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Thermal damping and retardation in karst conduits

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Details of numerical simulations

Tables S1 and S2 include values for parameters that were different from those provided in Table 1 as well as thermal transmission factors and retardation values for all numerical simulations included in Figures 2 and 3. Table S1 provides details about cylindrical simulations, and planar simulations are summarized in Table S2.

Table S1. Parameter values used in cylindrical simuations and thermal transmission factors and retardation values of these simulations.

Simulation	Parameter values different from those given in Table 1 (units are the same as those given in Table 1)	F (-)	τ (s)
C1	D_{H} = 0.01	0.00	-
C2	D_{H} = 0.0178	0.00	-
C3	D_{H} = 0.0316	0.11	16,300
C4	D_{H} = 0.0562	0.43	7,360
C5	D_{H} = 0.1	0.71	3,590
C6	D_{H} = 0.178	0.87	1,840
C7	D_{H} = 0.316	0.94	978
C8	-	0.99	297
C9	D_{H} = 3.16	1.00	93.3
C10	D_{H} = 10	1.00	30.0
C11	L = 100	1.00	29.9
C12	L = 316	1.00	96.5
C13	L = 3,160	0.96	952
C14	L = 10,000	0.87	2,990
C15	L = 31,600	0.64	9,700
C16	V = 0.00626	0.31	15,700
C17	V = 0.0111	0.48	11,900
C18	V = 0.0198	0.65	7,830
C19	V = 0.0352	0.78	4,770
C20	V = 0.0626	0.87	2,830
C21	V = 0.198	0.96	924
C22	V = 1.98	1.00	95.2
C23	V = 6.26	1.00	30.1
C24	$\mathcal{R}_{\mathrm{D}}$ = 1,900	0.94	51.4
C25	$\mathcal{R}_{\mathrm{D}}$ = 6,000	0.96	92.5
C26	$\mathcal{R}_{\mathrm{D}}$ = 19,000	0.98	166

Table S1. Continued.

Simulation	Parameter values different from those given in Table 1 (units are the same as those given in Table 1)	F (-)	τ (s)
C27	$\mathcal{R}_\mathrm{D}$ = 190,000	0.99	538
C28	$\mathcal{R}_\mathrm{D}$ = 600,000	0.99	983
C29	$\mathcal{R}_\mathrm{A}$ = 1	0.99	297
C30	$\mathcal{R}_\mathrm{A}$ = 3.16	0.99	298
C31	$\mathcal{R}_\mathrm{A}$ = 31.6	0.99	298
C32	$\mathcal{R}_\mathrm{A}$ = 100	0.99	297
C33	k_r = 1	0.99	203
C34	k_r = 1.5	0.99	248
C35	k_r = 2	0.99	286
C36	k_r = 2.5	0.98	320
C37	k_r = 3	0.98	351
C38	$c_\mathrm{p,r}$ = 700	0.99	276
C39	$c_\mathrm{p,r}$ = 800	0.99	295
C40	$c_\mathrm{p,r}$ = 900	0.99	313
C41	$c_\mathrm{p,r}$ = 1,000	0.98	330
C42	ρ_r = 2,000	0.99	276
C43	ρ_r = 2,250	0.99	292
C44	ρ_r = 2,500	0.99	308
C45	ρ_r = 2,750	0.98	323
C46	ρ_r = 3,000	0.98	337
C47	k_w = 0.5	0.99	297
C48	k_w = 0.55	0.99	297
C49	k_w = 0.6	0.99	297
C50	k_w = 0.65	0.99	297
C51	k_w = 0.7	0.99	297
C52	$c_\mathrm{p,w}$ = 4,100	0.99	304

Table S1. Continued.

Simulation	Parameter values different from those given in Table 1 (units are the same as those given in Table 1)	F (-)	τ (s)
C53	$c_{p,w}$ = 4,150	0.99	300
C54	$c_{p,w}$ = 4,250	0.99	293
C55	$c_{p,w}$ = 4,300	0.99	290
C56	ρ_w = 980	0.99	303
C57	ρ_w = 990	0.99	300
C58	ρ_w = 1,010	0.99	294
C59	ρ_w = 1,020	0.99	291
C60	μ_w = 0.0006	0.99	298
C61	μ_w = 0.0009	0.99	297
C62	μ_w = 0.0012	0.99	297
C63	μ_w = 0.0015	0.99	297
C64	μ_w = 0.0018	0.99	296
C65	D_H = 0.1; V = 0.0346	0.00	-
C66	D_H = 10; V = 0.907	1.00	20.5
C67	D_H = 0.1; V = 0.110	0.15	21,400
C68	D_H = 10; V = 2.87	1.00	6.66
C69	D_H = 0.1; V = 0.346	0.54	6,530
C70	L = 100; V = 0.198	1.00	92.9
C71	L = 10,000; V = 0.198	0.64	9,530
C72	L = 100; V = 1.98	1.00	9.31
C73	L = 10,000; V = 1.98	0.96	946
C74	V = 0.198; $\mathcal{R}_D$ = 6,000	0.89	283
C75	V = 0.198; $\mathcal{R}_D$ = 600,000	0.98	3,090
C76	V = 1.98; $\mathcal{R}_D$ = 6,000	0.99	29.5
C77	V = 1.98; $\mathcal{R}_D$ = 600,000	1.00	295
C78	V = 0.198; $\mathcal{R}_A$ = 1	0.96	930

Table S1. Continued.

Simulation	Parameter values different from those given in Table 1 (units are the same as those given in Table 1)	F (-)	τ (s)
C79	V = 0.198; $\mathcal{R}_A$ = 100	0.96	930
C80	V = 1.98; $\mathcal{R}_A$ = 1	1.00	94.8
C81	V = 1.98; $\mathcal{R}_A$ = 100	1.00	94.5
C82	D_H = 0.316; V = 0.273	0.87	2,240
C83	L = 20,000	0.75	6,040
C84	L = 100; V = 0.0626	0.99	289
C85	L = 10,000; V = 6.26	0.99	300
C86	D_H = 0.05; V = 0.0586; $\mathcal{R}_D$ = 6,000,000	0.00	-
C87	L = 200,000; $\mathcal{R}_D$ = 6,000,000	0.51	733,000
C88	D_H = 0.2; V = 0.0609; $\mathcal{R}_D$ = 6,000,000	0.61	287,000
C89	L = 10,000; $\mathcal{R}_D$ = 6,000,000	0.97	35,600
C90	L = 10,000; V = 0.198; $\mathcal{R}_D$ = 6,000,000	0.90	113,000
C91	D_H = 0.02; V = 0.213; $\mathcal{R}_D$ = 6,000,000	0.00	-
C92	D_H = 0.632; L = 3,430; V = 0.231; $\mathcal{R}_D$ = 6,000,000	0.04	1,560,000
C93	D_H = 0.2; L = 28,600; V = 0.609; $\mathcal{R}_D$ = 6,000,000	0.24	871,000
C94	D_H = 0.02; L = 100; V = 0.213; $\mathcal{R}_D$ = 600	0.04	559
C95	D_H = 0.0356; L = 110; V = 0.131; $\mathcal{R}_D$ = 600	0.08	478
C96	D_H = 0.0632; L = 343; V = 0.231; $\mathcal{R}_D$ = 600	0.12	500
C97	D_H = 0.02; L = 100; V = 0.213	0.25	8,440
C98	D_H = 0.0632; L = 343; V = 0.231	0.52	5,790
C99	D_H = 0.02; V = 0.213	0.00	-
C100	D_H = 0.0632; L = 3,430; V = 0.231	0.00	-
C101	D_H = 0.2; L = 28,600; V = 0.609	0.04	61,200
C102	D_H = 10; L = 20,000; V = 0.287	0.95	1,280
C103	D_H = 0.3; L = 20,000; V = 0.263; $\mathcal{R}_D$ = 6,000,000	0.32	802,000
C104	D_H = 0.5; L = 20,000; V = 0.383; $\mathcal{R}_D$ = 6,000,000	0.71	275,000

Table S2. Parameter values used in planar simuations and thermal transmission factors and retardation values of these simulations.

Simulation	Parameter values different from those given in Table 1 (units are the same as those given in Table 1)	F (-)	τ (s)
P1 (equivalent to C1)	D_{H} = 0.01	0.35	33,200
P2 (equivalent to C2)	D_{H} = 0.0178	0.55	17,700
P3 (equivalent to C3)	D_{H} = 0.0316	0.71	9,670
P4 (equivalent to C4)	D_{H} = 0.0562	0.82	5,360
P5 (equivalent to C5)	D_{H} = 0.1	0.90	2,990
P6 (equivalent to C6)	D_{H} = 0.178	0.94	1,670
P7 (equivalent to C7)	D_{H} = 0.316	0.97	935
P8 (equivalent to C65)	D_{H} = 0.1; V = 0.0346	0.17	63,900
P9 (equivalent to C67)	D_{H} = 0.1; V = 0.110	0.54	17,700
P10 (equivalent to C69)	D_{H} = 0.1; V = 0.346	0.82	5,430
P11 (equivalent to C82)	D_{H} = 0.316; V = 0.273	0.92	2,140
P12 (equivalent to C86)	D_{H} = 0.05; V = 0.0586; $\mathcal{R}_{\mathrm{D}}$ = 6,000,000	0.79	645,000
P13 (equivalent to C88)	D_{H} = 0.2; V = 0.0609; $\mathcal{R}_{\mathrm{D}}$ = 6,000,000	0.94	153,000
P14 (equivalent to C91)	D_{H} = 0.02; V = 0.213; $\mathcal{R}_{\mathrm{D}}$ = 6,000,000	0.85	443,000
P15 (equivalent to C92)	D_{H} = 0.0632; L = 3,430; V = 0.231; $\mathcal{R}_{\mathrm{D}}$ = 6,000,000	0.85	443,000
P16 (equivalent to C93)	D_{H} = 0.2; L = 28,600; V = 0.609; $\mathcal{R}_{\mathrm{D}}$ = 6,000,000	0.85	443,000
P17 (equivalent to C94)	D_{H} = 0.02; L = 100; V = 0.213; $\mathcal{R}_{\mathrm{D}}$ = 600	0.22	503
P18 (equivalent to C95)	D_{H} = 0.0356; L = 110; V = 0.131; $\mathcal{R}_{\mathrm{D}}$ = 600	0.22	476
P19 (equivalent to C96)	D_{H} = 0.0632; L = 343; V = 0.231; $\mathcal{R}_{\mathrm{D}}$ = 600	0.22	495
P20 (equivalent to C97)	D_{H} = 0.02; L = 100; V = 0.213	0.85	4,410
P21 (equivalent to C98)	D_{H} = 0.0632; L = 343; V = 0.231	0.85	4,400
P22 (equivalent to C99)	D_{H} = 0.02; V = 0.213	0.22	52,200
P23 (equivalent to C100)	D_{H} = 0.0632; L = 3,430; V = 0.231	0.22	52,100
P24 (equivalent to C101)	D_{H} = 0.2; L = 28,600; V = 0.609	0.22	52,300
P25 (equivalent to C103)	D_{H} = 0.3; L = 20,000; V = 0.263; $\mathcal{R}_{\mathrm{D}}$ = 6,000,000	0.84	478,000
P26 (equivalent to C104)	D_{H} = 0.5; L = 20,000; V = 0.383; $\mathcal{R}_{\mathrm{D}}$ = 6,000,000	0.93	195,000