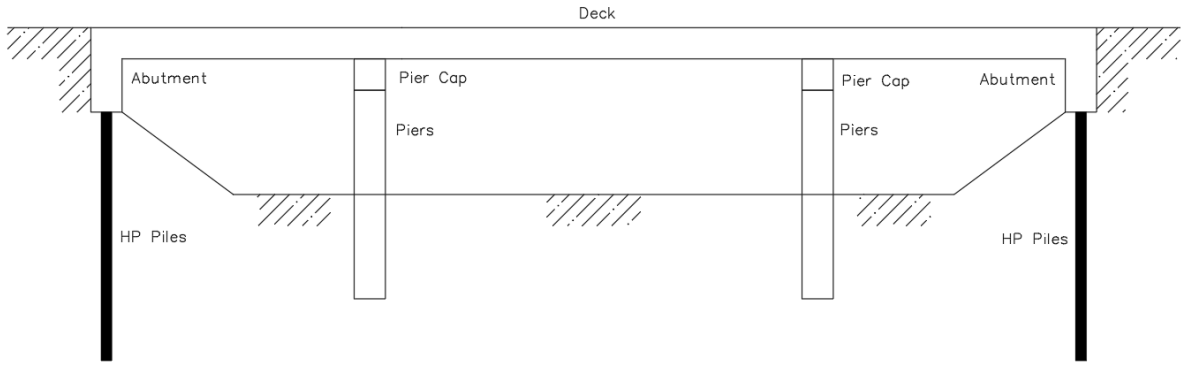
Selected sample of three-span non-skew IABs

Length = 150 ft (45, 60, 45) Width =59 ft

Length = 275 ft (80, 115, 80) Width = 59 ft

Length = 400 ft (115, 170 , 115) Width = 59 ft

Length = 550 ft (160, 230, 160) Width = 59 ft



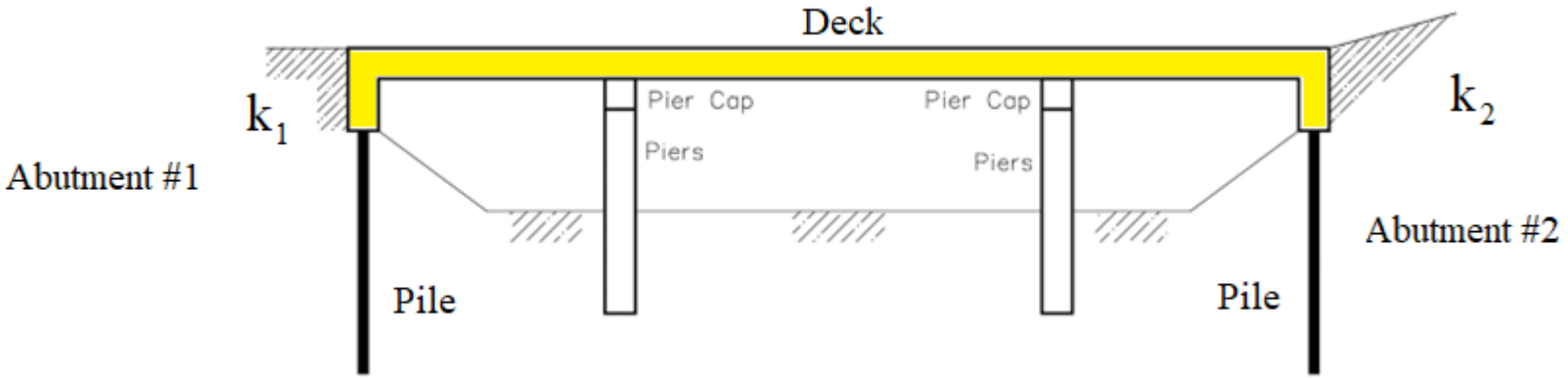
Assumptions for the sample three-span non-skew IABs

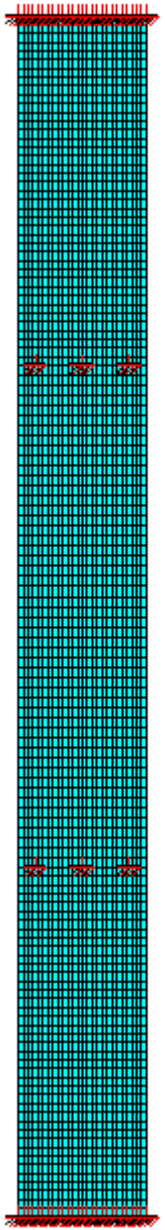
- Seven girders equally spaced (9ft)
- Seven W or HP piles equally spaced (9ft)
- Nonlinear springs around the piles.
- Nonlinear springs behind the abutment walls
- Abutment walls 3ft wide and 8ft, 10 ft, or 12ft high
- 8.5-inch concrete slab
- 8 ft pre-drilled holes around the piles
- Solid pile cap with three columns at each bent
- Wingwalls lining up with the abutment walls

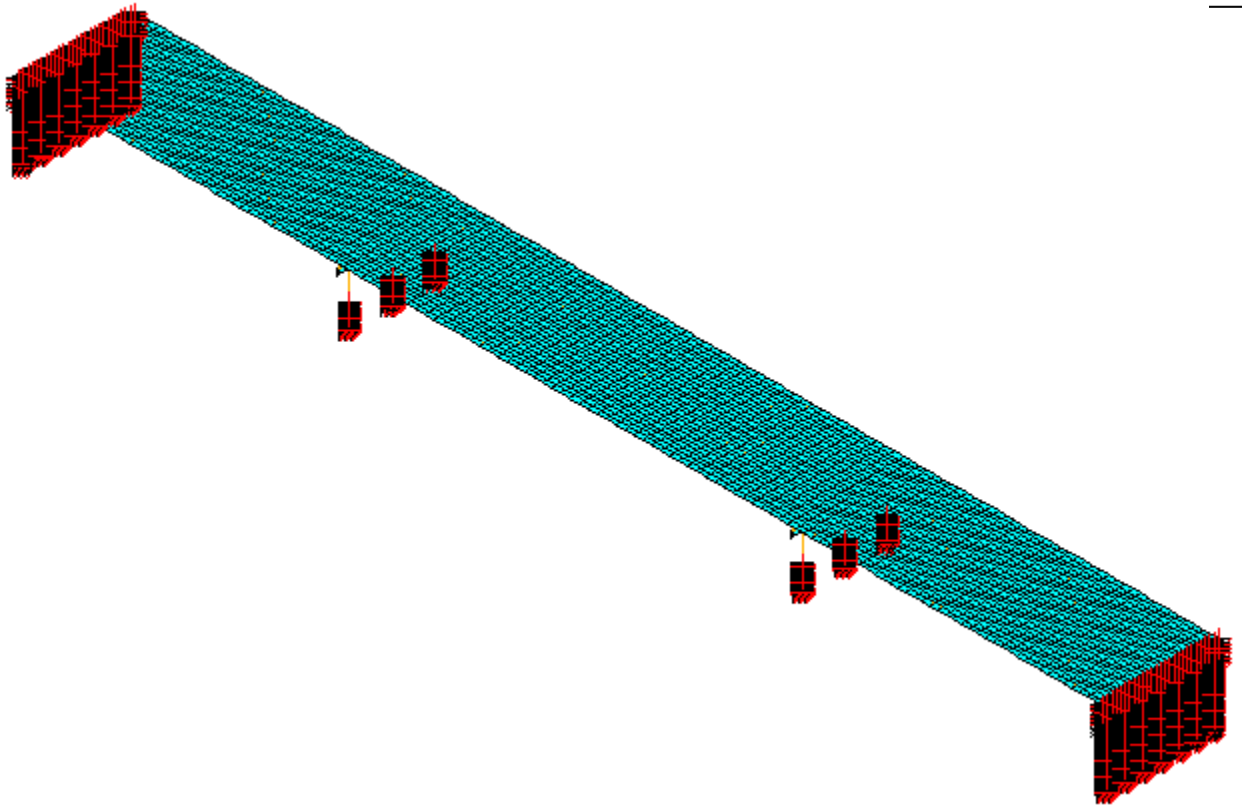
For the sample IABS: Variation of the abutment wall height

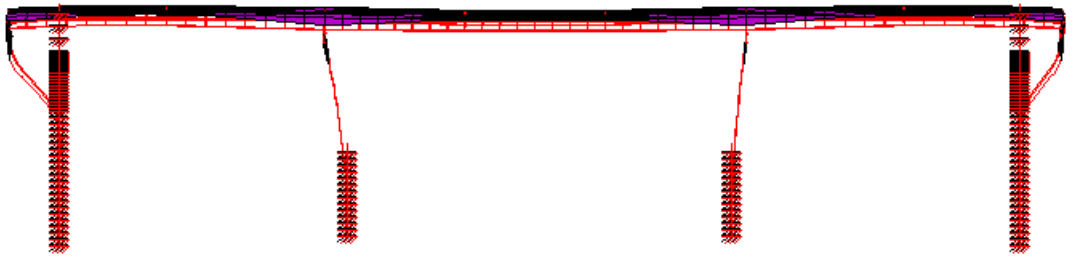
(i) Keeping the soil behind the abutment walls identical

(ii) Variation of the soil profile behind the wall from one abutment to another



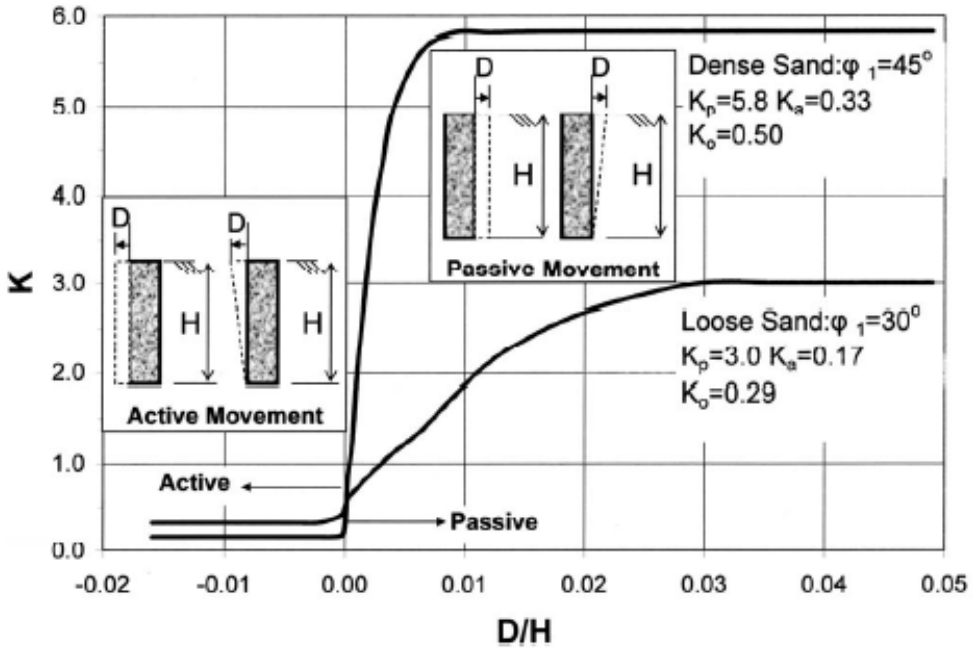


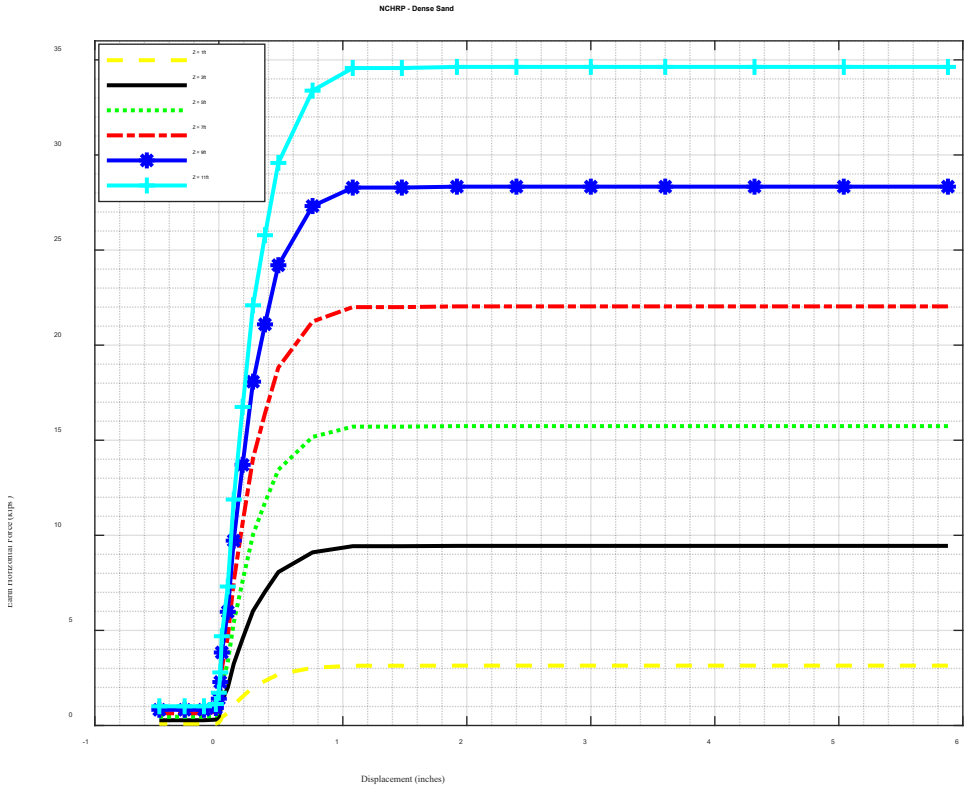


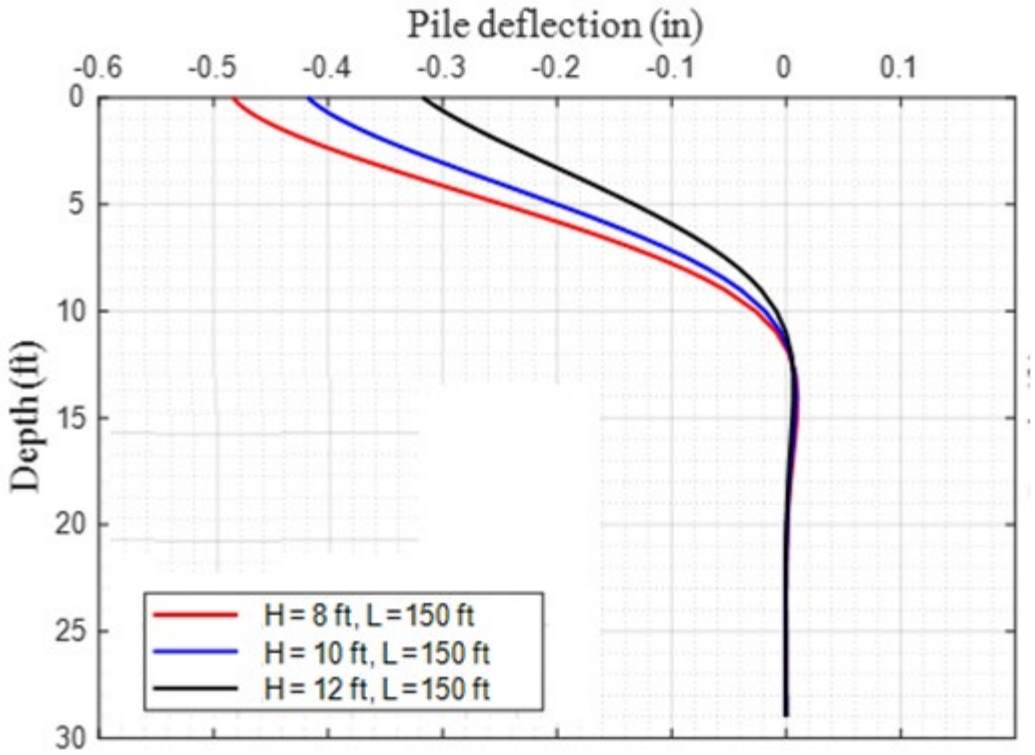


Geotechnical properties of soil around pile

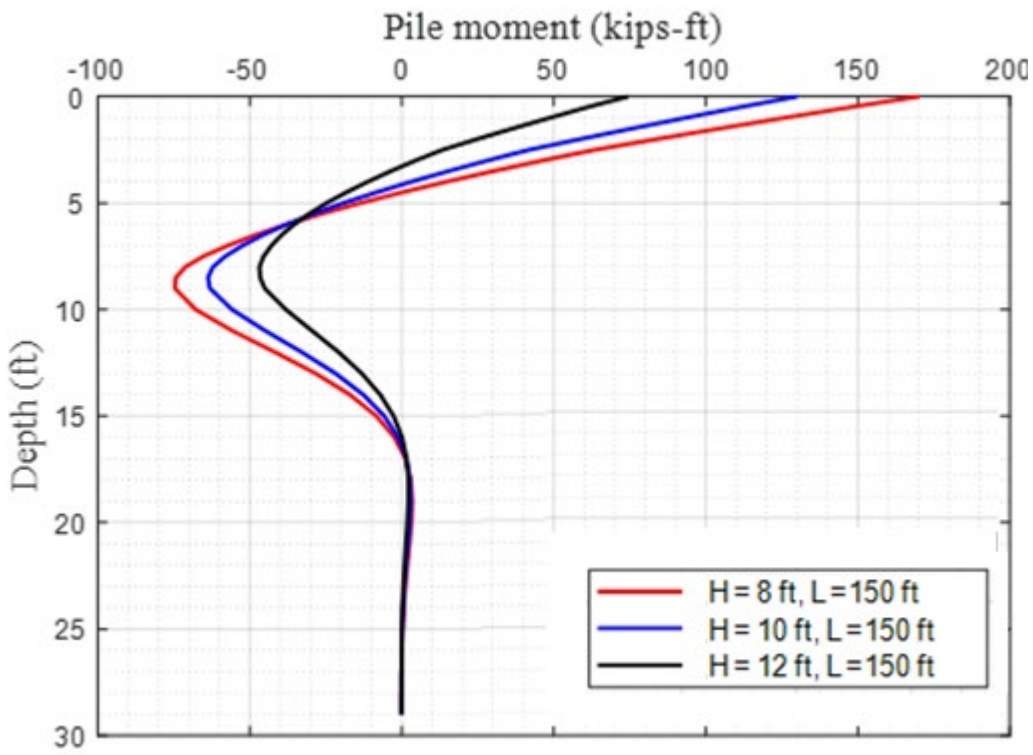
Soil	Layer Depth	γ [kg/m³(lb/ ft³)]	Φ (deg)	k [N/mm³(lb/ in.³)]
Sand	0.0′ – 8.0′ [pre-drilled]	1602 (100)	30	0.068 (250)
	8.0′ – 14.5′	1922 (120)	40	0.034 (125)
	14.5′ – 36.0′	1201 (75)	38	0.034 (125)
	36.0′- 50.0′	1201 (75)	40	0.034 (125)


6.0
5.0
4.0
3.0
2.0
1.0
0.0
K
-0.02
-0.01
0.00
0.01
0.02
0.03
0.04
0.05
D/H
D
H
Active Movement
Active
Passive
Passive Movement
Dense Sand:φ 1=45°
Kp=5.8 Ka=0.33
Ko=0.50
Loose Sand:φ 1=30°
Kp=3.0 Ka=0.17
Ko=0.29

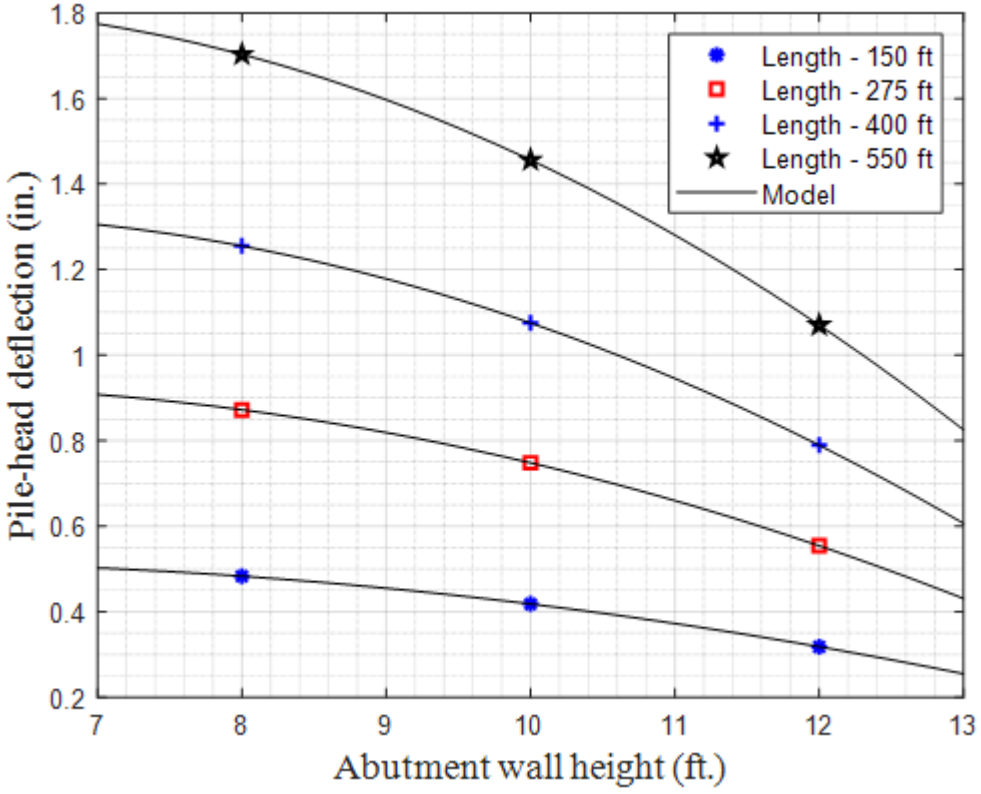

NCHRP - Dense Sand
Displacement (inches)



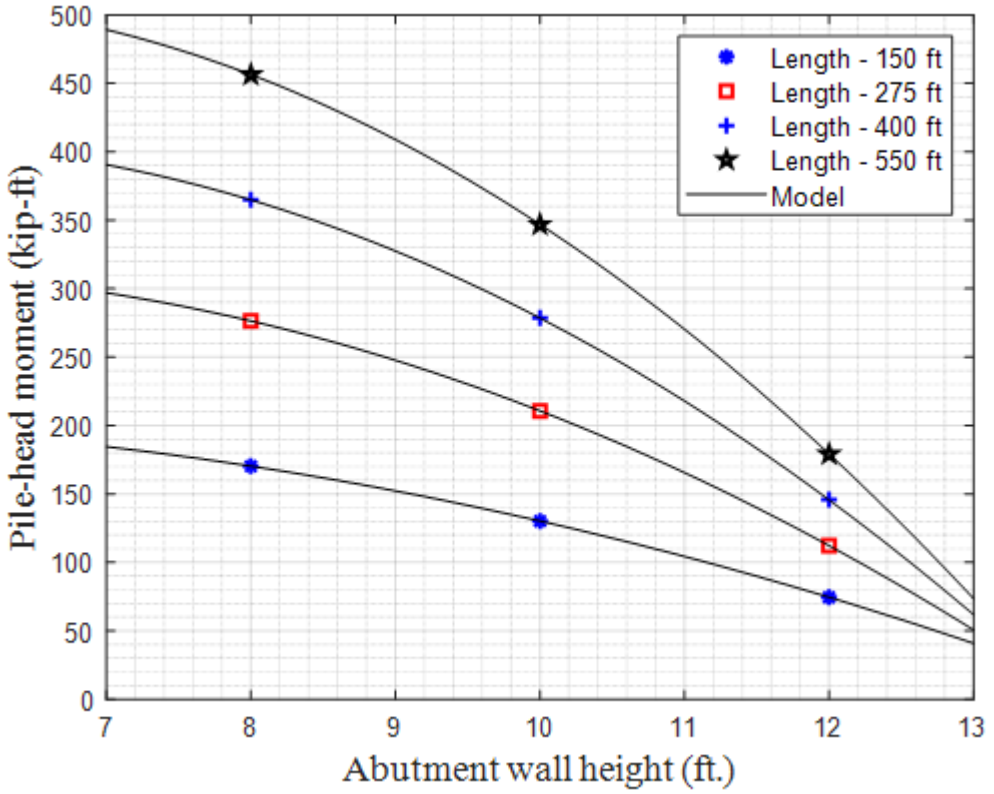
Pile displacement profile for thermal loading



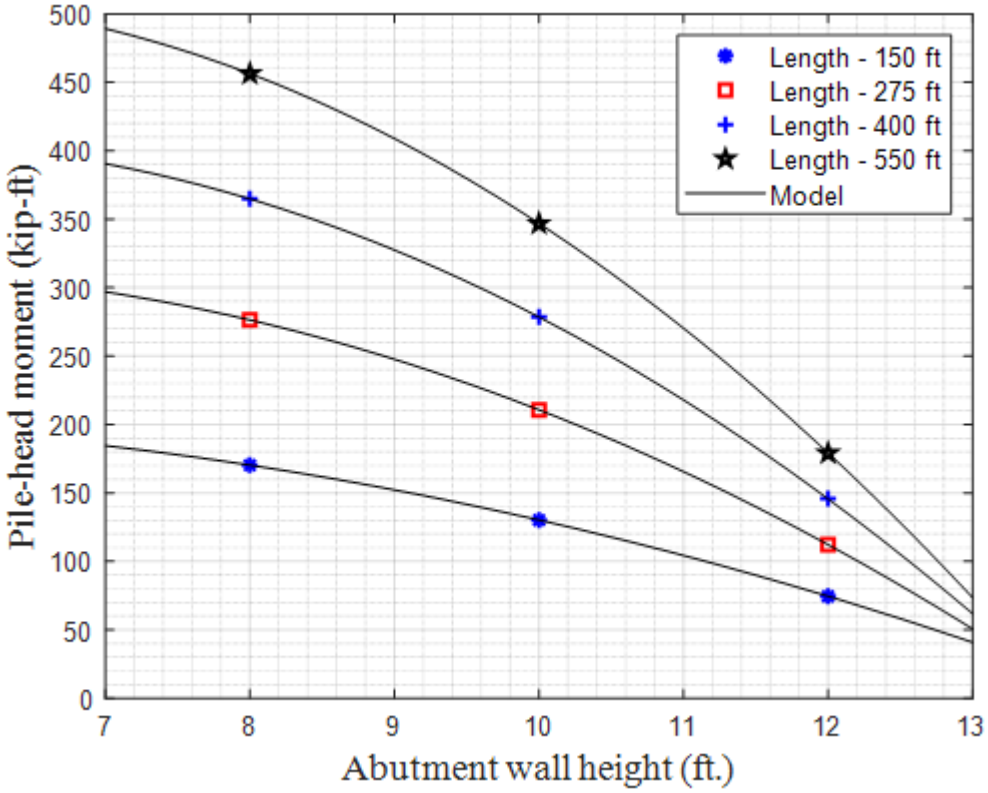
Pile moment profile for thermal loading



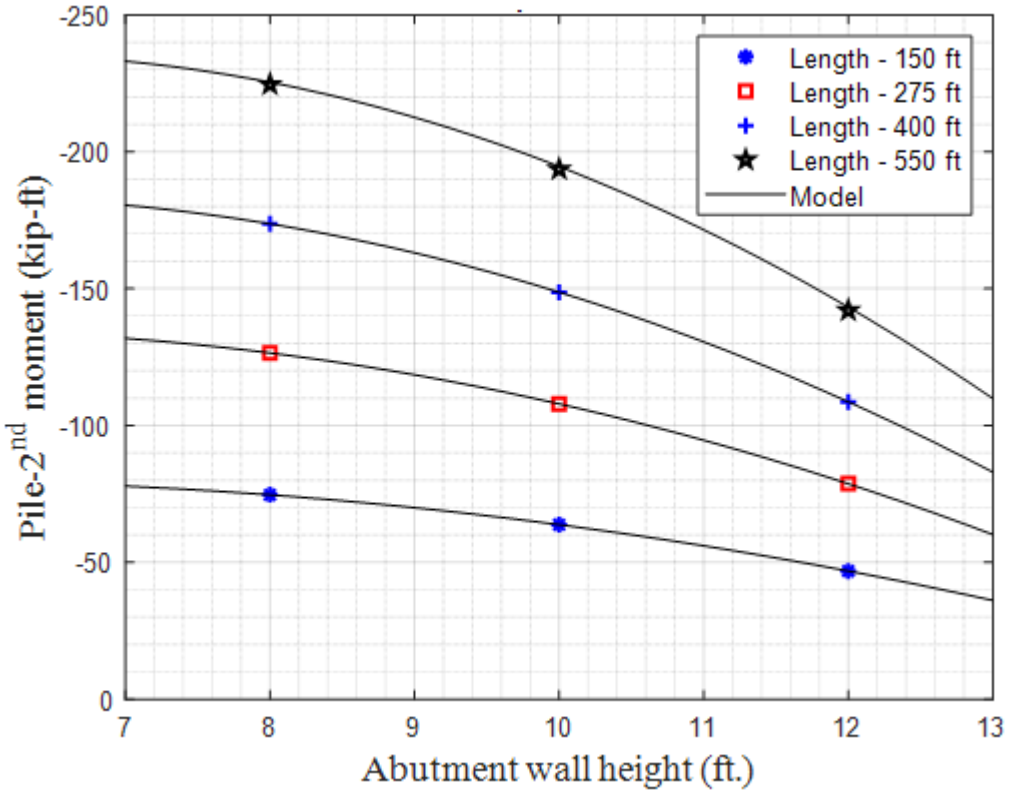
(a) Pile-head displacement for thermal loading



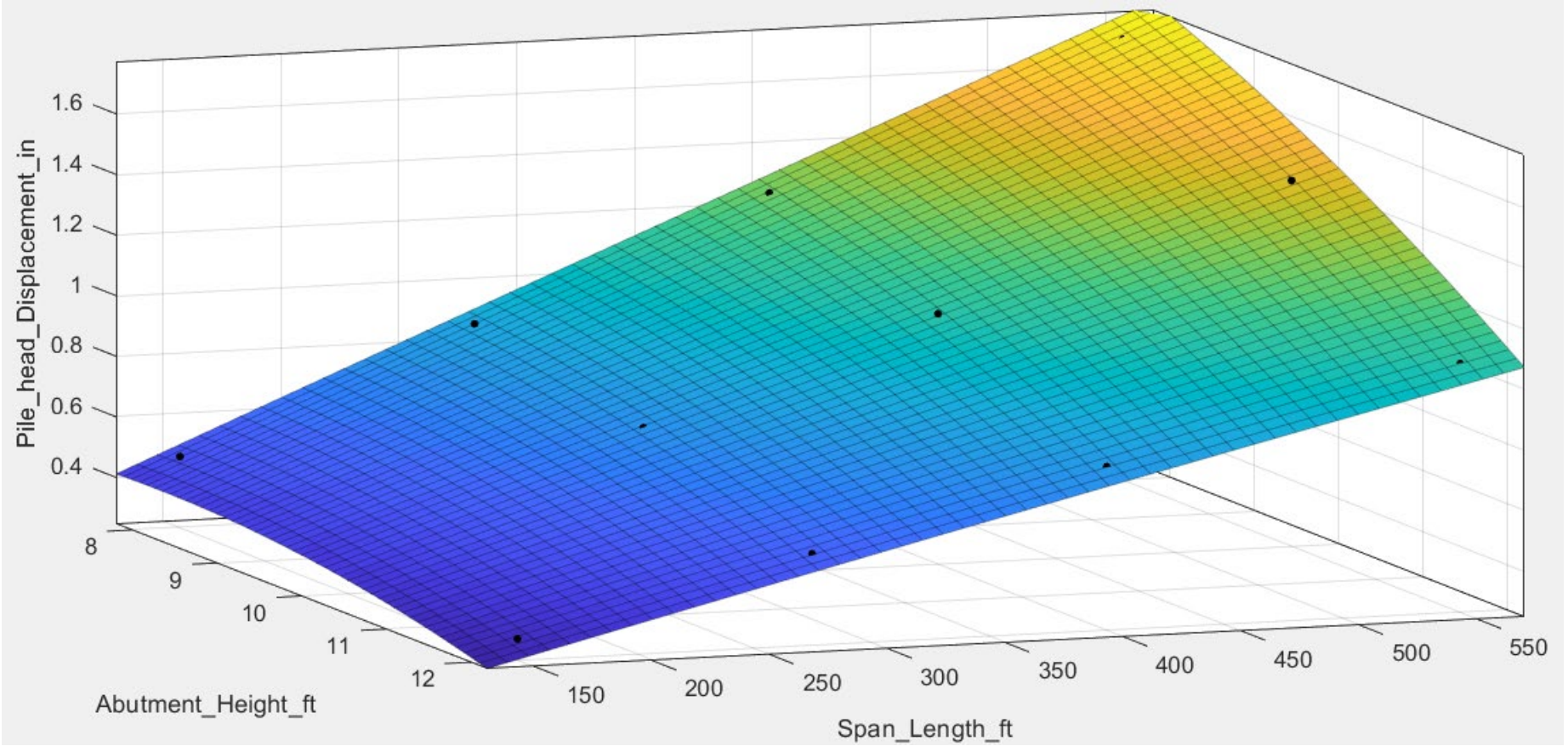
(b) Pile-head moment for thermal loading



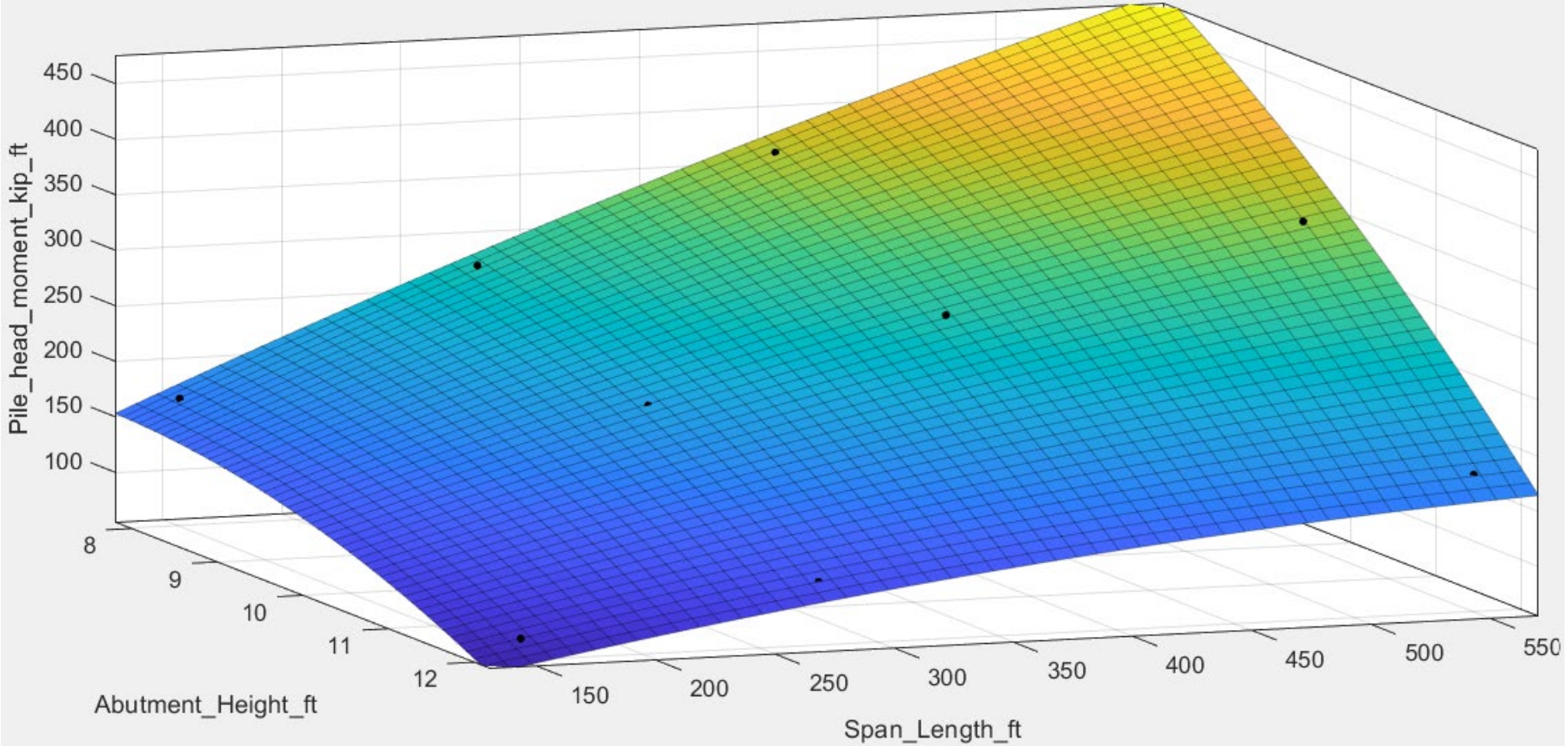
(b) Pile-head moment for thermal loading



(c) Pile 2nd moment for thermal loading

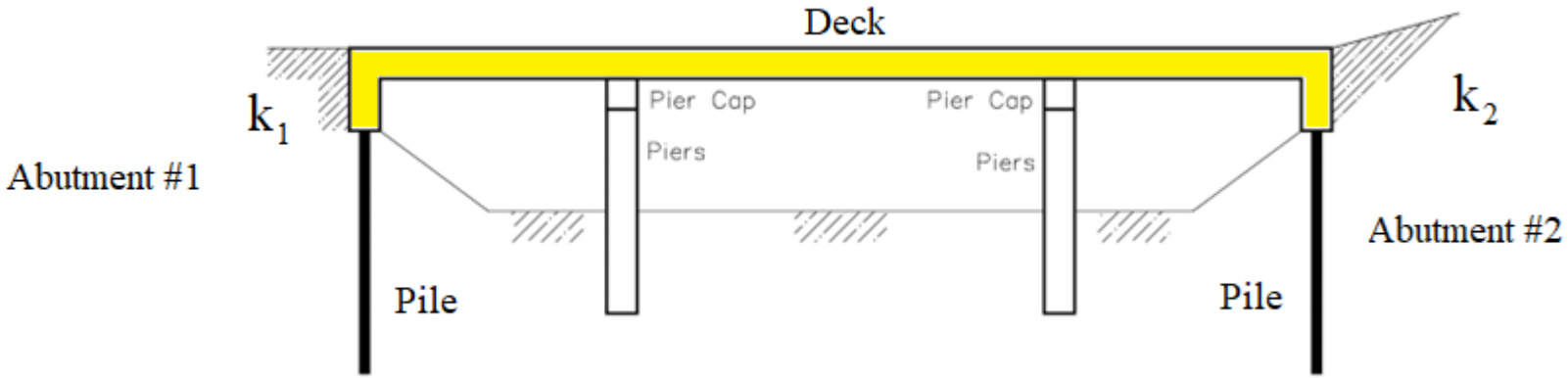


Variation of pile head displacement vs. span length and abutment wall height



Variation of pile head moment vs. span length and abutment wall height

Variation of the soil profile behind the wall from one abutment to another



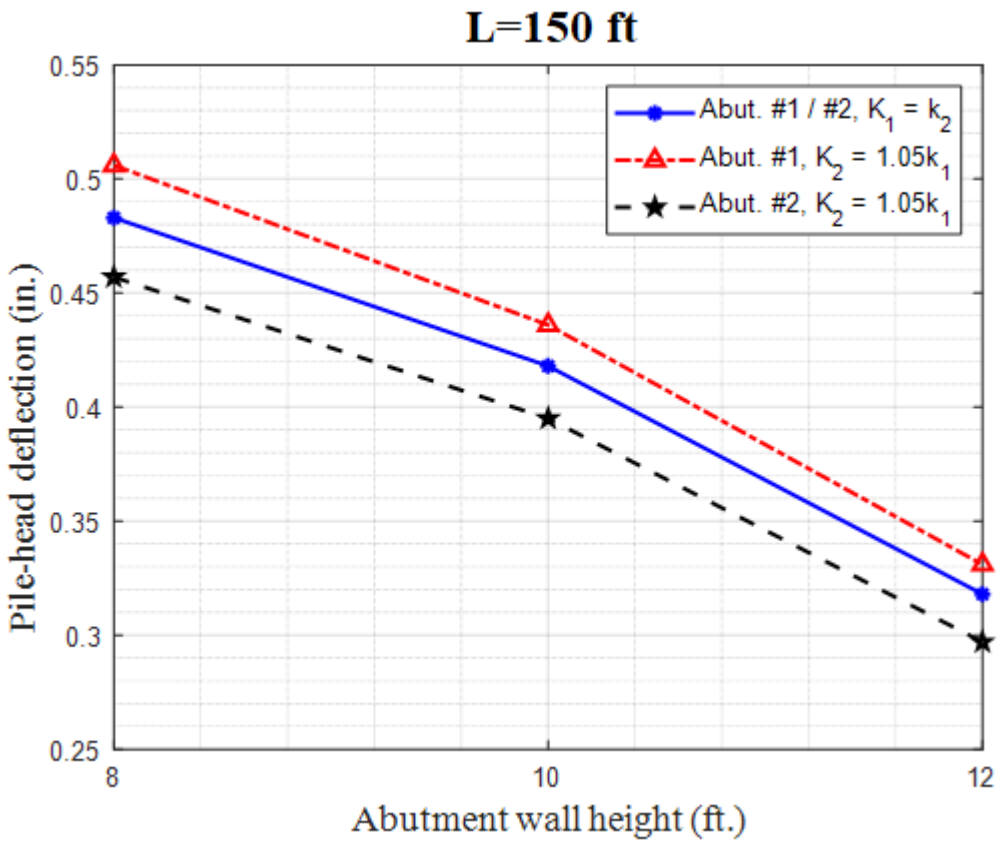
$$k_2 = k_1$$

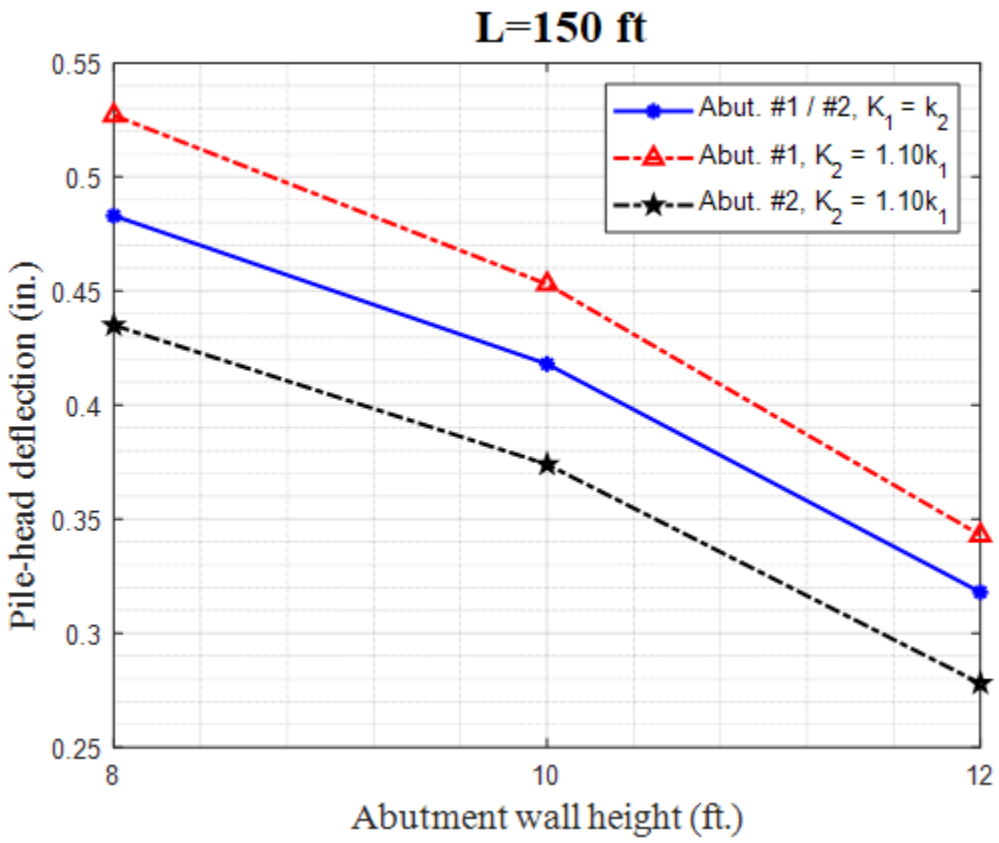
$$k_2 = 1.05\ k_1$$

$$k_2 = 1.10\ k_1$$

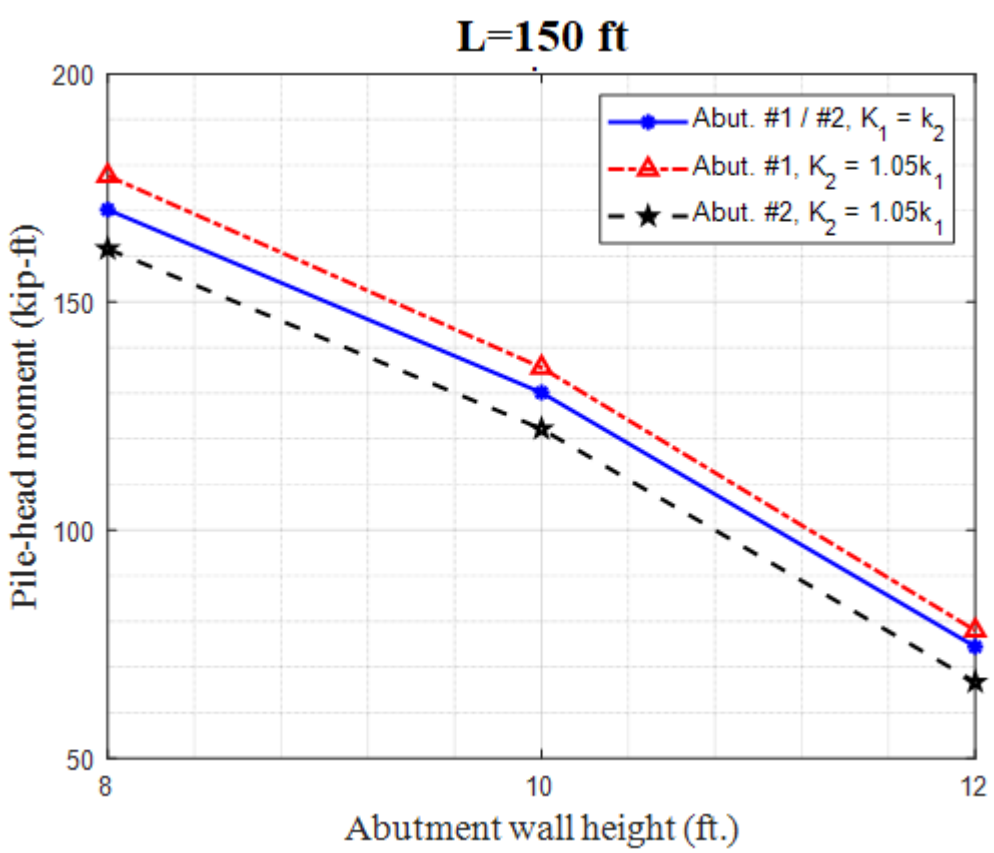
L= 150 ft, Thermal loading

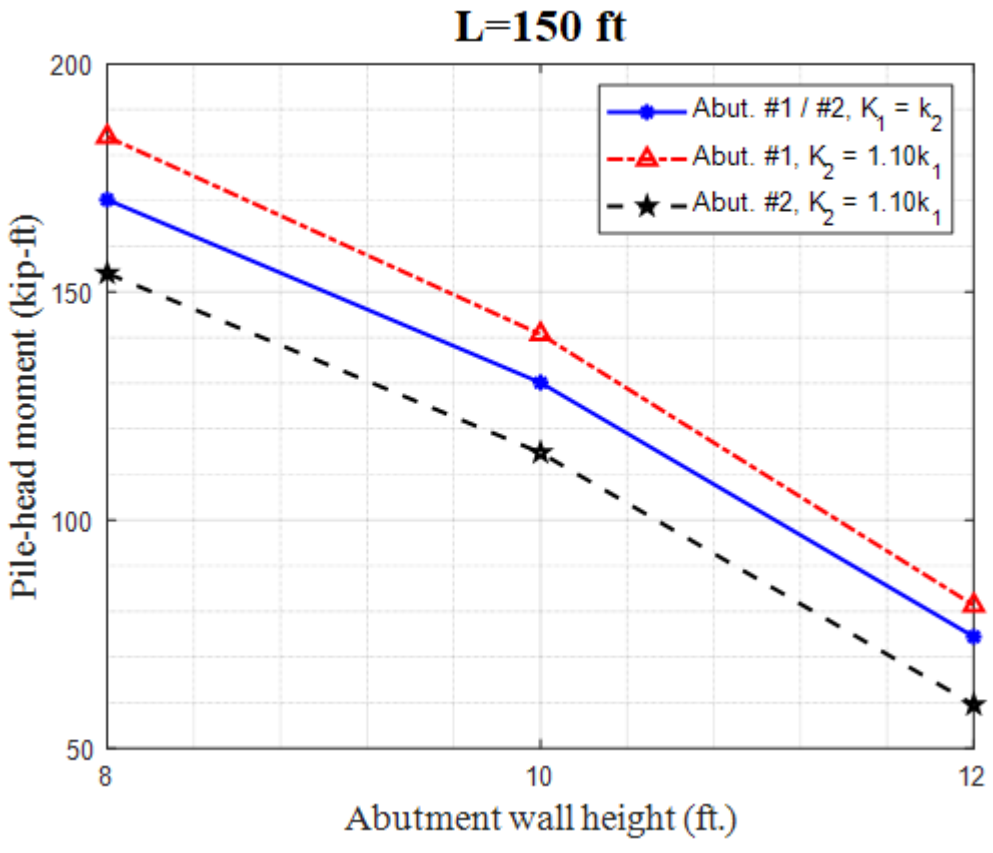
Abutment wall Height (ft)	Stiffness of Soil Behind Abutment Walls	Abutment Source	Deck Deflection Δ (inch)	Deflection δ (inch)	Rotation θ (radian)	Pile V (kips)	M_1 (kip-ft)	M_2 (kip-ft)
H = 8	$K_2 = k_1$	#1, #2	±0.523	±0.486	±0.00069	46.2	±181.81	±74.66
	$K_2 = 1.05\ k_1$	#1	-0.547	-0.509	+0.00072	47.9	-189.66	+77.99
		#2	+0.497	+0.460	-0.00068	44.3	+172.74	-70.99
	$K_2 = 1.10\ k_1$	#1	-0.569	-0.530	+0.00074	49.3	-196.40	+80.86
		#2	+0.474	+0.438	-0.00068	42.5	+164.74	-67.72
H=10	$K_2 = k_1$	#1, #2	±0.523	±0.422	±0.00128	38.58	±139.78	±63.76
	$K_2 = 1.05\ k_1$	#1	-0.544	-0.441	+0.00131	39.93	-145.63	+66.40
		#2	+0.500	+0.399	-0.00127	36.74	+131.39	-60.41
	$K_2 = 1.10\ k_1$	#1	-0.564	-0.458	+0.00135	41.19	-151.04	+68.86
		#2	+0.479	±0.378	-0.00127	35.03	+123.54	-57.29
H=12	$K_2 = k_1$	#1, #2	±0.523	±0.323	±0.00191	27.3	±81.28	±46.83
	$K_2 = 1.05\ k_1$	#1	-0.542	-0.337	+0.00196	28.3	-85.06	+48.78
		#2	+0.504	±0.303	-0.00191	25.5	+73.10	-43.69
	$K_2 = 1.10\ k_1$	#1	-0.559	±0.349	+0.00200	29.1	-88.63	+50.61
		#2	+0.486	±0.284	-0.00191	23.9	+65.51	-40.79



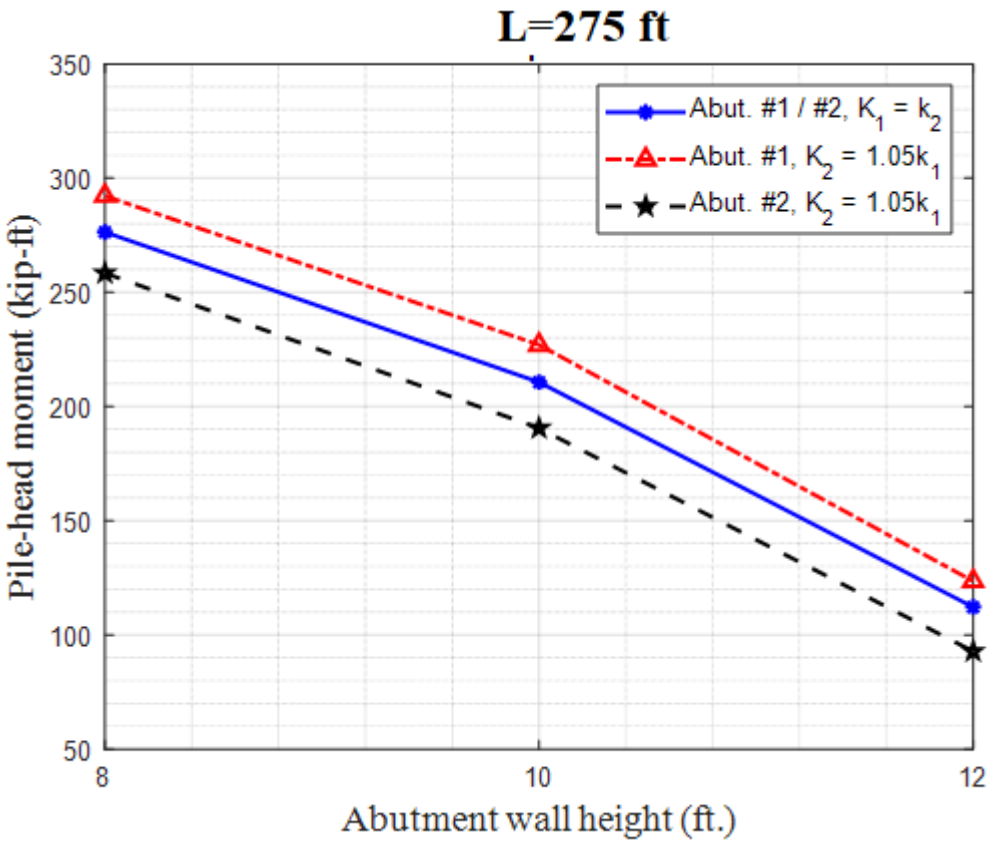


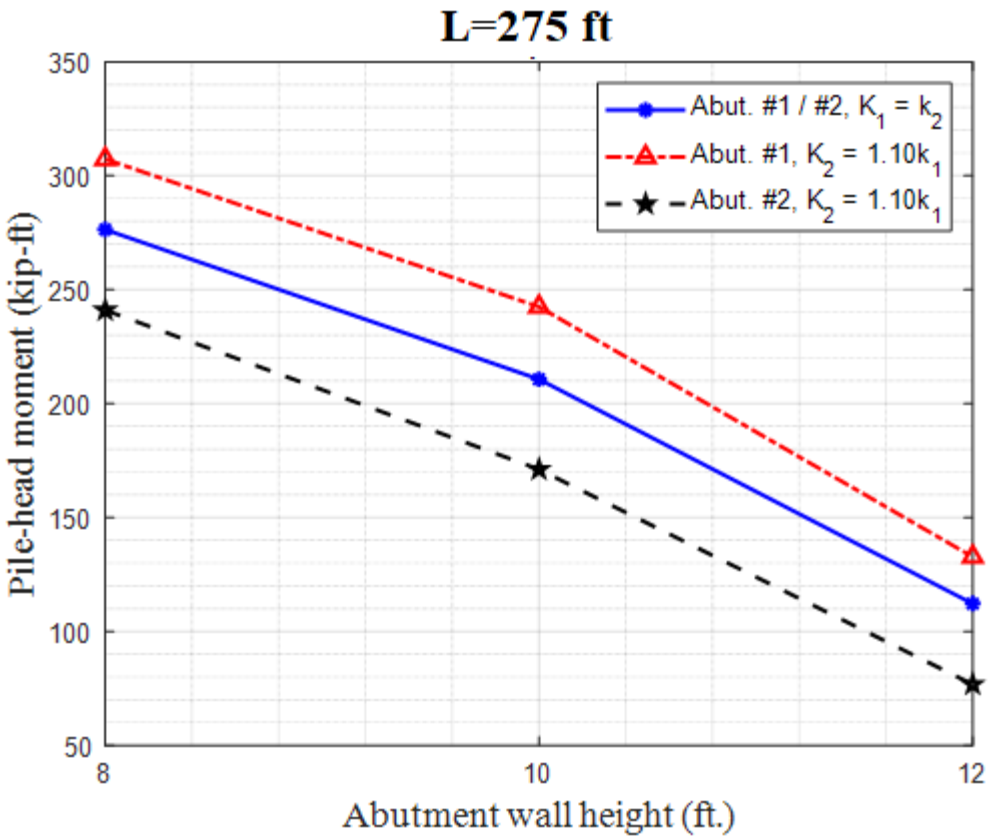
Pile head displacement vs. abutment wall height under thermal loading





Pile head moment vs. abutment wall height under thermal loading





Pile head moment vs. abutment wall height under thermal loading

- Under thermal expansion, increasing the abutment wall height will decrease the pile head displacement, the pile's maximum moment, and the effective length of the fixity point.

- Under thermal expansion, varying the stiffness of the soil behind one abutment wall with respect to the other one, will decrease the piles' maximum moment and the lateral displacement at the abutment with stiffer soil and will increase them on the other abutment. The decrease or increase in the pile's maximum moment or displacement will be larger for IABs with longer spans and longer wall heights. Therefore, we should design accordingly.

Thank you!