Electronic supplementary materials

For https://doi.org/10.1631/jzus.A2500175

Decomposition method for existing tunnel lining displacement induced by undercrossing: a case study

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Taking the left line of Line 11 passing through the exit line of Line 14 as an example, the monitoring results from node C4 to C9 between April 12 and April 25 were selected to calculate the dislocation as Table S1, rotation, and elliptical deformation of the lining rings.

Table S1 Daily monitoring data of the exit line of Line 14 (mm)

date	4.12		4.13		4.14		4.15		4.16		4.17		4.18		4.19		4.20		4.21		4.22		4.23		4.24		4.25	
direction	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x	y	x
C4-1	-0.1	0	0.2	-0.1	-0.1	0.1	-0.2	0.2	-0.1	0.3	-0.3	1.1	-0.2	1.2	-0.1	1.2	0	1.3	-0.4	0.9	0	1.3	-0.4	0.9	-0.3	1	-0.3	1
C4-2	-0.1	0	-0.1	-0.3	0	0	-0.2	0.2	-0.1	0.3	-0.2	1.2	-0.2	1.4	-0.2	1.2	0	1.4	0	1.4	0	1.4	0	1.4	-0.2	1.2	-0.2	1.2
C4-3	-0.1	0	-0.3	-0.2	-0.1	0.1	-0.1	0.2	-0.3	0.3	-0.3	1.2	-0.2	1.4	0	1.4	-0.2	1.2	0	1.4	0	1.4	-0.3	1.1	-0.1	1.3	-0.2	1.2
C4-4	-0.1	0	-0.2	-0.2	0	0.1	-0.1	0.1	-0.1	0.3	0	1	0	1.2	-0.3	1	0	1.3	-0.2	1.1	-0.1	1.2	-0.3	1	-0.3	1	-0.2	1.1
C4-5	-0.1	0	0.1	-0.2	0	0.1	-0.1	0.1	0	0.3	0	1	0.1	1.2	0.2	1.4	0	1.2	-0.1	1.1	-0.2	1	0.1	1.3	0.2	1.4	-0.1	1.1

C5-1	-0.1	0.1	0	-0.3	-0.1	0	-0.3	0.2	-0.3	0.3	-0.5	1.2	-0.5	2.1	-0.3	2.1	-0.3	2.1	-0.6	1.8	-0.3	2.1	-0.3	2.1	-0.5	1.9	-0.5	1.9
C5-2	-0.1	0	0.1	-0.1	-0.1	0.3	-0.2	0.2	-0.2	0.3	-0.3	1.3	-0.4	2.3	-0.4	2	-0.2	2.2	-0.3	2.1	-0.2	2.2	-0.4	2	-0.2	2.2	-0.4	2
C5-3	-0.1	0	0	-0.1	-0.1	0.2	-0.1	0.2	-0.1	0.3	-0.4	1.3	-0.4	2.2	-0.5	1.9	-0.3	2.1	-0.3	2.1	-0.4	2	-0.3	2.1	-0.2	2.2	-0.4	2
C5-4	0.2	-0.1	0.2	-0.2	0.1	0.2	0.1	0	0.1	0.3	0	1.5	0	1.9	-0.1	1.9	0.1	2.1	-0.3	1.7	0	2	-0.1	1.9	-0.3	1.7	-0.2	1.8
C5-5	0	0	-0.3	-0.2	0	0.2	0	0.1	0	0.3	-0.1	1.4	0	1.9	-0.1	2.1	-0.4	1.8	0	2.2	-0.3	1.9	-0.2	2	-0.1	2.1	-0.3	1.9
C6-1	-0.2	-0.1	0.1	-0.1	-0.2	0.2	-0.3	0.1	-0.3	0.3	-0.5	1.2	-0.5	2.5	-0.5	2.2	-0.4	2.3	-0.5	2.2	-0.3	2.4	-0.5	2.2	-0.4	2.3	-0.5	2.2
C6-2	-0.1	-0.1	0	-0.2	-0.1	0.2	-0.2	0.1	-0.3	0.4	-0.4	1.4	-0.4	2.4	-0.3	2.8	-0.6	2.5	-0.6	2.5	-0.4	2.7	-0.3	2.8	-0.6	2.5	-0.6	2.5
C6-3	-0.2	-0.1	-0.3	-0.3	-0.1	0	-0.2	0.2	-0.2	0.4	-0.3	1.4	-0.4	2.7	-0.3	2.8	-0.3	2.8	-0.5	2.6	-0.6	2.5	-0.3	2.8	-0.3	2.8	-0.5	2.6
C6-4	0	-0.1	-0.1	-0.3	0	0	-0.1	0	0	0.3	-0.1	1.3	0	2.4	-0.4	2.5	-0.4	2.5	-0.3	2.6	-0.3	2.6	-0.4	2.5	-0.2	2.7	-0.4	2.5
C6-5	0	0	0.1	-0.2	0	0.2	0	0.1	0	0.3	0	1.3	-0.1	2.4	-0.2	2.6	-0.4	2.4	-0.2	2.6	-0.2	2.6	-0.1	2.7	-0.1	2.7	-0.3	2.5
C7-1	-0.2	-0.1	0.1	-0.1	-0.3	0.3	-0.3	0	-0.4	0.4	-0.7	1.4	-0.7	2.5	-0.7	2.8	-0.8	2.7	-0.6	2.9	-0.7	2.8	-0.9	2.6	-0.5	3	-0.8	2.7
C7-2	0.1	-0.2	-0.1	-0.1	0	0.1	-0.1	0	-0.2	0.3	-0.4	1.4	-0.3	2.6	-0.5	3	-0.5	3	-0.7	2.8	-0.6	2.9	-0.4	3.1	-0.6	2.9	-0.6	2.7
C7-3	0	-0.3	0.1	-0.1	0.1	-0.1	-0.1	-0.1	0	0.3	-0.2	1.4	-0.2	2.5	-0.4	2.8	-0.1	3.1	-0.2	3	-0.4	2.8	-0.4	2.8	-0.2	3	-0.4	2.8
C7-4	0	-0.1	0	-0.2	0	0.1	-0.1	0	0	0.3	-0.2	1.3	-0.1	2.4	-0.1	3	-0.3	2.8	-0.2	2.9	0	3.1	-0.3	2.8	-0.3	2.8	-0.3	2.6
C7-5	0	-0.1	0.2	-0.2	0.1	-0.1	-0.1	0	-0.1	0.3	0	1.3	0	2.5	-0.1	2.9	0.1	3.1	0	3	-0.2	2.8	-0.2	2.8	-0.1	2.9	-0.2	2.8
C8-1	-0.3	-0.2	0	-0.2	-0.2	0.2	-0.3	-0.1	-0.4	0.3	-0.6	1.4	-0.7	2.5	-0.7	2.8	-0.7	2.8	-0.7	2.8	-0.6	2.9	-0.5	3	-0.7	2.8	-0.8	2.7
C8-2	0.1	-0.2	0.1	-0.2	0	0.1	-0.1	-0.2	-0.1	0.1	-0.2	1.4	-0.2	2.4	-0.3	3.2	-0.6	2.9	-0.6	2.9	-0.3	3.2	-0.2	3.3	-0.2	3.3	-0.5	2.5
C8-3	-0.1	-0.4	0	-0.3	0	-0.2	-0.1	-0.3	-0.1	0.1	-0.2	1.4	-0.2	2.2	-0.5	2.8	-0.4	2.9	-0.4	2.9	-0.4	2.9	-0.4	2.9	-0.4	2.9	-0.5	2.7
C8-4	0.1	-0.1	-0.2	-0.2	0	0.1	0	-0.1	0	0.3	0	1.3	-0.1	2	-0.3	2.8	-0.1	3	-0.1	3	-0.2	2.9	-0.4	2.7	-0.1	3	-0.3	2.5
C8-5	-0.1	-0.1	0.1	-0.3	0	0	0	-0.1	-0.1	0.3	0	1.3	0	2.1	-0.1	3	-0.3	2.8	-0.2	2.9	0	3.1	-0.3	2.8	-0.1	3	-0.3	2.6
C9-1	-0.1	-0.2	-0.3	-0.3	-0.1	0.1	-0.1	-0.2	-0.4	0	-0.4	1.3	-0.6	1.9	-0.6	2.4	-0.6	2.4	-0.3	2.7	-0.4	2.6	-0.6	2.4	-0.3	2.7	-0.6	2.4
C9-2	0.2	-0.4	-0.1	-0.2	0	0	0	-0.3	0	0	0	1.3	0	1.9	-0.2	2.9	-0.2	2.9	0	3.1	-0.4	2.7	-0.2	2.9	-0.3	2.8	-0.3	2.6
C9-3	0.2	-0.1	0.1	-0.2	0.1	-0.1	0	-0.4	0	0	0.1	1.2	0	1.4	0.4	2.6	0.3	2.5	0.4	2.6	0.2	2.4	0.1	2.3	0.2	2.4	0.2	2
C9-4	0.1	-0.2	0.1	-0.3	0.1	0	0.1	-0.2	0.1	-0.1	0.2	0.8	0	1.1	0.1	2.4	0.1	2.4	0.2	2.5	0.2	2.5	0.1	2.4	0.1	2.4	0	1.5
C9-5	0.1	-0.1	0.1	-0.1	0.1	0	0.1	-0.1	0	0.2	0.1	0.9	0.1	1.2	0.1	2.5	-0.2	2.3	-0.2	2.3	0.2	2.6	0.2	2.6	0.2	2.6	-0.1	2

Employing Equation (25) from the article, the *z*-direction displacement of the lining ring was calculated, and the results are presented in Table S2.

Table S2 The *z*-direction displacement of the lining ring (mm)

Distance from crossing center (m)	April 12	April 13	April 14	April 15	April 16	April 17	April 18	April 19	April 20	April 21	April 22	April 23	April 24	April 25
-10.2	0	-0.2	0.08	0.16	0.3	1.1	1.28	1.24	1.28	1.18	1.26	1.14	1.18	1.12
-5.1	0	-0.18	0.18	0.14	0.3	1.34	2.08	2	2.06	1.98	2.04	2.02	2.02	1.92
0	0	-0.14	0.2	0.18	0.42	1.4	2.56	2.66	2.58	2.58	2.64	2.68	2.68	2.54
5.1	0	0.02	0.22	0.14	0.48	1.52	2.66	3.06	3.1	3.08	3.04	2.98	3.08	2.88
10.5	0	-0.04	0.24	0.04	0.42	1.56	2.44	3.12	3.08	3.1	3.2	3.14	3.2	2.8
15.9	0	-0.02	0.2	-0.04	0.22	1.3	1.7	2.76	2.7	2.84	2.76	2.72	2.78	2.3
25.5	0	-0.22	-0.12	-0.08	-0.3	0.18	0.34	0.64	0.56	0.54	0.48	0.5	0.52	0.46
35.1	0	-0.14	-0.1	-0.02	-0.36	-0.22	-0.2	0.08	0.08	0.02	0.04	0.06	-1.11022E-17	-0.06

Employing Equations (10) to (17) from the article, the rotation of the lining ring was calculated iteratively, and the results are presented in Table S3.

Table S3 Lining ring ellipticity calculation results ($\times 10^{-3}$ °)

Distance from crossing center (m)	April 12	April 13	April 14	April 15	April 16	April 17	April 18	April 19	April 20	April 21	April 22	April 23	April 24	April 25
-5.1	0	0.33428	0.2821	0.33428	0.1751	0.1751	0.1751	0.15101	0.01592	3.47346E-5	0.12925	0.49346	0.00815	0.11316
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.1	0	-0.1911	-0.49346	-0.33428	-0.08035	-0.04594	-0.02205	-0.33428	-3.157E-6	-0.03338	-0.1751	-0.49346	-0.06469	-0.02969
10.5	0	-0.70746	-0.76313	-0.77905	-0.18726	-0.10706	-0.05138	-0.32517	-0.01504	-0.18207	-0.11559	-0.66125	-0.2395	-0.13327
15.9	0	-0.55011	-1.0133	-1.1381	-0.09404	-0.1564	-0.20563	-0.68584	-0.02591	-0.48315	-0.18855	-0.83772	-0.26462	-0.06679
25.5	0	-0.60068	-0.56717	-0.64077	-0.08459	-0.09967	-0.14038	-0.60024	-0.01296	-0.24873	-0.10144	-1.25969	-0.24255	-0.22622

Employing Equations (20) to (24) from the article, the ovality of the fitted ellipse was calculated after eliminating the effects of rotation and *z*-direction displacement from the monitoring data, and the results are presented in Table S4.

Table S4 The *z*-direction displacement of the lining ring ($\times 10^{-3}$ m)

Distance from crossing center (m)	April 12	April 13	April 14	April 15	April 16	April 17	April 18	April 19	April 20	April 21	April 22	April 23	April 24	April 25
-10.2	0	0.43677	0.24833	0.53504	0.65105	2.3862	3.00552	2.51558	2.94128	2.64733	3.26487	2.05138	2.91255	2.06936
-5.1	0	0.00441	0.34566	0.10354	0.52075	2.34739	4.72129	3.57906	4.5047	3.96768	4.73565	3.45474	4.9992	3.20013
0	0	0.31227	0.24503	0.36088	0.81415	2.70606	5.55043	5.56922	5.85328	4.99562	5.8324	4.97798	6.20941	4.16361
5.1	0	0.23346	0.34355	0.42858	0.06297	2.57815	5.0616	5.79639	6.19241	5.4901	5.85391	4.84456	6.14699	4.27618
10.5	0	0.03166	0.0186	0.00293	0.13711	2.82175	4.68631	6.34246	6.05136	5.85127	6.52122	5.27162	6.53226	4.03692
15.9	0	0.2905	0.61916	0.07648	0.68002	1.96526	2.78235	5.50396	5.14612	5.15931	4.86825	3.83022	4.94537	3.18054
25.5	0	0.16503	0.31613	0.06757	0.66998	0.37632	0.55014	1.65749	1.15205	1.73192	1.17774	0.93139	1.31311	0.90295
35.1	0	0.10685	0.09533	0.03471	0.69966	0.26685	0.31098	0.08111	0.17927	0.39431	0.17324	0.17898	0.47084	0.26837