CHAPTER V

CONCLUSION

This paper considers vertical load transfer from pile group to a multi-layered poroelastic medium. The contact surface between each pile and the supporting medium is assumed to be perfectly bonded and fully permeable. Each pile in the group is considered to be a one-dimensional elastic continuum. The present scheme is based on the development of the total potential energy functional for pile group-multi-layered system

The convergence of the present solution scheme with respect to ξ_L, Nt and Ne are first investigated in Chapter IV. It is found that the numerical solutions converge for $\xi_L = 40$, $Nt = 8$ and for Ne equal to 30 and 40 for $20 < L/a \leq 60$ and $60 < L/a \leq 100$ respectively. In addition, the accuracy of the present scheme is confirmed by comparing with existing solutions.

Numerical results presented in Chapter IV indicate that this problem is governed by a complicated combination of several parameters and the influence from those parameters can be summarized below.

1. The vertical settlements of pile group are significantly influenced by the spacing between the center of piles, number of piles and length of piles. However, the influence of pile length is reduced when the pile stiffness is decreased.

2. The moduli of elastic piles and the poroelastic material properties have a significant influence on vertical settlements of pile group.

3. The consolidation of pile group depends significantly on the permeability of each layer.

4. The vertical settlements of pile group depend on the depth of rigid base.

The scheme presented in this thesis is useful in studying the vertical load transfer of the pile group embedded in multi-layered poroelatic half-space. The present scheme can be extended to study the quasi-static response of a pile group under other types of loading such as lateral and moment loading, etc. However, in those problem, influence functions corresponding to appropriate loading applied in the multi-layered poroelastic medium have to be employed in the analysis.

Table 1. Convergence of axial stiffness (Kv) for an axially loaded pile group in a homogeneous poroelastic half-space with respect to ξ_L $(L = 40a\ ;\ Ne = 30\ ;\ d = 5a$ and $Nt = 14)$

ξ_L	$Ep/\mu = 100$			
	P1	P2	P3	P4
10	24.24	38.09	47.49	55.94
20	24.23	38.07	47.49	55.93
40	24.23	38.06	47.48	55.92
60	24.23	38.06	47.48	55.92

ξ_L	$Ep/\mu = 6000$			
	P1	P2	P3	P4
10	64.82	84.25	93.94	102.91
20	64.80	84.23	93.91	102.88
40	64.79	84.22	93.91	102.88
60	64.79	84.22	93.91	102.88

ξ_L	$Ep/\mu = \infty$			
	P1	P2	P3	P4
10	68.42	87.36	96.55	105.29
20	68.39	87.33	96.52	105.26
40	68.38	87.32	96.52	105.26
60	68.38	87.32	96.52	105.26

Table 2. Convergence of axial stiffness (Kv) for an axially loaded pile group in a homogeneous poroelastic half-space with respect to Nt ($L = 40a$; $Ne = 30$; $d = 5a$ and $\xi_L = 80$)

Nt	$Ep/\mu = 100$			
	P1	P2	P3	P4
2	27.25	40.70	49.53	57.64
4	24.25	38.10	47.54	55.99
6	24.24	38.08	47.50	55.95
8	24.23	38.06	47.49	55.94
10	24.23	38.06	47.49	55.94

Nt	$Ep/\mu = 6000$			
	P1	P2	P3	P4
2	64.90	84.29	93.95	102.91
4	64.80	84.23	93.91	102.88
6	64.79	84.22	93.91	102.88
8	64.79	84.22	93.91	102.88
10	64.79	84.22	93.91	102.88

Table 3. Comparison of solutions for single pile in a nonhomogeneous elastic medium with rigid base

	Settlement influence factor (I_w)			
	$Ep/Es(L) = 100$		$Ep/Es(L) = 1000$	
	$L = 20a$	$L = 50a$	$L = 20a$	$L = 50a$
Chow (1987)	0.116	0.127	0.084	0.057
Polous (1979)	0.116	0.125	0.092	0.059
Present study	0.114	0.127	0.081	0.057

Table 4. Layered soil properties for a multi-layered elastic medium with rigid base

	Case A	Case B	Case C
Layer 1	E_1=1*E_{ref}	E_1=4*E_{ref}	E_1=2*E_{ref}
Layer 2	E_2=2*E_{ref}	E_2=2*E_{ref}	E_2=1*E_{ref}
Layer 3	E_3=4*E_{ref}	E_3=1*E_{ref}	E_3=4*E_{ref}

for all cases, ν_s =0.3 and $Ep = 1000E_{ref}$

Table 5. Comparison of settlement influence factor (I_w) for single pile in a multi-layered elastic medium with rigid base

	Poulos (1979) AXIL5	Poulos (1979) ISOPE	Present study
Case A	0.0386	0.0377	0.0389
Case B	0.0330	0.0430	0.0442
Case C	0.0366	0.0382	0.0397

Table 6. Comparison of interaction factor for two piles in a multi-layered elastic medium with rigid base

	Chow (1987)	Present study
Case A	0.31	0.316
Case B	0.54	0.540
Case C	0.35	0.344

Table 7. Material properties of poroelastic layered systems in Figure 12

Layer	B	ν	ν_u	κ	μ
1	1.00	0.25	0.50	vary	1.0
2	0.80	0.25	0.40	$\kappa^{(2)}$	1.5
3 / half-space	0.60	0.20	0.35	$0.5\kappa^{(2)}$	2.0

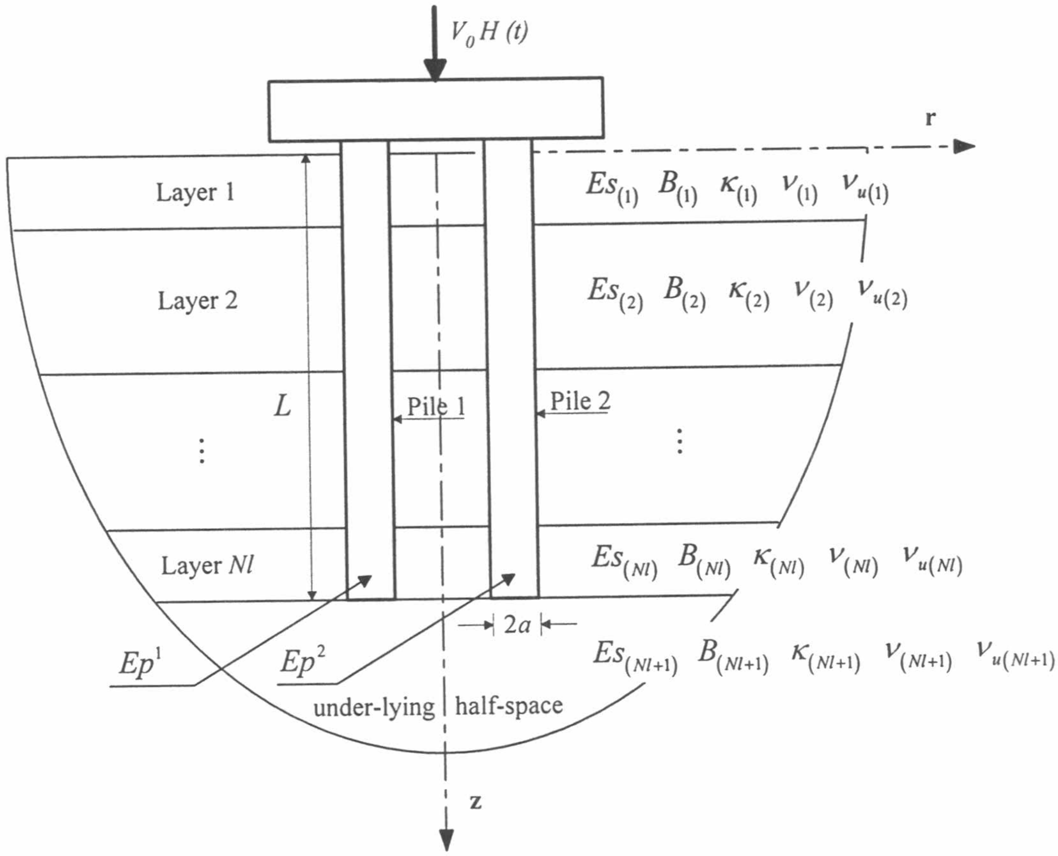


Figure 1. Axially loaded pile group in a multi-layered poroelastic half-space

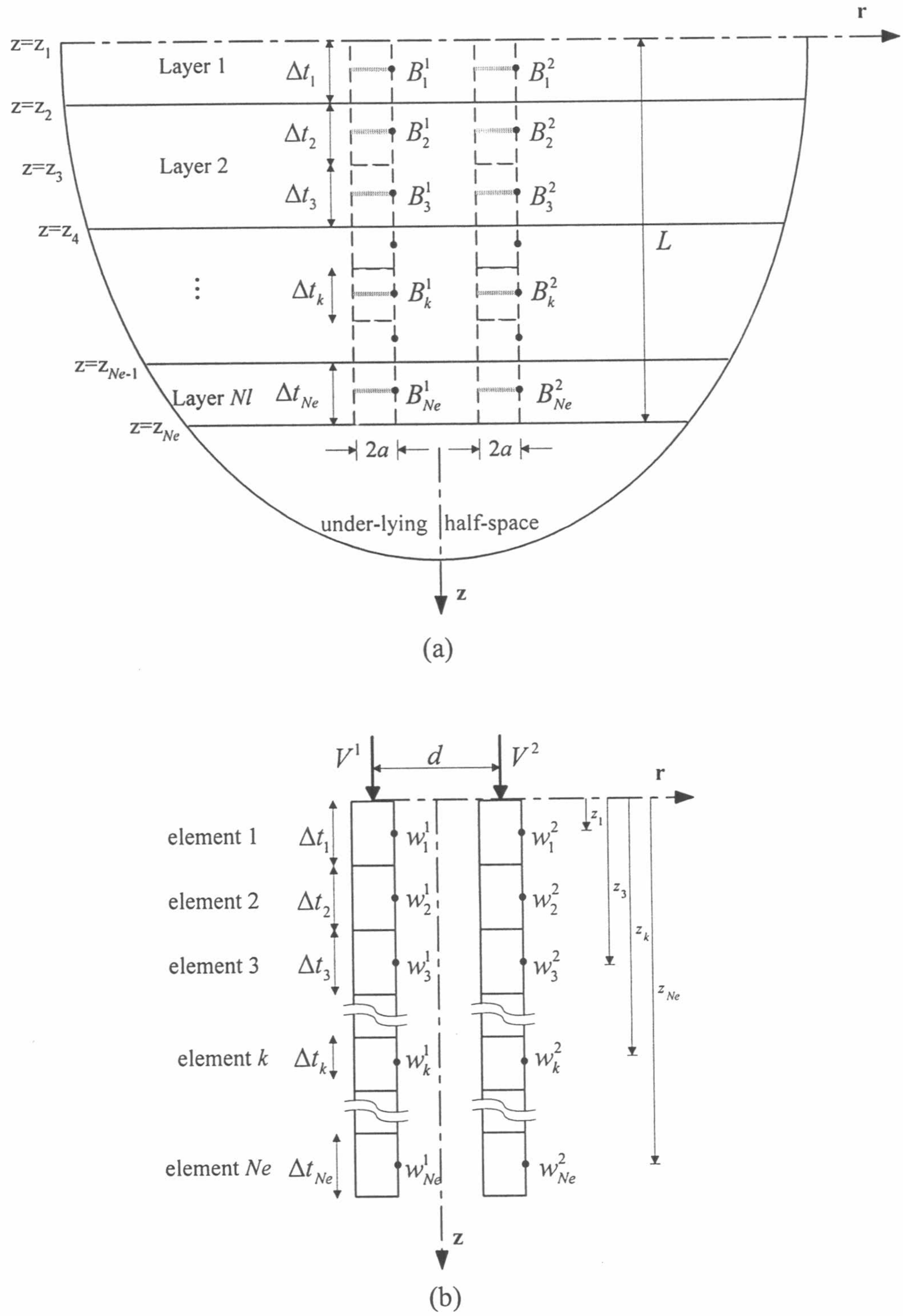
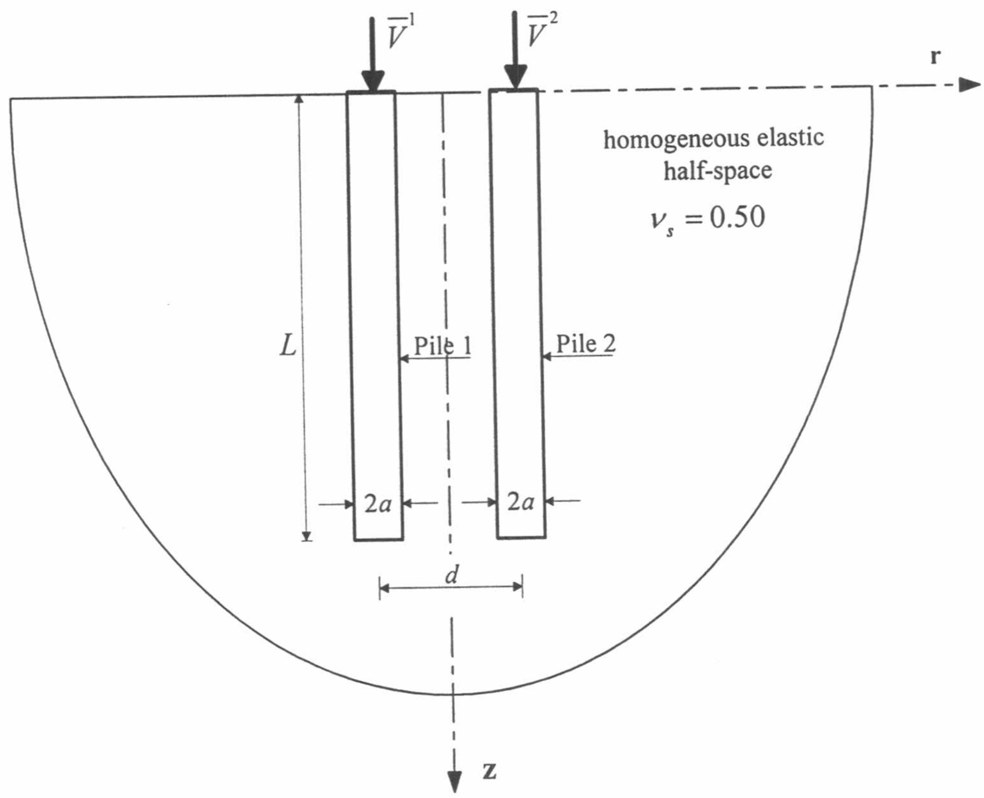


Figure 2. Decomposition of pile group-half-space system :
(a) Extended multi-layered poroelastic half-space subjected to body force field
(b) Discretization of fictitious piles



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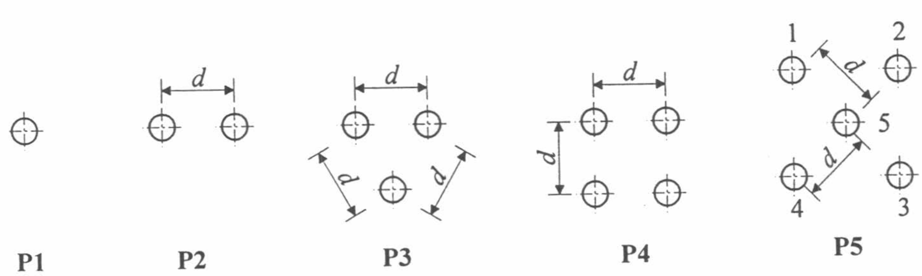

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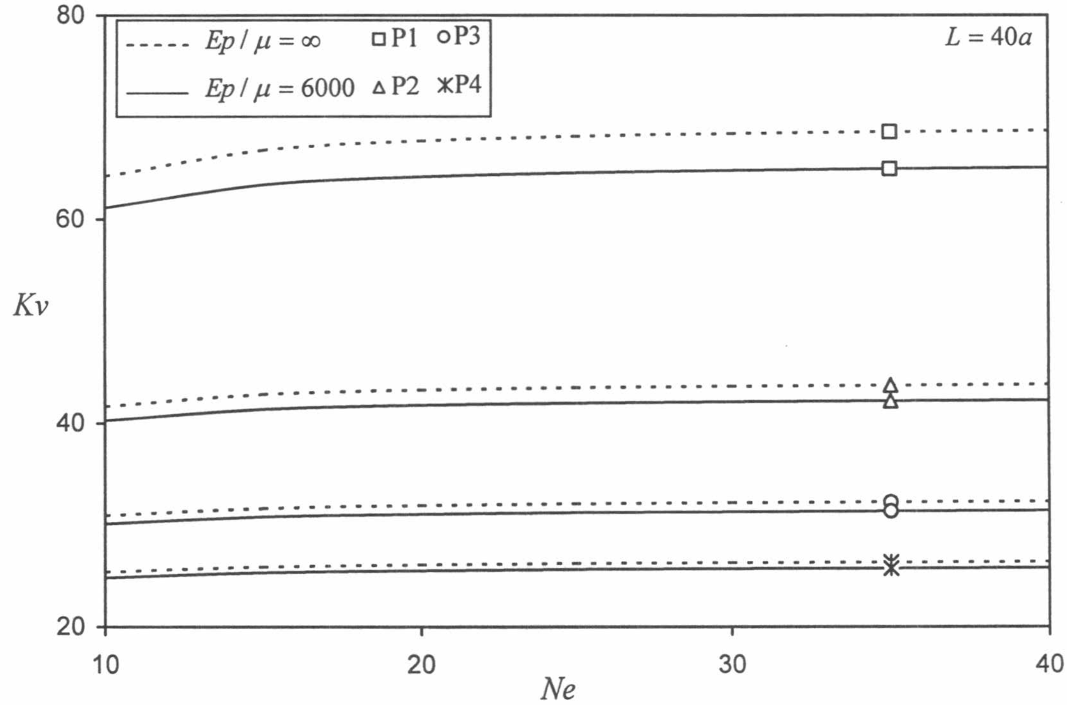
Figure 3. (a) Geometry of axially loaded pile group in a homogeneous elastic half-space ; (b) configurations of pile group



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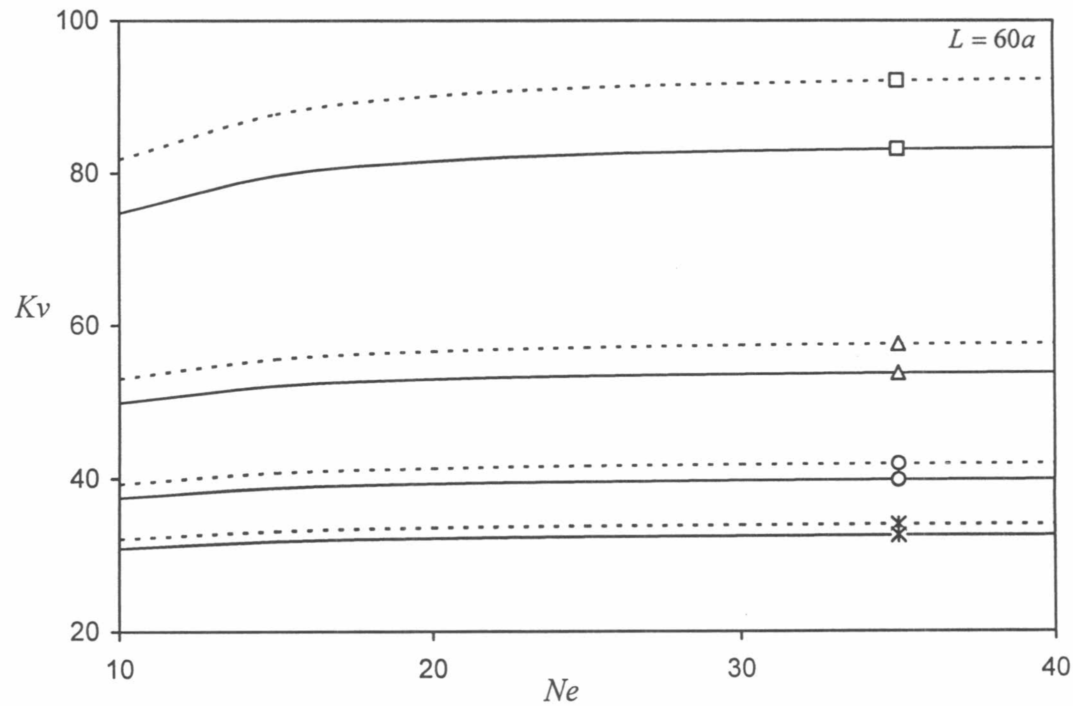
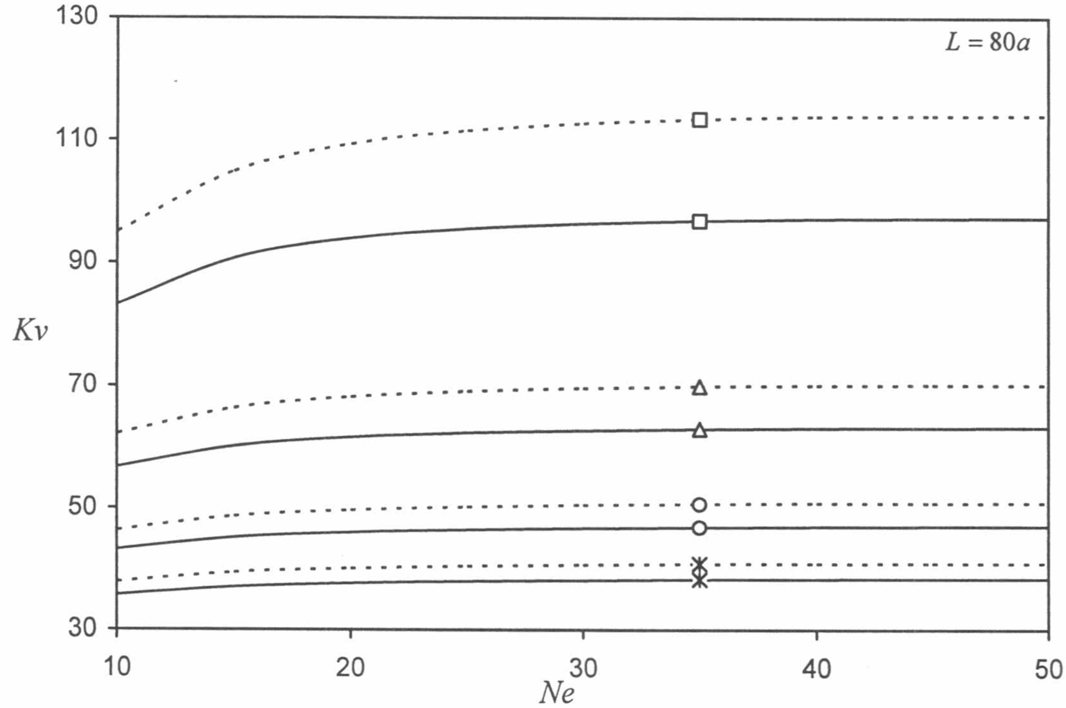


(b)

Figure 4. Convergence of solutions with Ne for an elastic pile group embedded in a homogeneous poroelastic half-space vary L/a: (a) $L = 40a$; (b) $L = 60a$; (c) $L = 80a$; (d) $L = 100a$



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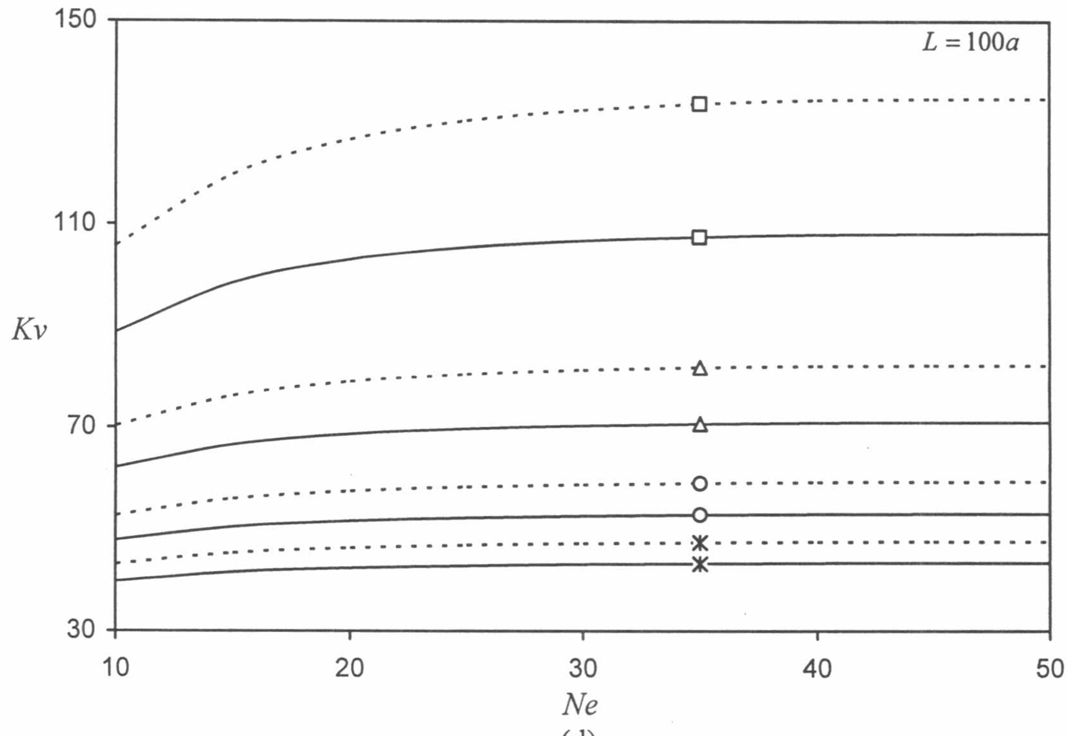


(d)

Figure 4 (cont.). Convergence of solutions with Ne for an elastic pile group embedded in a homogeneous poroelastic half-space vary L/a: (a) $L = 40a$; (b) $L = 60a$; (c) $L = 80a$; (d) $L = 100a$.

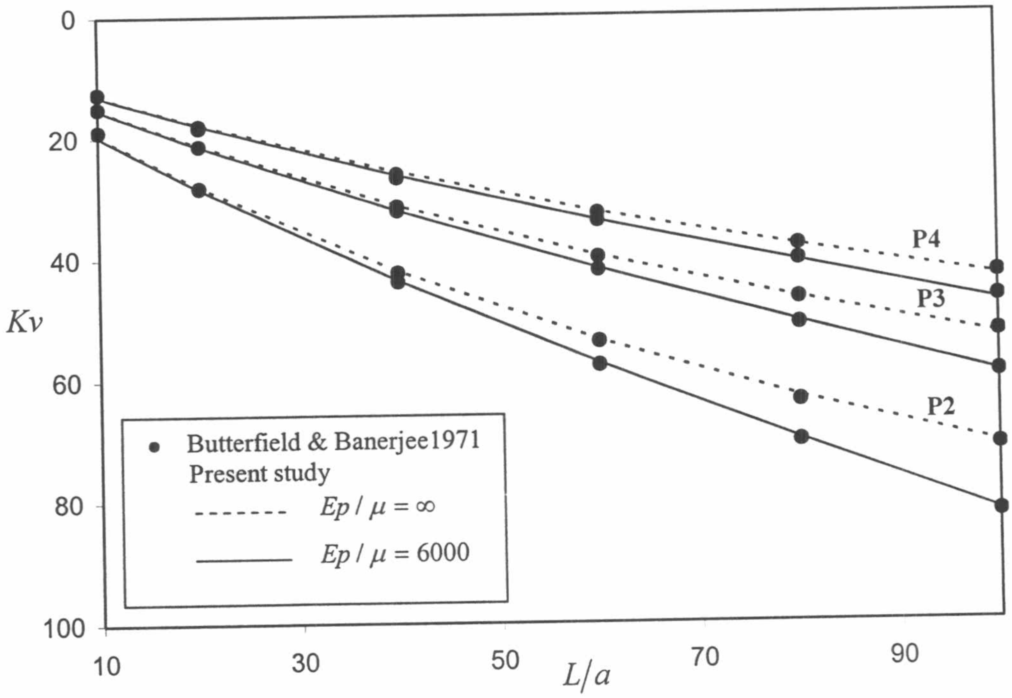


Figure 5. Comparison of axial stiffness (Kv) with L/a for axially loaded pile group(P1, P2, P3 and P4) embedded in a homogeneous elastic half-space

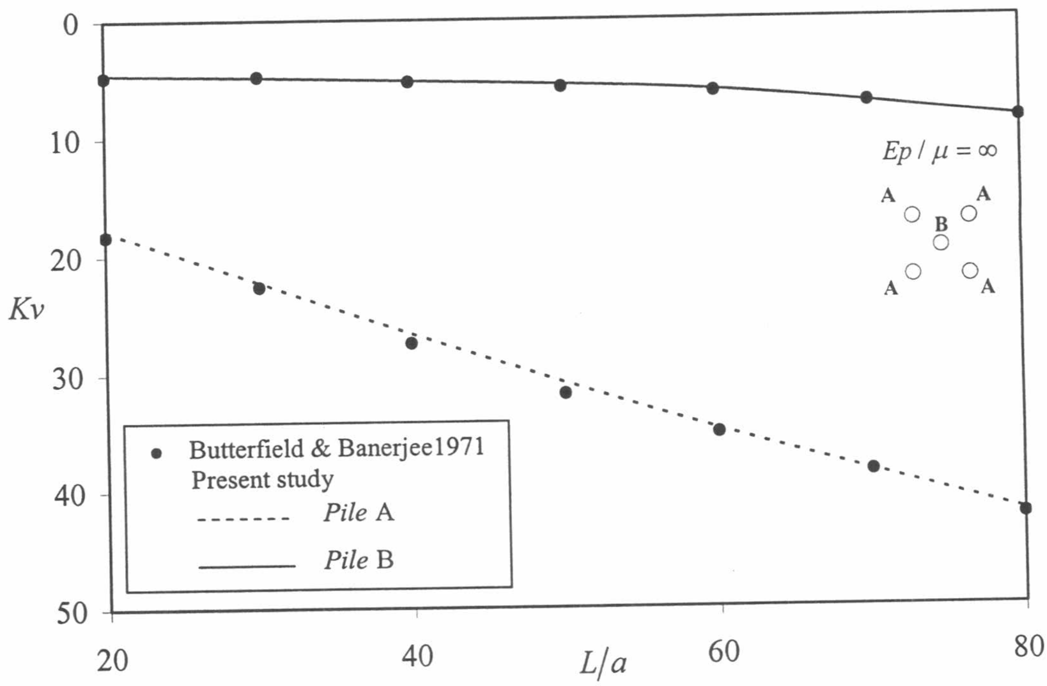


Figure 6. Comparison of axial stiffness (Kv) with L/a for axially loaded pile group(P5) embedded in a homogeneous elastic half-space

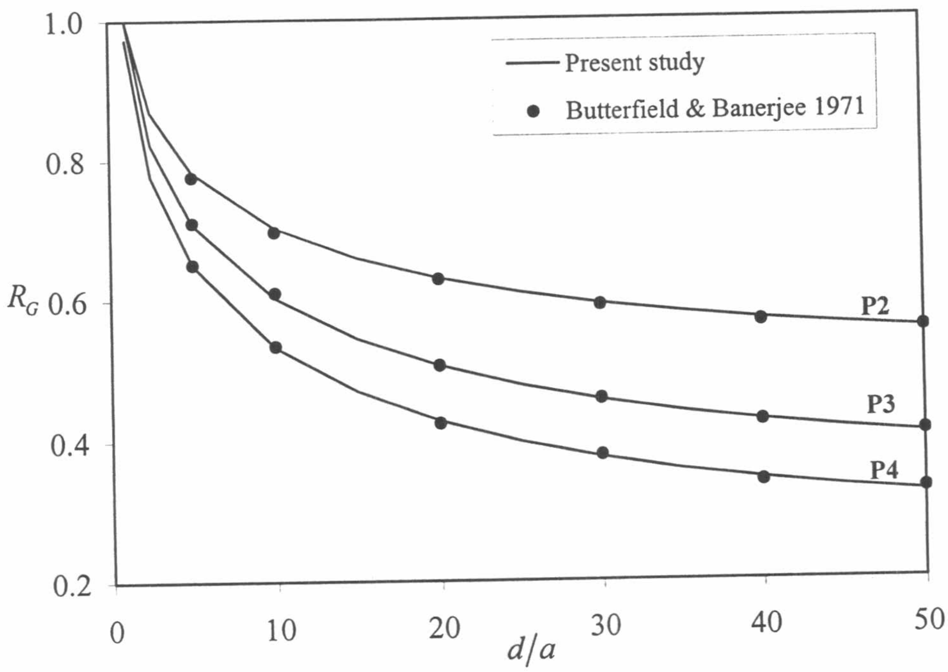


Figure 7. Comparison of group reduction factor (R_G) with d/a for axially loaded pile group embedded in a homogeneous elastic half-space

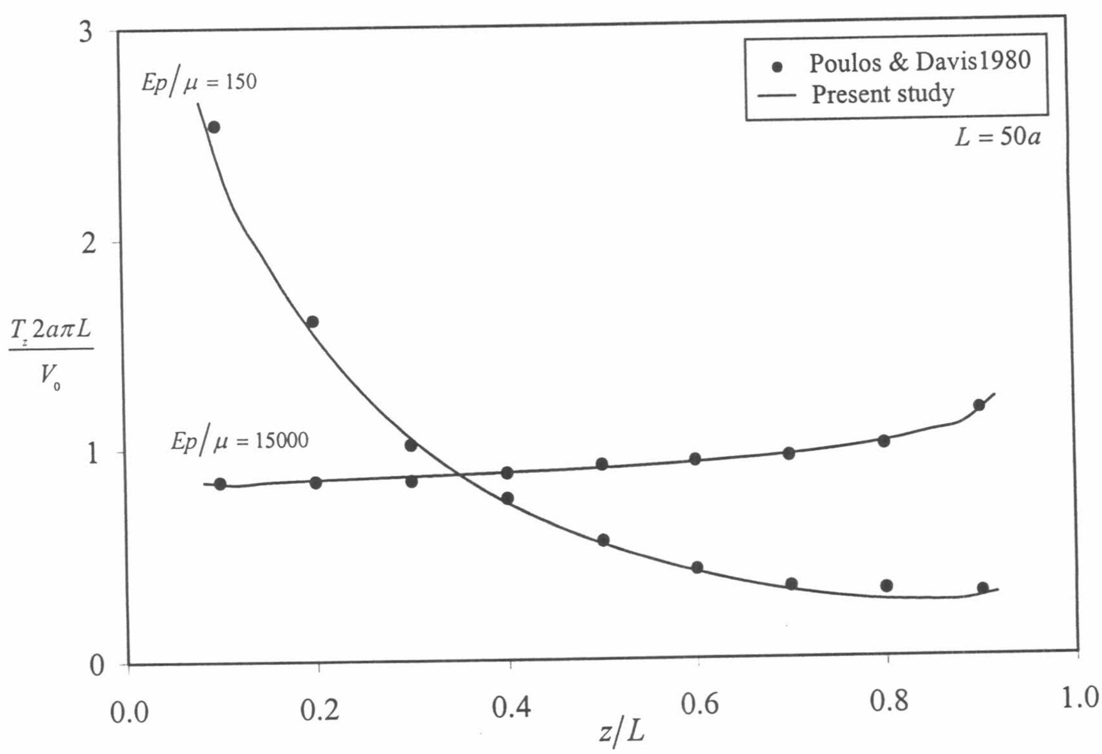
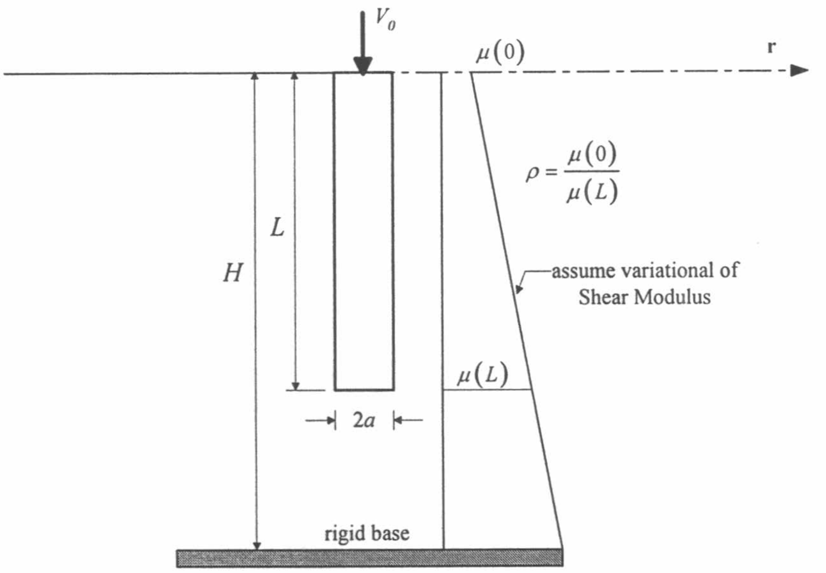
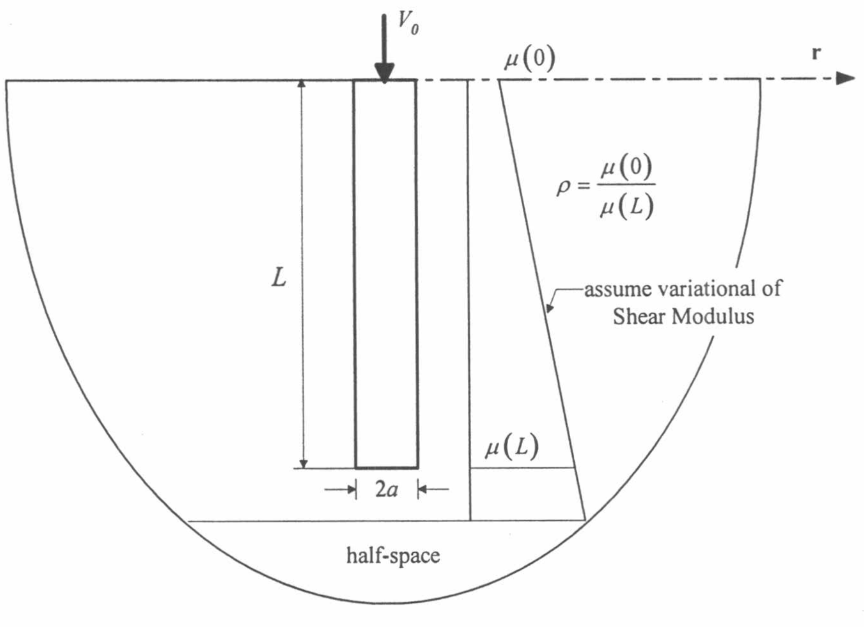


Figure 8. Comparison of distribution of shear stress along pile for single pile embedded in a homogeneous elastic half-space



(a)

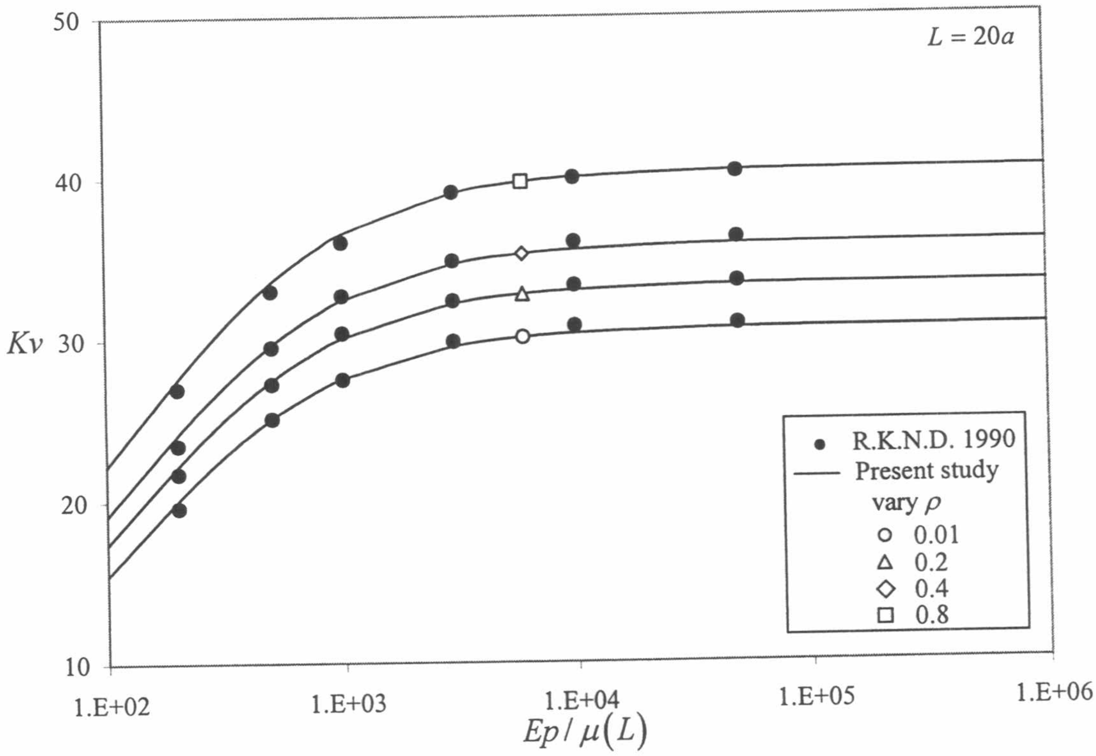


(b)

Figure 9. Axially loaded single pile in a nonhomogeneous medium :

(a) nohomogeneous elastic medium with rigid base;

(b) nonhomogeneous elastic half-space



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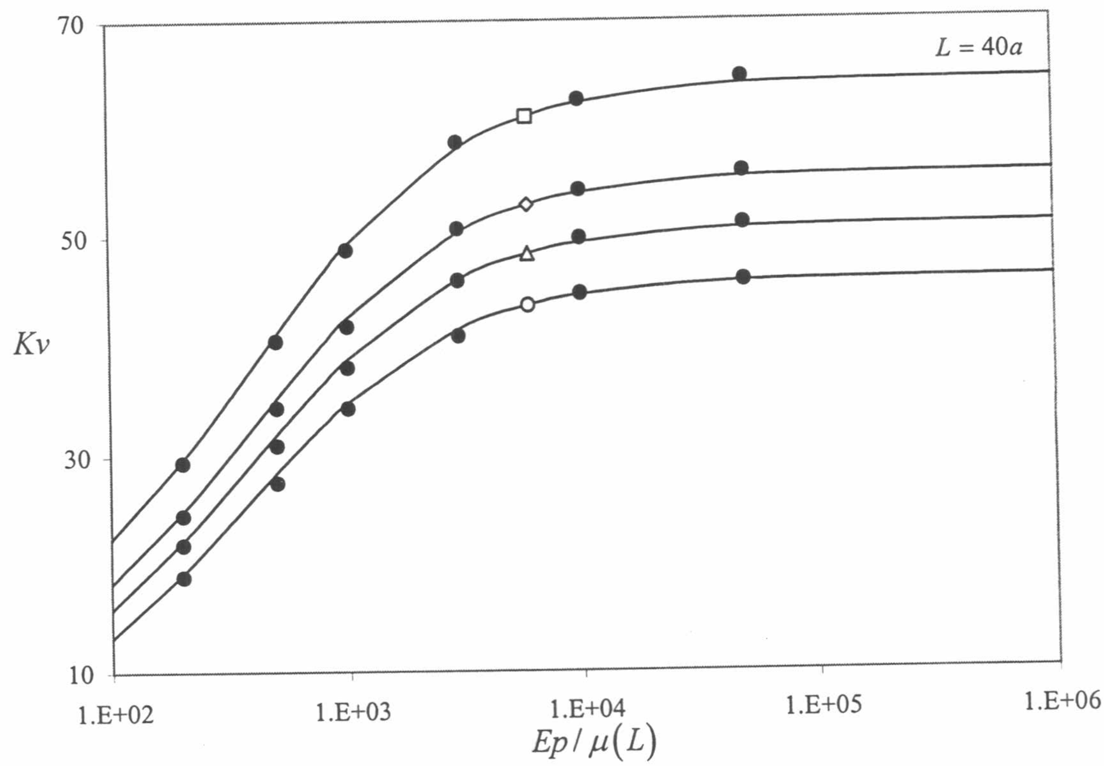


(b)

Figure 10. Comparison of axial stiffness with ρ for axially loaded single pile embedded in a nonhomogeneous elastic half-space : (a) $L = 20a$; (b) $L = 40a$

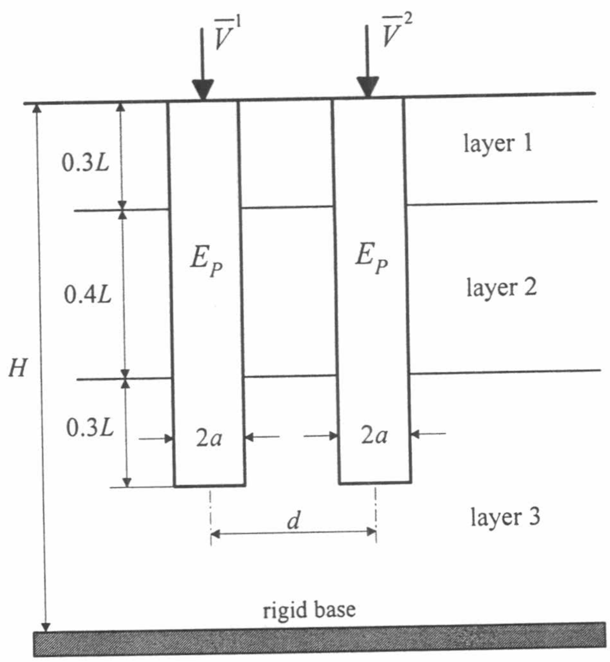
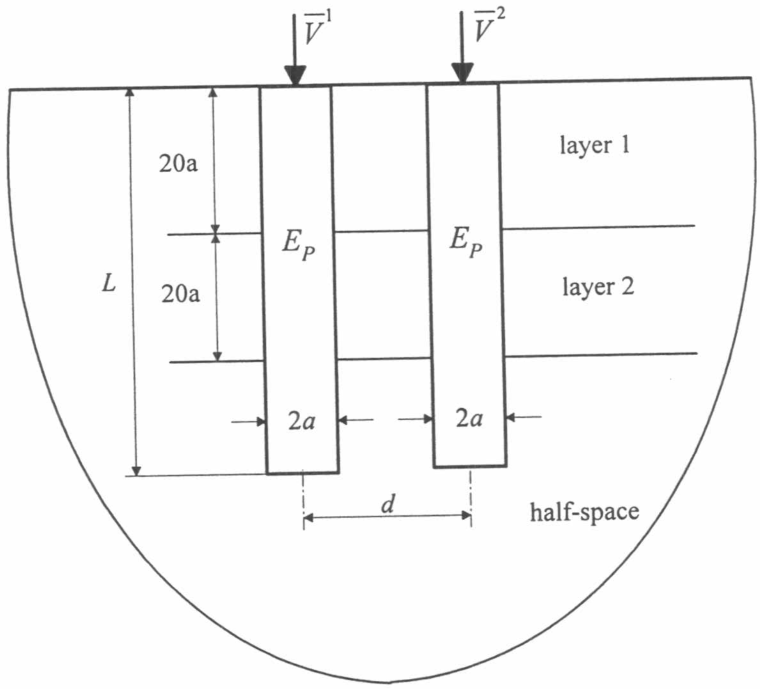


Figure 11. Axially loaded pile group in a multi-layered elastic medium with rigid base



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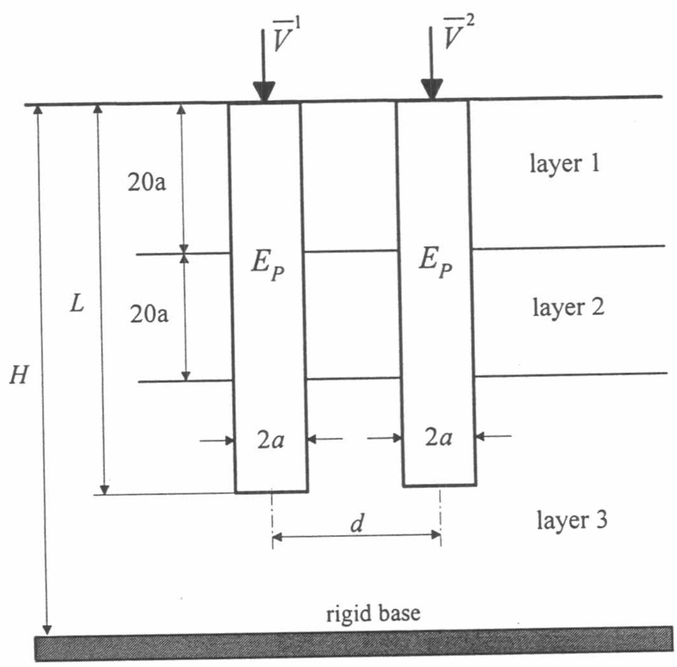
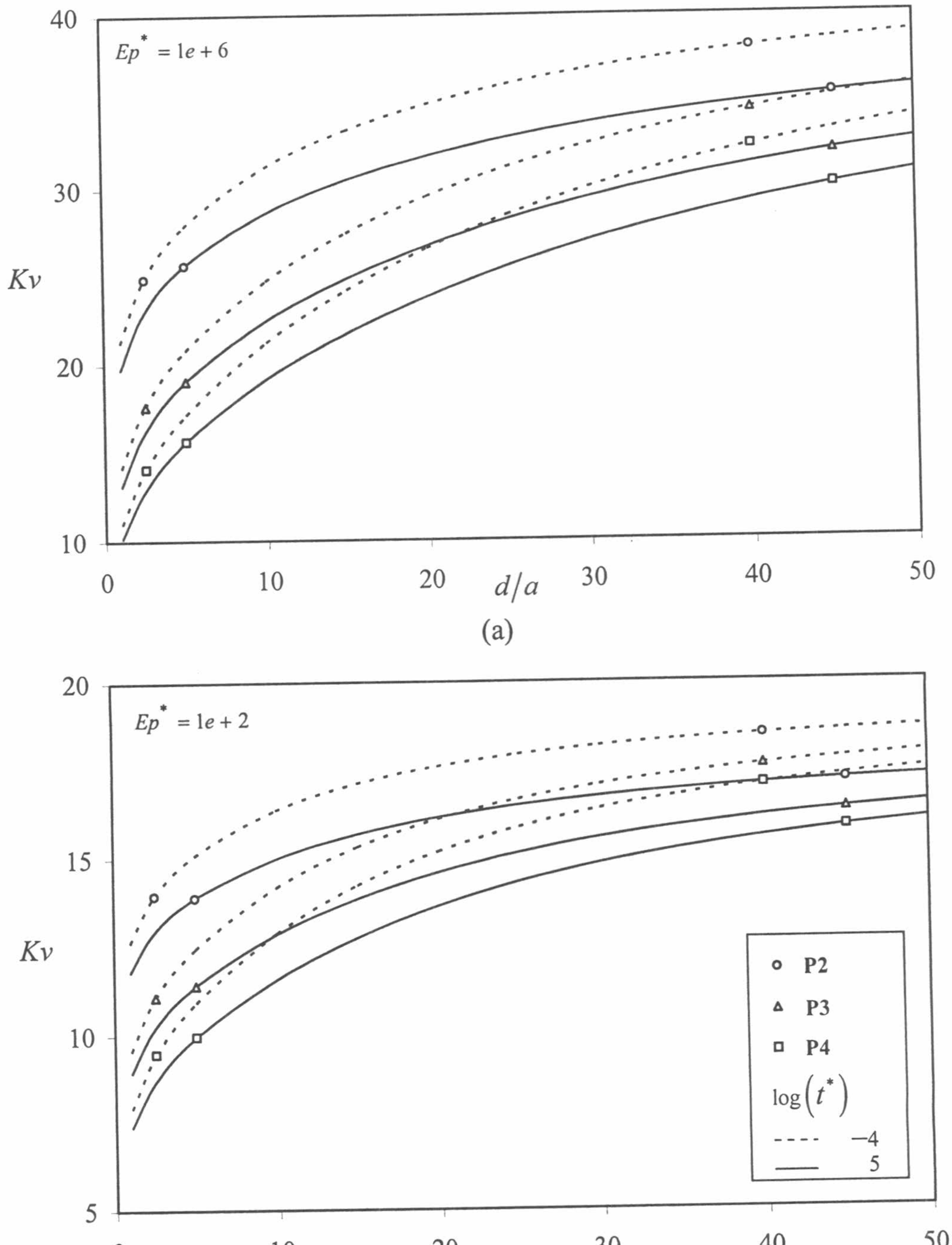


(b)

Figure 12. Axially loaded pile group in a multi-layered poroelastic medium :

(a) multi-layered poroelastic half-space ;

(b) multi-layered poroelastic medium with rigid base



(a)

(b)

Figure 13. Axial stiffness for different spacing between center of piles in a multi-layered poroelastic half-space with $\kappa^{(1)}/\kappa^{(2)} = 0.1$ and $L = 40a$: (a) $Ep^* = 1e+6$; (b) $Ep^* = 1e+2$

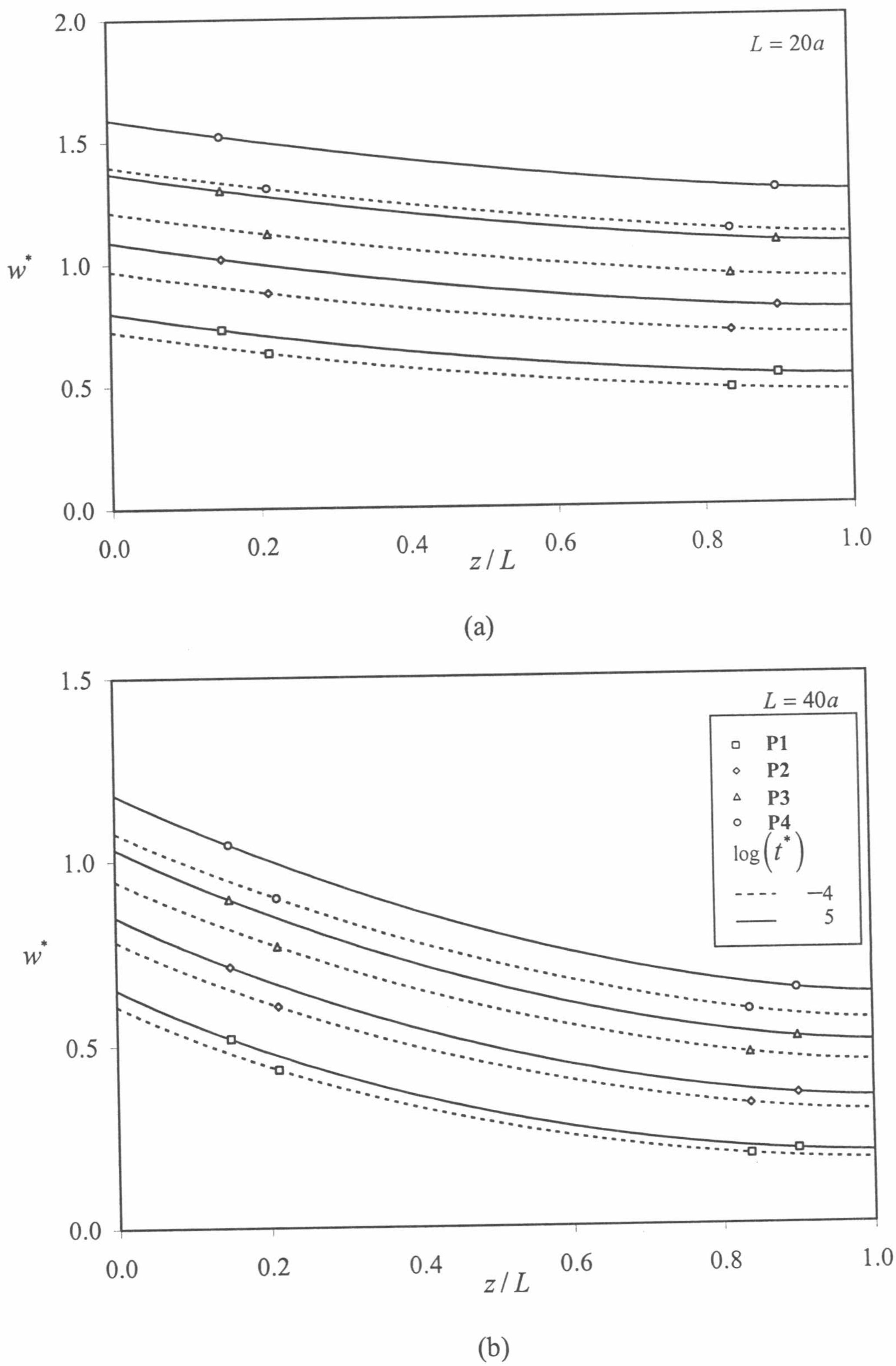
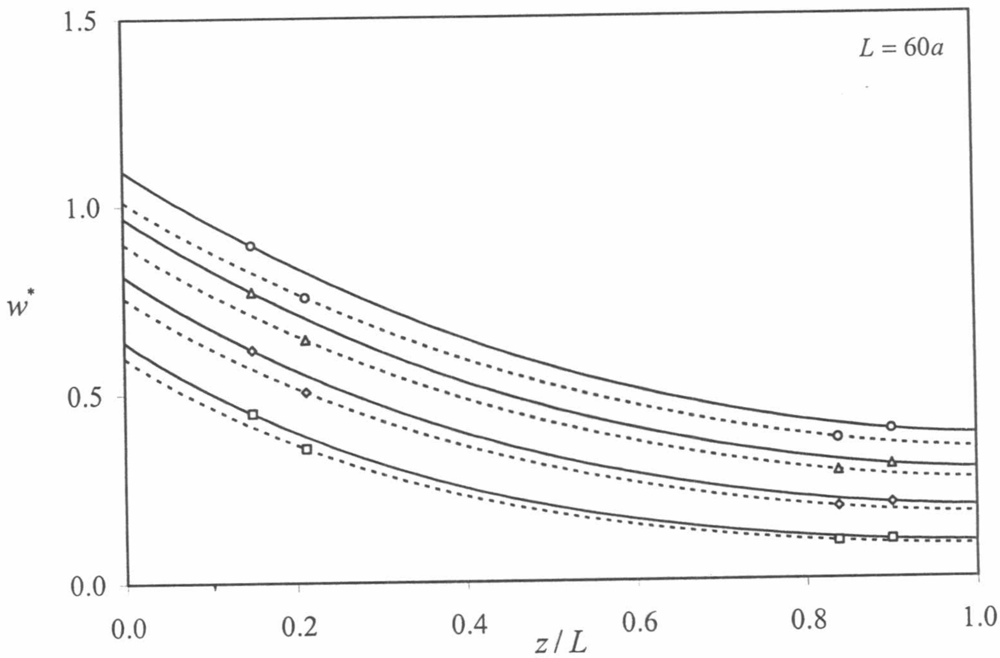


Figure 14. Profile of non-dimensional pile settlement for axially loaded pile group in a multi-layered poroelastic half-space along z axis with $\kappa^{(1)}/\kappa^{(2)} = 0.1$; $Ep^* = 1e+2$:
(a) $L = 20a$; (b) $L = 40a$; (c) $L = 60a$; (d) $L = 100a$



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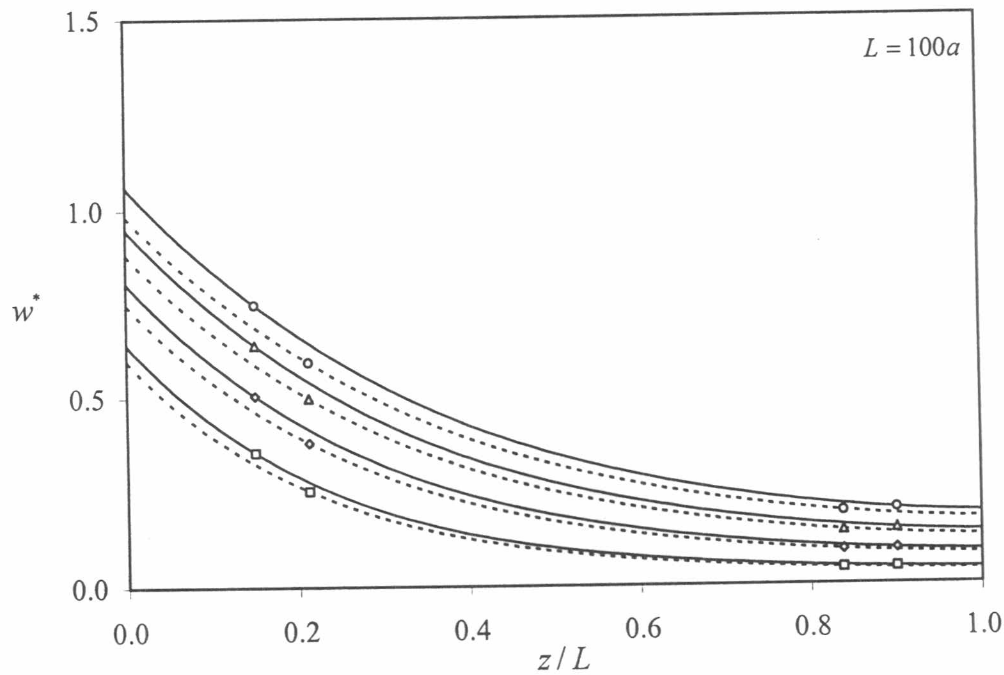
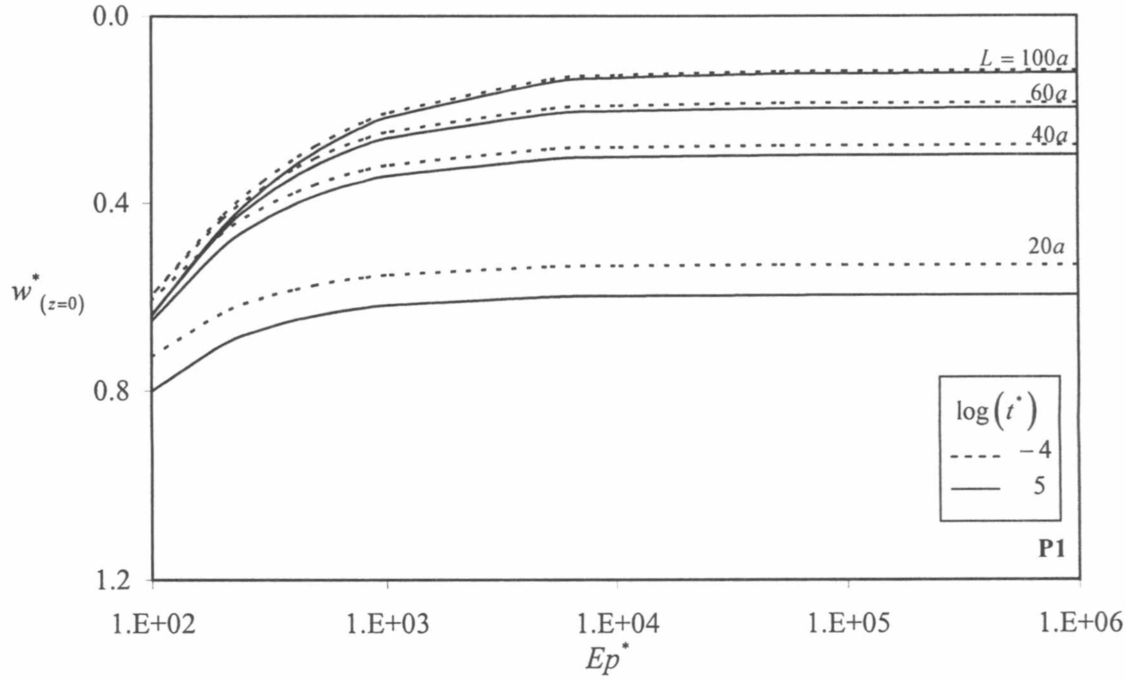
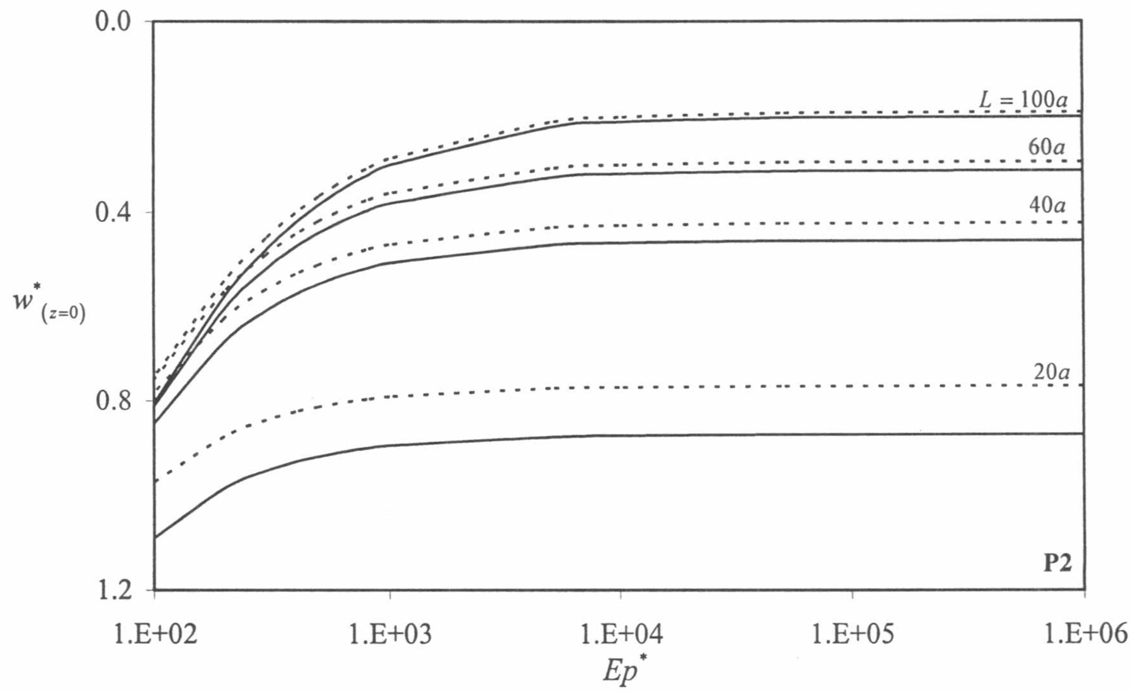


(d)

Figure 14(cont.). Profile of non-dimensional pile settlement for axially loaded pile group in a multi-layered poroelastic half-space along z axis with $\kappa^{(1)}/\kappa^{(2)} = 0.1$; $Ep^* = 1e+2$:
(a) $L = 20a$; (b) $L = 40a$; (c) $L = 60a$; (d) $L = 100a$

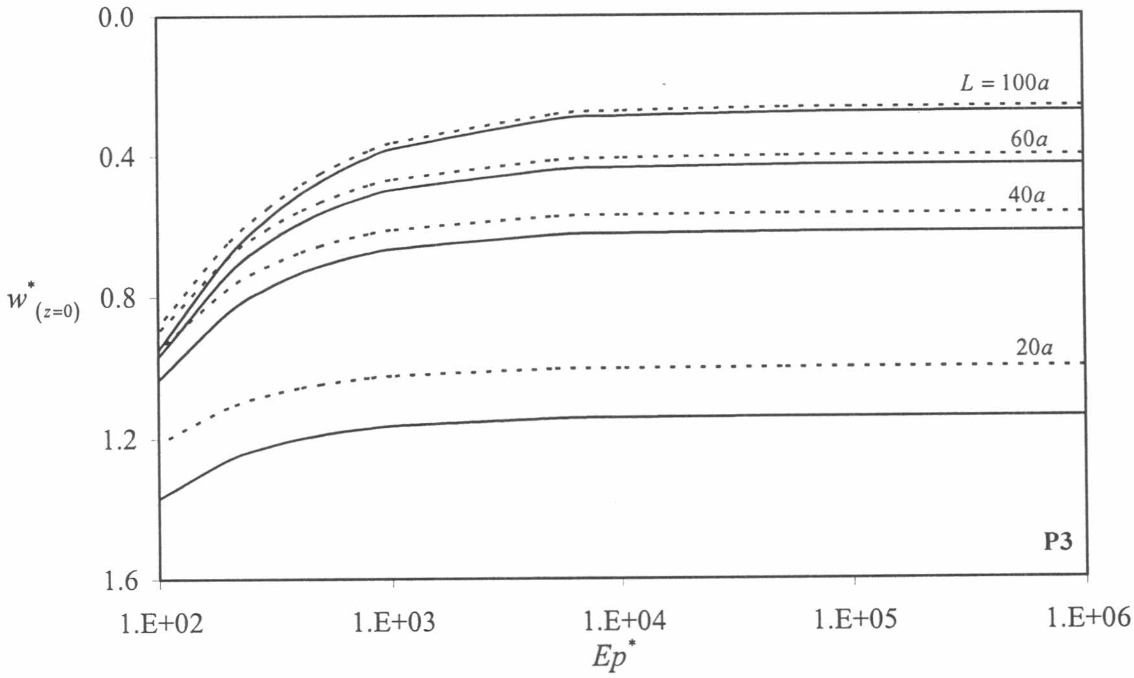


(a)



(b)

Figure 15. Non-dimensional pile settlement at $z = 0$ for an axially loaded pile group in a multi-layered poroelastic half-space with $\kappa^{(1)}/\kappa^{(2)} = 0.1$: (a) single pile; (b) two piles; (c) three piles; (d) four piles



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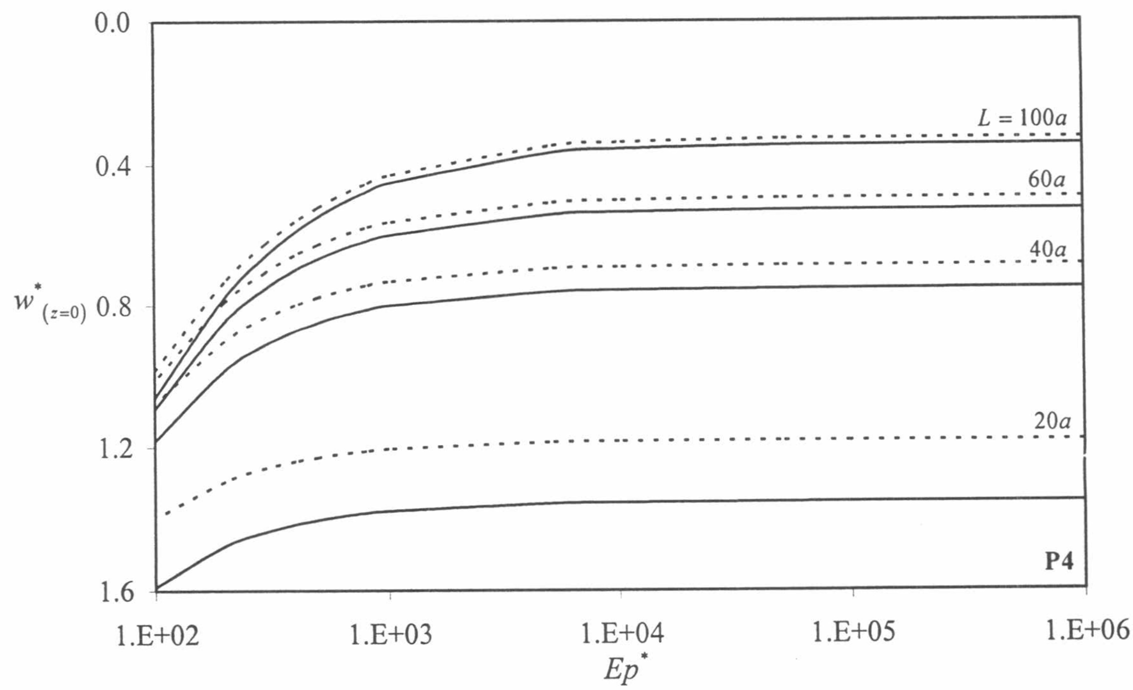


(d)

Figure 15(cont.). Non-dimensional pile settlement at $z = 0$ for an axially loaded pile group in a multi-layered poroelastic half-space with $\kappa^{(1)}/\kappa^{(2)} = 0.1$:
(a) single pile; (b) two piles; (c) three piles; (d) four piles

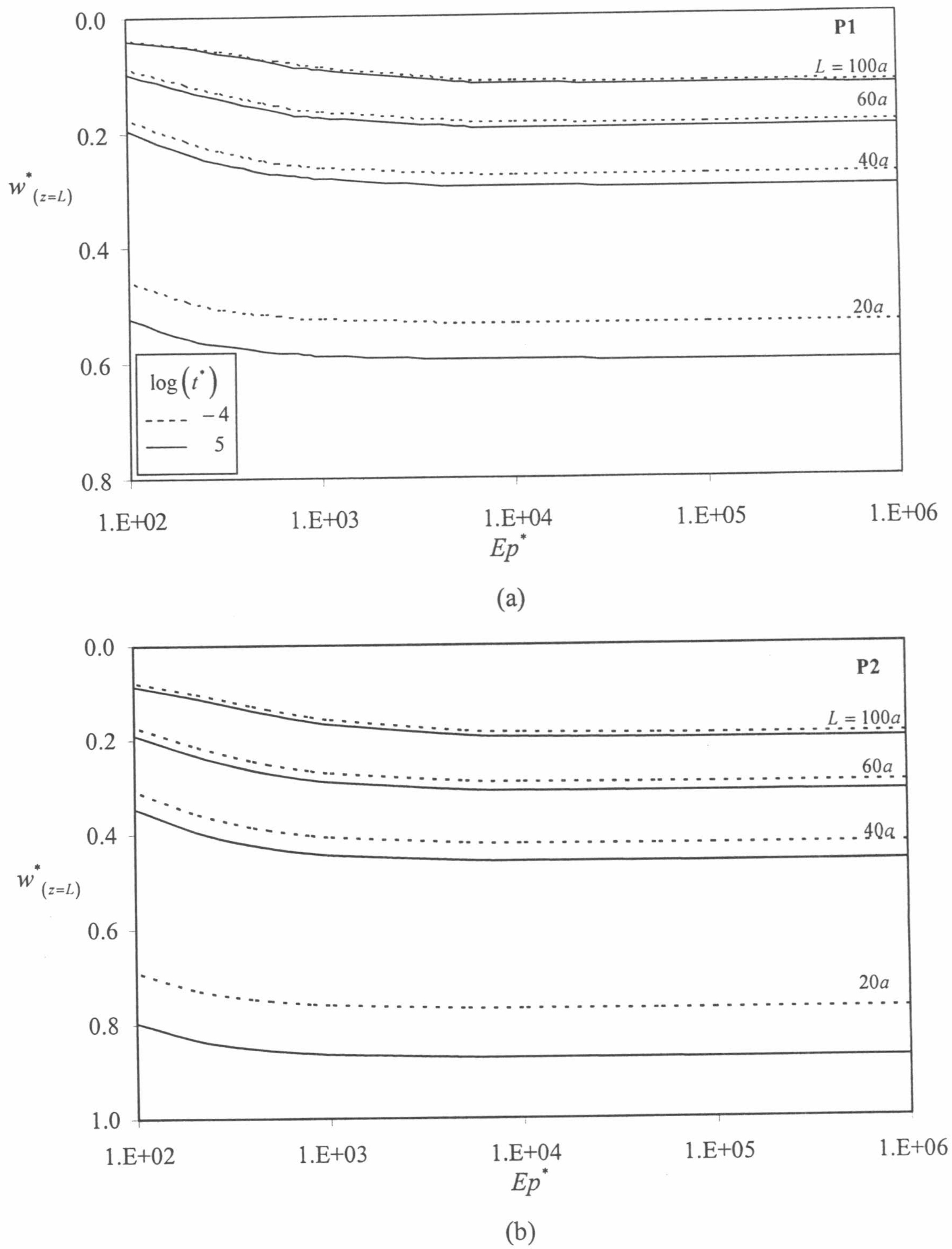
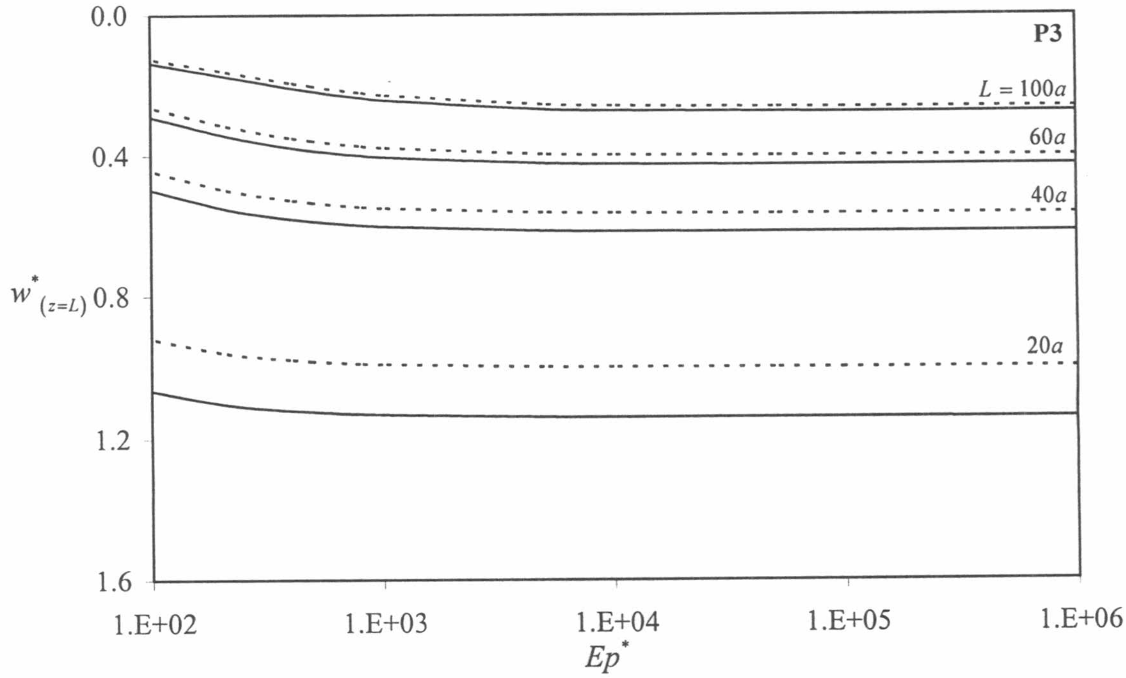


Figure 16. Non-dimensional pile settlement at $z = L$ for an axially loaded pile group in a multi-layered poroelastic half-space with $\kappa^{(1)}/\kappa^{(2)} = 0.1$: (a) single pile; (b) two piles; (c) three piles; (d) four piles



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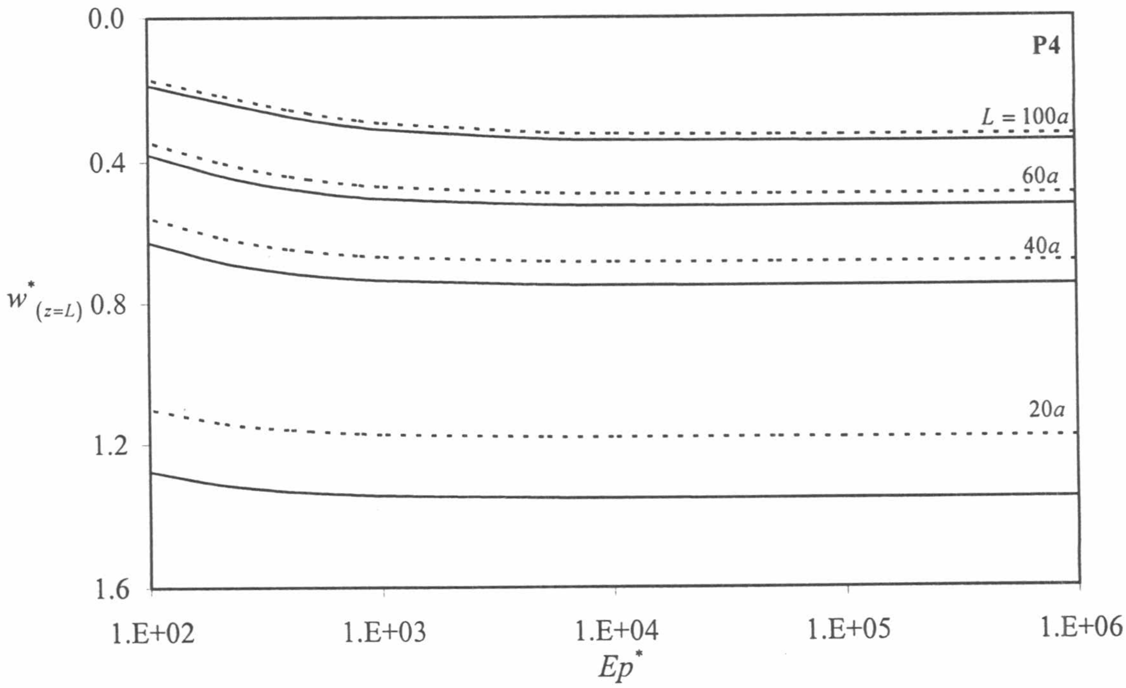
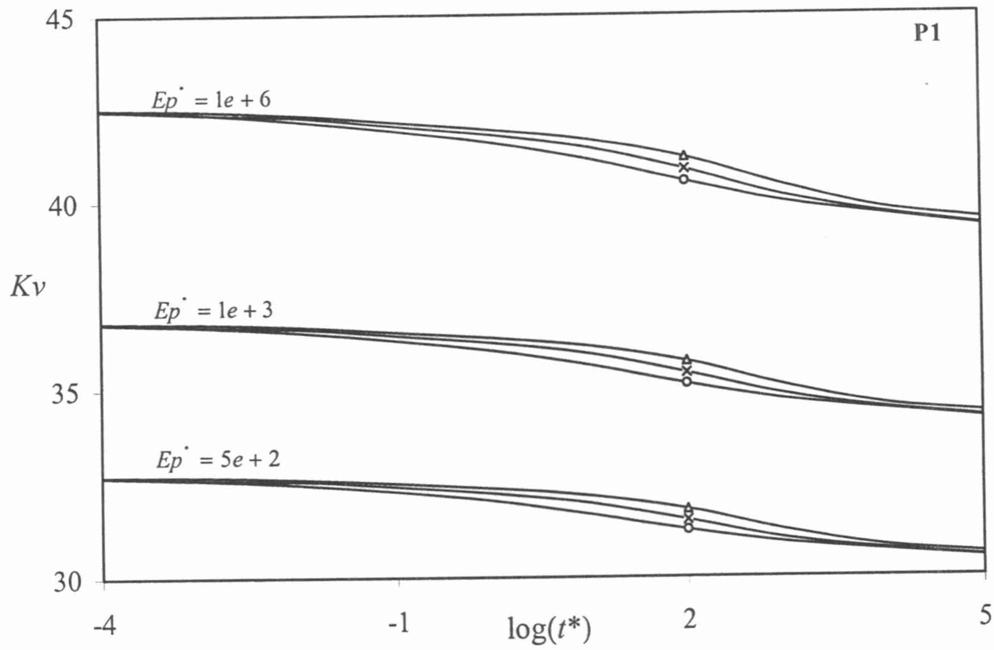
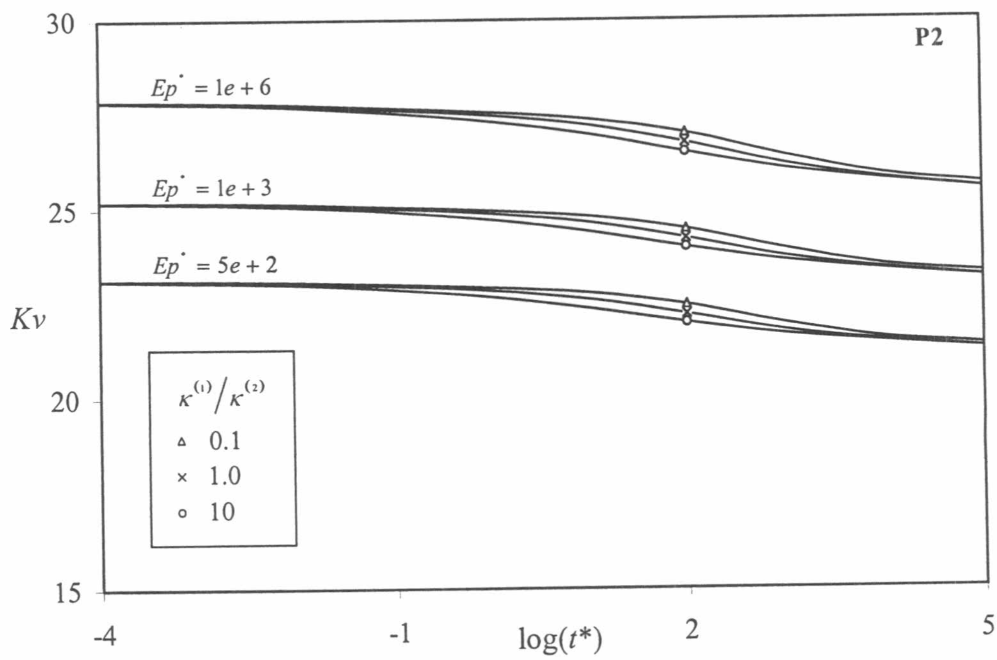


(d)

Figure 16(cont.). Non-dimensional pile settlement at $z = L$ for an axially loaded pile group in a multi-layered poroelastic half-space with $\kappa^{(1)}/\kappa^{(2)} = 0.1$:
(a) single pile; (b) two piles; (c) three piles; (d) four piles

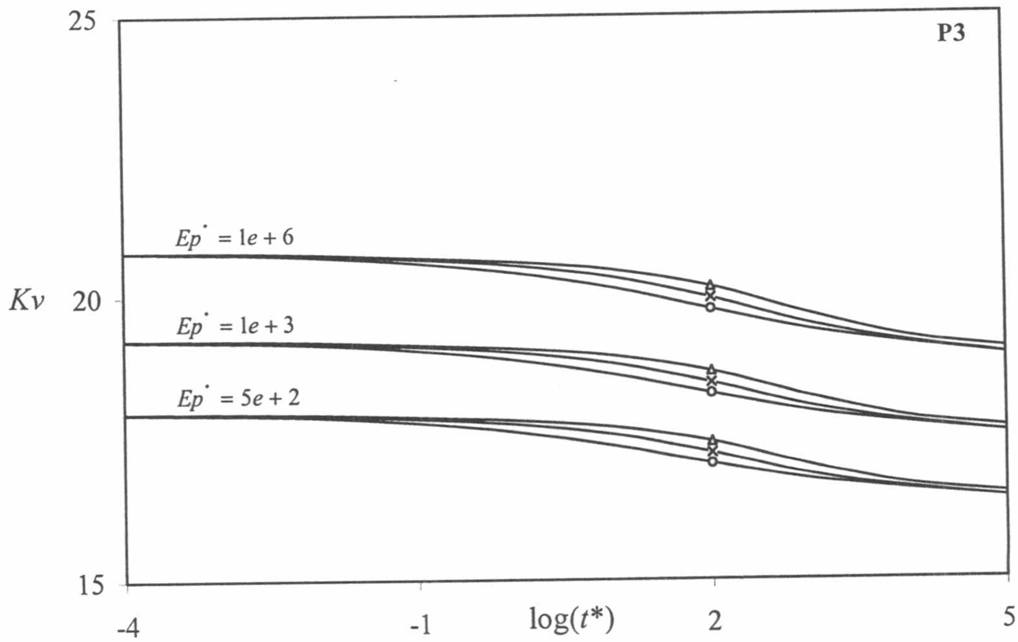


(a)



(b)

Figure 17. Time history of axial stiffness for an axially loaded pile group in a multi-layered poroelastic half-space with $L = 40a$ for different ratio $\kappa^{(1)}/\kappa^{(2)}$:
(a) single pile; (b) two piles; (c) three piles; (d) four piles



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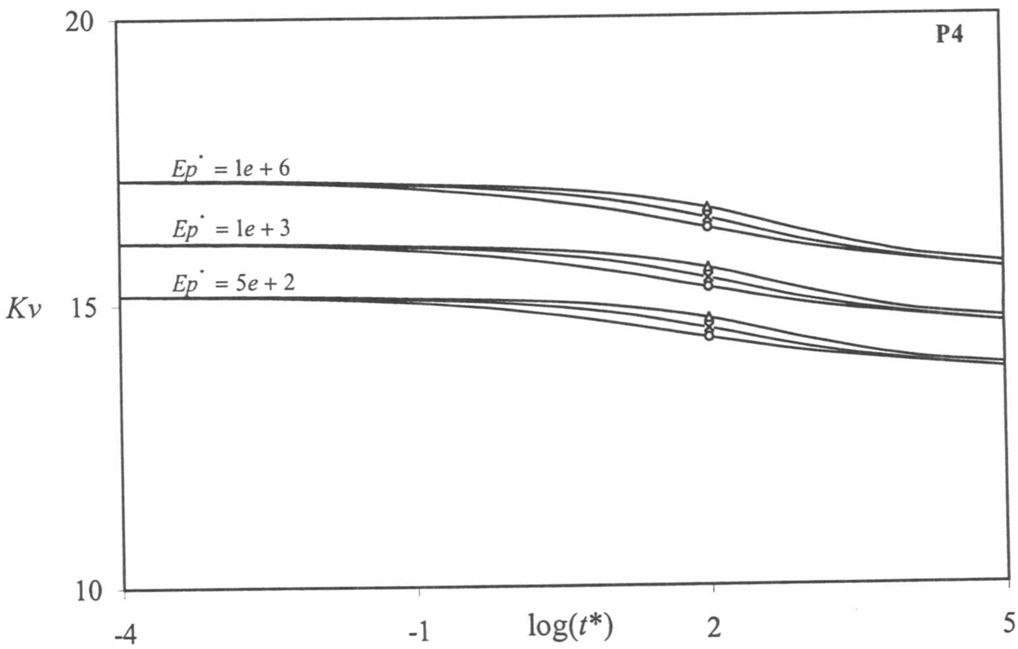
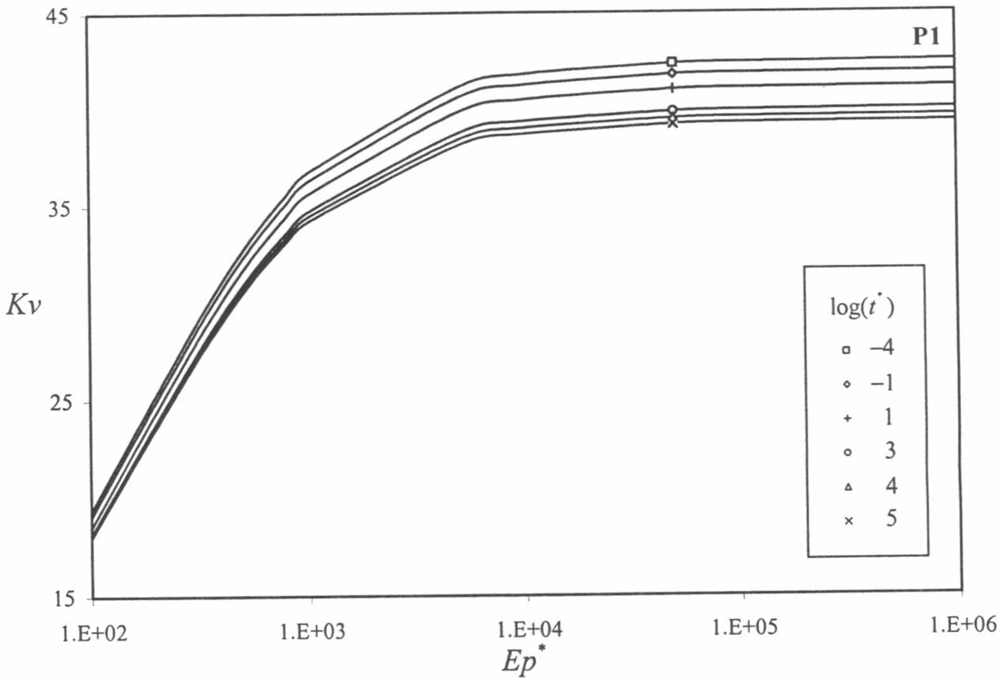
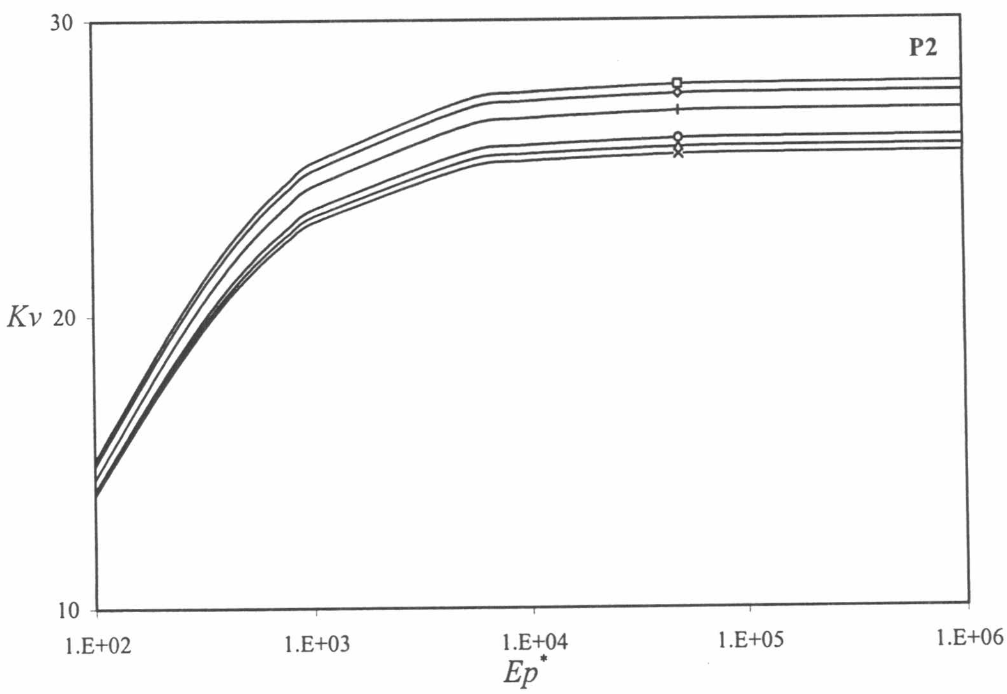


(d)

Figure 17(cont.) Time history of axial stiffness for an axially loaded pile group in a multi-layered poroelastic half-space with $L = 40a$ for different ratio $\kappa^{(1)}/\kappa^{(2)}$:
(a) single pile; (b) two piles; (c) three piles; (d) four piles

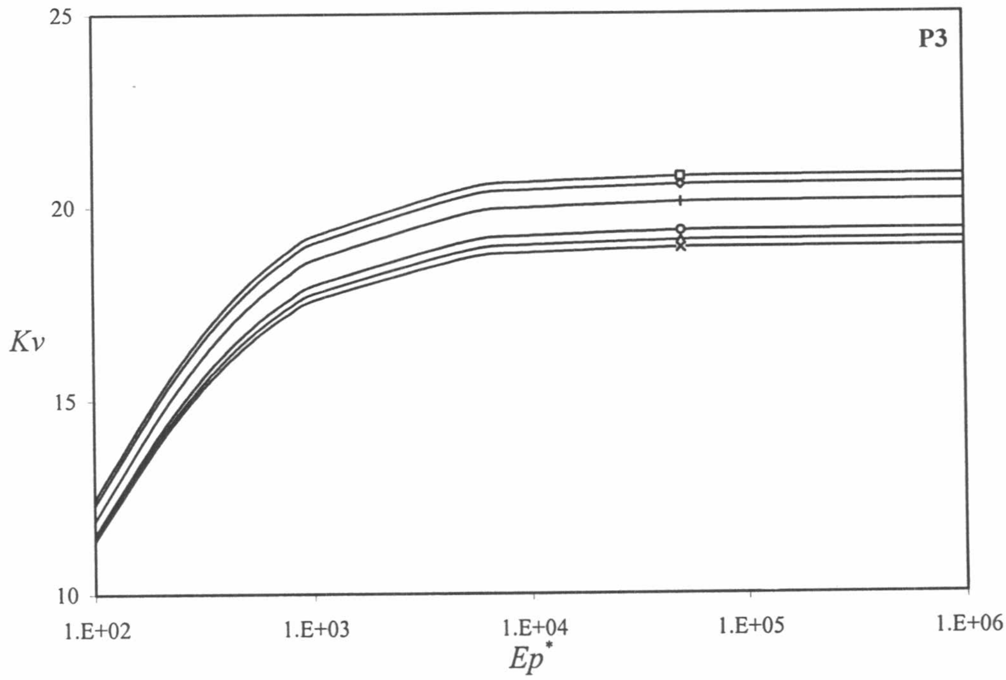


(a)



(b)

Figure 18. Axial stiffness for an axially loaded pile group in a multi-layered poroelastic half-space with $\kappa^{(1)}/\kappa^{(2)} = 10$ and $L = 40a$: (a) single pile; (b) two piles; (c) three piles; (d) four piles



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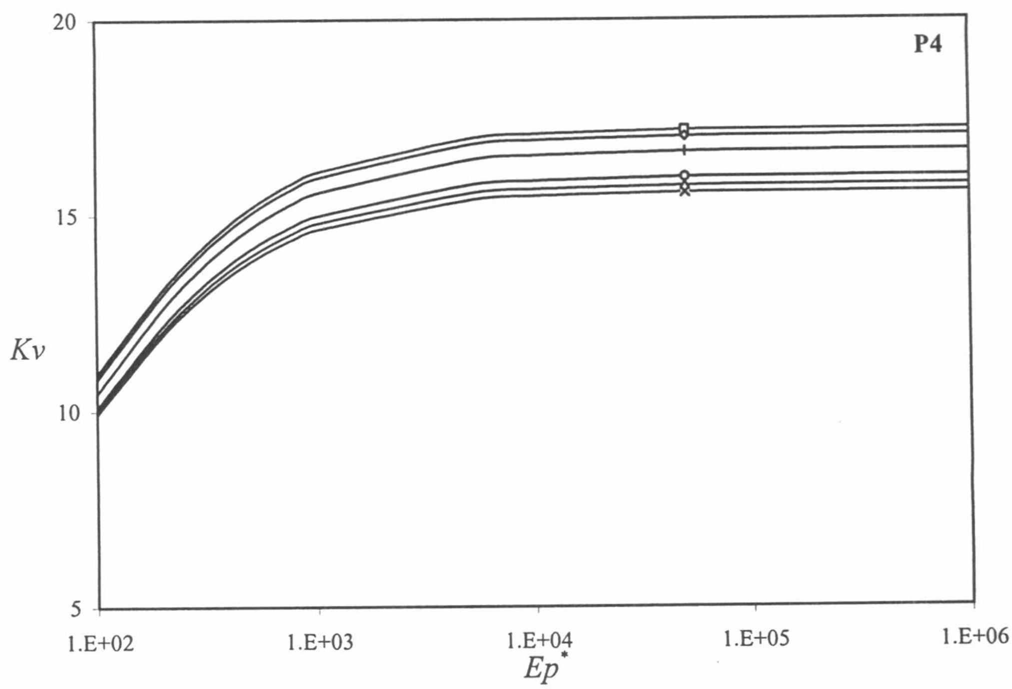
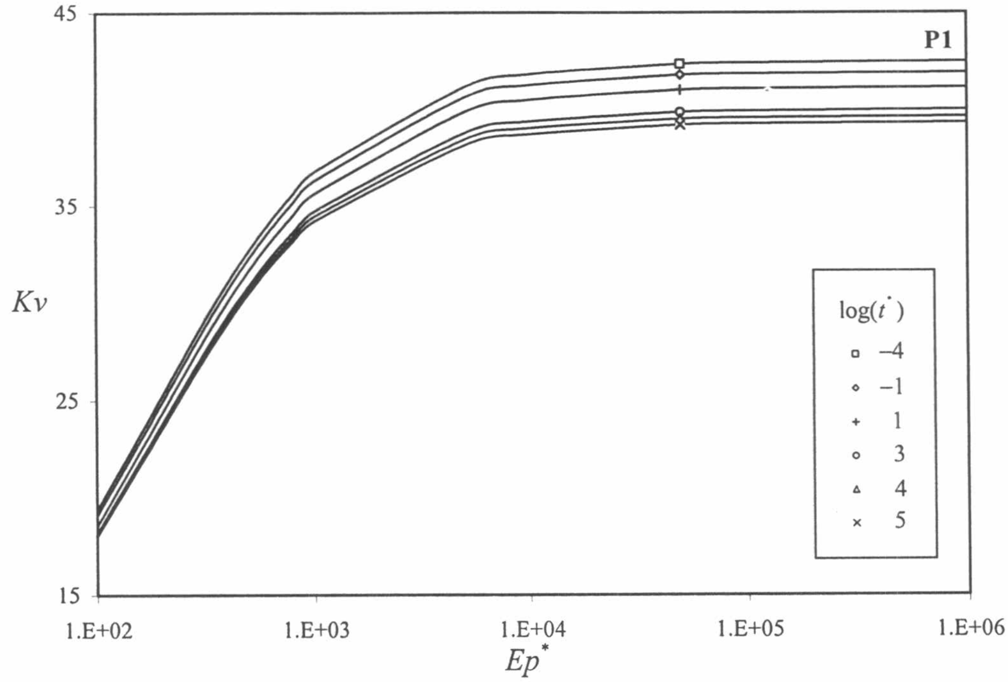


(d)

Figure 18 (cont.). Axial stiffness for an axially loaded pile group in a multi-layered poroelastic half-space with $\kappa^{(1)}/\kappa^{(2)} = 10$ and $L = 40a$: (a) single pile; (b) two piles; (c) three piles; (d) four piles



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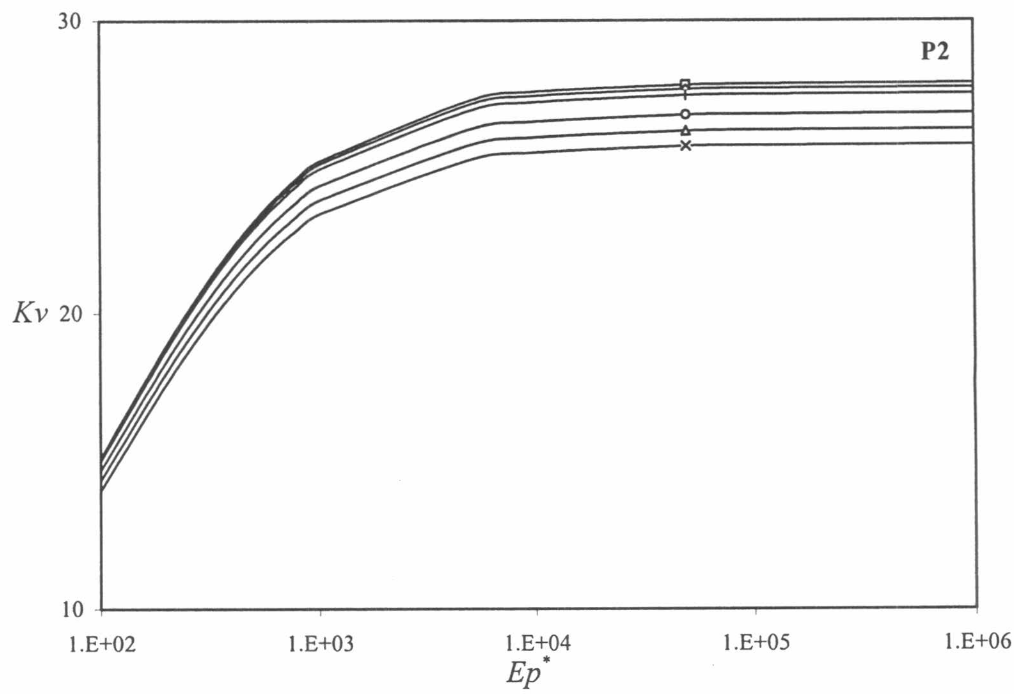
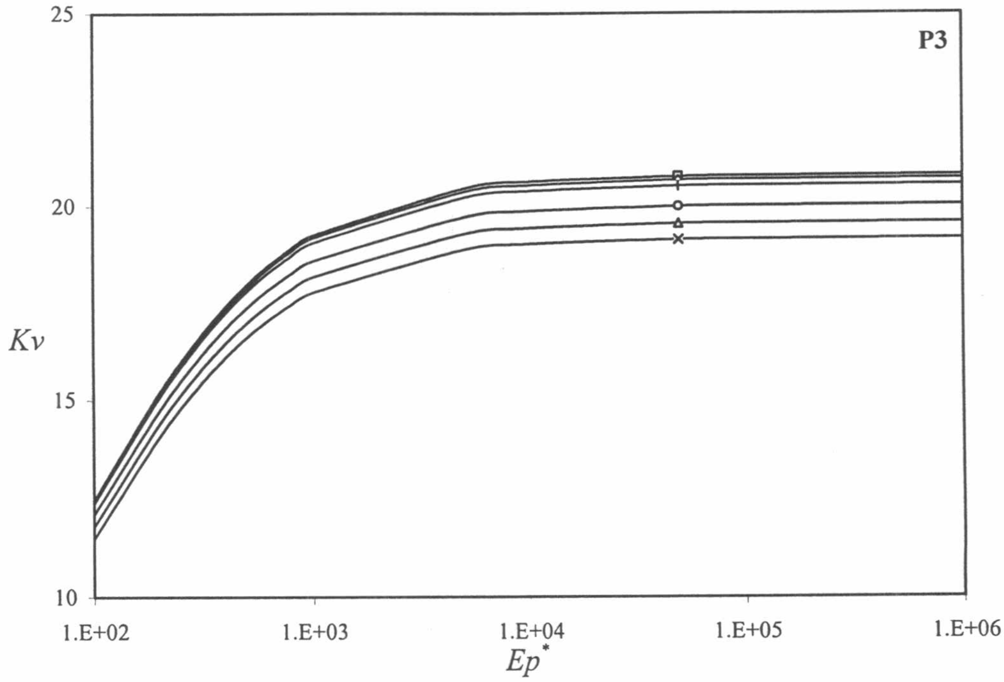


(b)

Figure 19. Axial stiffness for an axially loaded pile group
in a multi-layered poroelastic half-space
with $\kappa^{(1)}/\kappa^{(2)} = 0.001$ and $L = 40a$:
(a) single pile; (b) two piles; (c) three piles; (d) four piles



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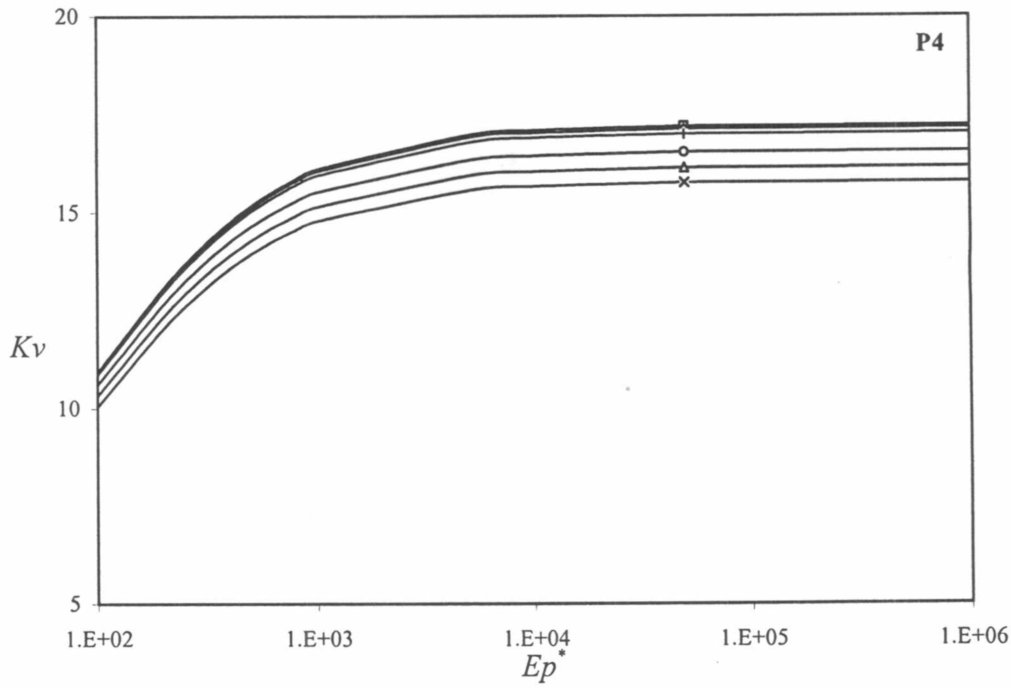


(d)

Figure 19 (cont.). Axial stiffness for an axially loaded pile group in a multi-layered poroelastic half-space with $\kappa^{(1)}/\kappa^{(2)} = 0.001$ and $L = 40a$:
(a) single pile; (b) two piles; (c) three piles; (d) four piles

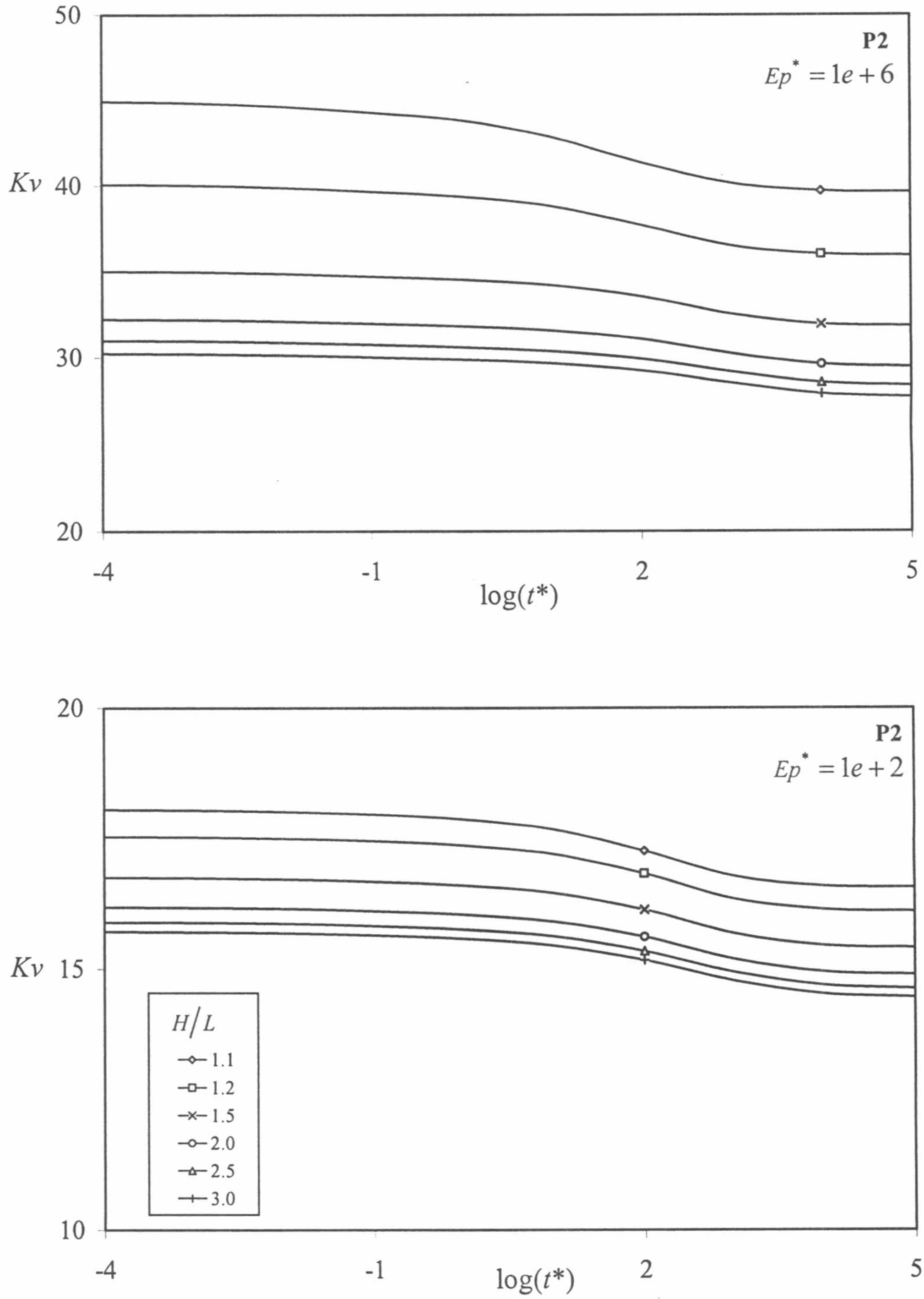
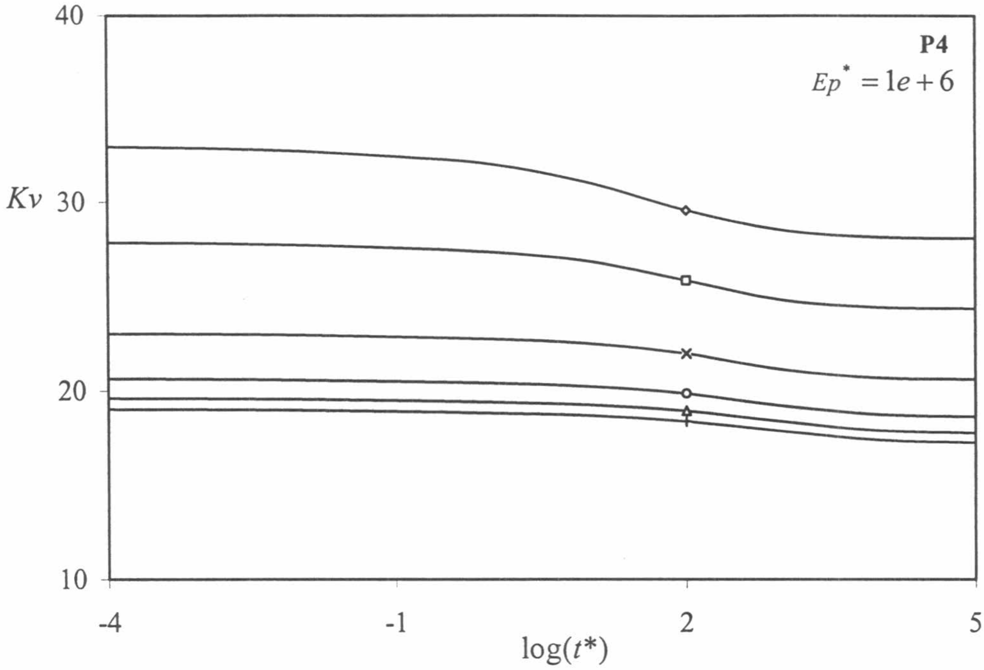


Figure 20. Time history of axial stiffness for an axially loaded pile group in a multi-layered poroelastic medium with rigid base for two piles $\kappa^{(1)}/\kappa^{(2)} = 0.1$; $L = 40a$ $\kappa^{(1)}/\kappa^{(2)}$ and different ratio H/L:
(a) $Ep^* = 1e+6$; (b) $Ep^* = 1e+2$



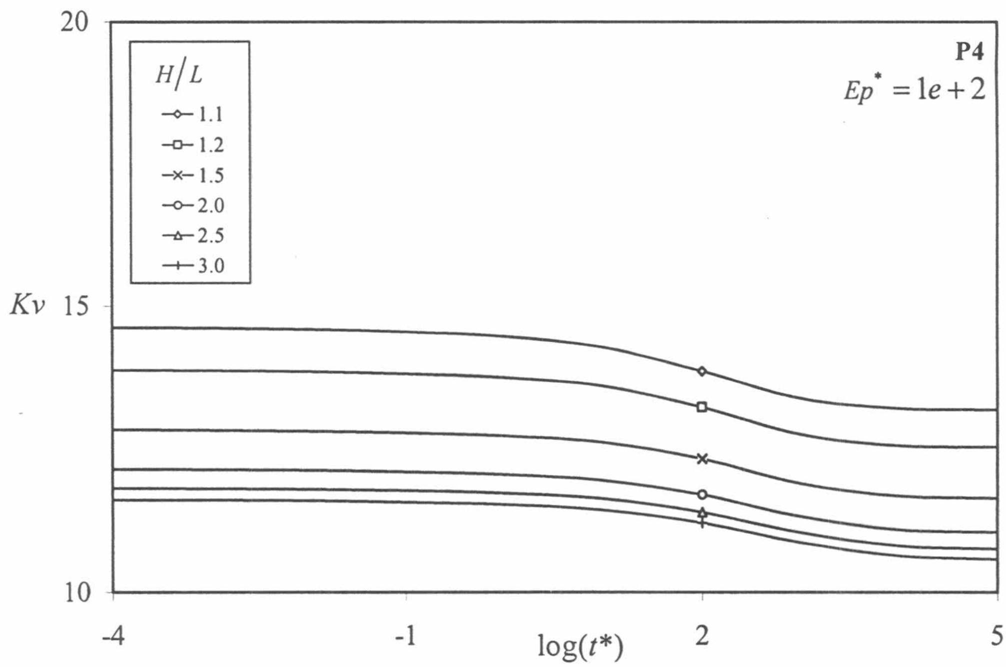


Figure 21. Time history of axial stiffness for an axially loaded pile group in a multi-layered poroelastic medium with rigid base for four piles $\kappa^{(1)}/\kappa^{(2)} = 0.1$; $L = 40a$ $\kappa^{(1)}/\kappa^{(2)}$ and different ratio H/L:
(a) $Ep^* = 1e+6$; (b) $Ep^* = 1e+2$