Supplementary Materials:

Table S1: Simplified Soil Layer Parameter Table.

Layer	Soil Layer Description	Layer Bottom Distribution Depth (GL.-m)	Average Distribution Elevation (GL.-m)	N Value	γ_t (t/m³)	W_n (%)	W_L (%)	S_u* (t/m²)	C' (t/m²)	φ'* (deg.)	C_c*	C_r*	E* (t/m²)
1	Backfill Layer (SF)	0.1~0.9 (0.5)	0.0~0.5	-	1.95*	--	--	--	0	29	--	--	--
2	Silty Clay Layer (CL)	1.8~3.7 (3.0)	0.5~3.0	2~7 (4)	1.95*	26.3	35.5	3.0	0	30	0.27	0.03	1200
3	Silty Sand Layer (SM)	9.2~10.6 (9.9)	3.0~9.9	2~13 (6)	2.02	20.2	--	--	0	30	--	--	1500
4	Silty Clay Layer (CL)	19.8~27.4 (23.1)	9.9~23.1	2~6 (3)	1.90	30.9	32.3	3.0~6.0	0	29	0.31	0.031	1500~3000
		40.0~41.5 (40.7)	23.1~40.7	4~14 (7)	1.92	29.8	32.1	6.0~10.0	0	30	0.30	0.030	3000~5000
5	Silty Sand Layer (SM)	40.9~45.0 (42.2)	40.7~42.2	11~24 (16)	1.94	24.7	--	--	0	31	--	--	4000
6	Silty Clay Layer (CL)	51.9~54.3 (52.7)	42.2~54.7	9~35 (19)	1.95	27.3	32.7	10.0~14.0	0	31	0.29	0.029	5000~7000
7	Gravel Layer (GW/GP)	-- (Drilling Depth)	>52.7	>50	2.2*	--	--	--	0	40	--	--	>12500

Note: 1. Values within the parentheses are averages or representative values. 2. Items marked with an asterisk (*) indicate estimated values based on experience.
3. The onsite measurement of the groundwater level is approximately between GL.-2.8m and GL.-3.6m below the ground surface. It is recommended that the constant groundwater level for temporary structural design be at GL.-2.8m, and the long-term groundwater level for permanent structural design be at the ground surface level.

Table S2. Material parameters for the Pile Wall (Embedded Beam)

Name	Unit	Parameter Value	Remarks
Young's Modulus E (fc′= 280kg/cm²)	kN/m²	1.48e7	Reduction factor 0.6
Unit Weight γ	kN/m³	10	
Predefined beam type			Massive square beam
Width	m	2.1	
Skin Friction at Pile Head $T_{skin,start,max}$	kN/m	250	
Skin Friction at Pile Base $T_{skin,end,max}$	kN/m	550	
Maximum Pile Bearing Capacity F_{max}	kN	12,000	

Note 1. Pile dimensions are 1.2 m x 3.5 m.

Note 2. Average pile shaft friction is calculated as 12,000 kN/30 = 400 kN/m.

Table S3. Material parameters for the Top-Down Steel Column (Beam)

Name	Unit	Parameter Value	Remarks
Material properties		Elastic	
Young's Modulus E (fc′= 560kg/cm²)	kN/m²	3.48e7	$E_c = 150{,}000 \times \sqrt{f_c'} \times 9.8(\mathrm{kN}/cm^2)$
Unit Weight γ	kN/m³	25	
Predefined beam type			Massive rectangle beam
Height	m	1.2	
Width	m	1.2	
Moment of inertia I	m⁴	0.1728	$I_2 = I_3$

Table S4. Node-to-Node Anchor Material Parameters

Parameter	Symbol	Node-to-Node Anchor	Unit	Notes
Material Type	Type	Elastic	--	Ø=0.7
Axial Stiffness	ØEA	8517144	KN	E=205947000; A=0.05908

Steel Profile	Minimum Preload (ton)	Site Preload (ton)	Allowable Axial Force (ton)
2H414×405×18×28mm	100 (per unit)	100 (per unit)	234.86 (per unit)

Note: Horizontal spacing of the bracing is 6m.

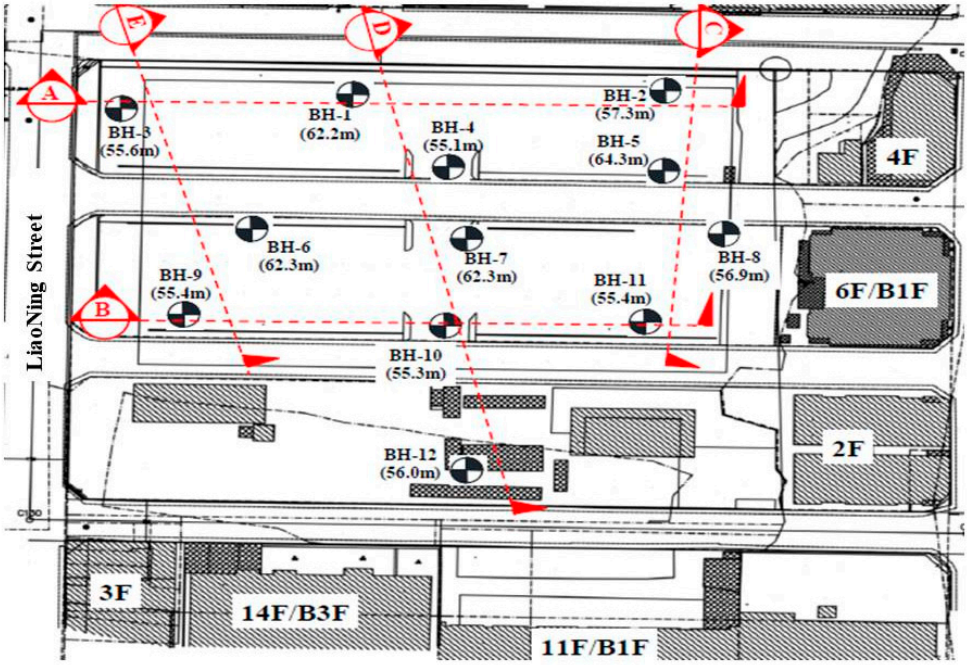


Figure S1. Borehole Plan Layout and Cross-Section Line.

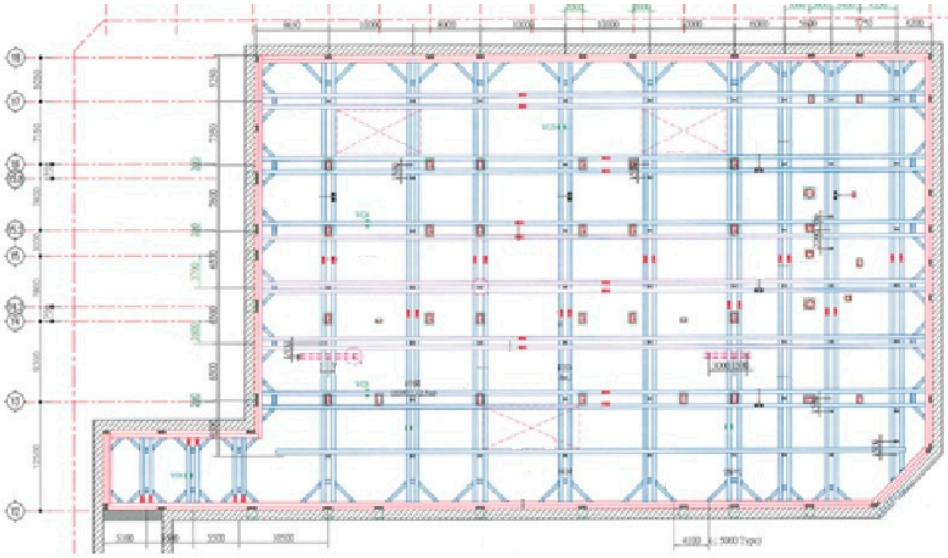


Figure S2. Ground Level Horizontal Bracing Layout

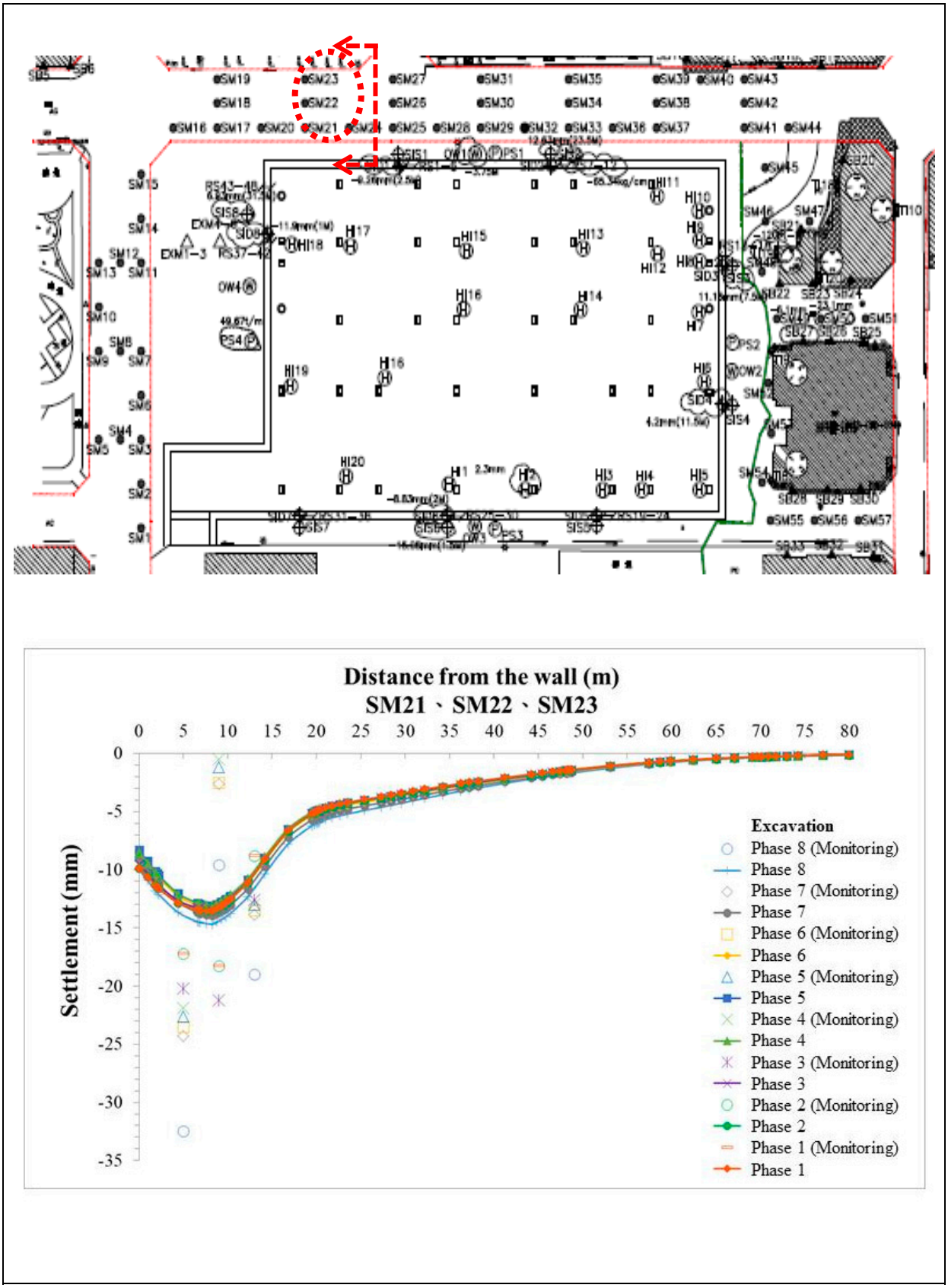


Figure S3. Comparison of Ground Subsidence Analysis and Monitoring Results for Each Excavation Phase on the Northeast Side

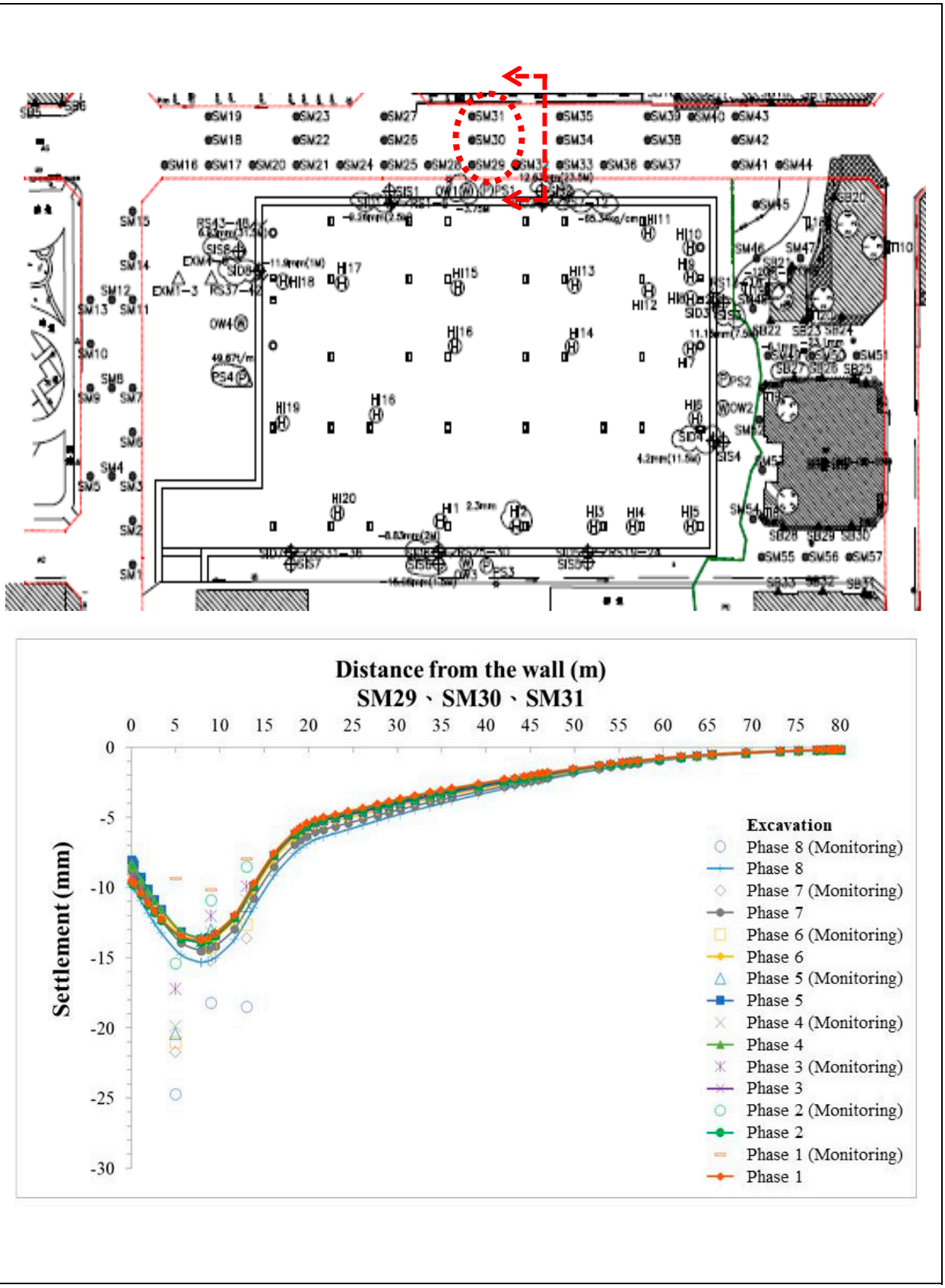


Figure S4 Comparison of Ground Subsidence Analysis and Monitoring Results for Each Excavation Phase on the North Side

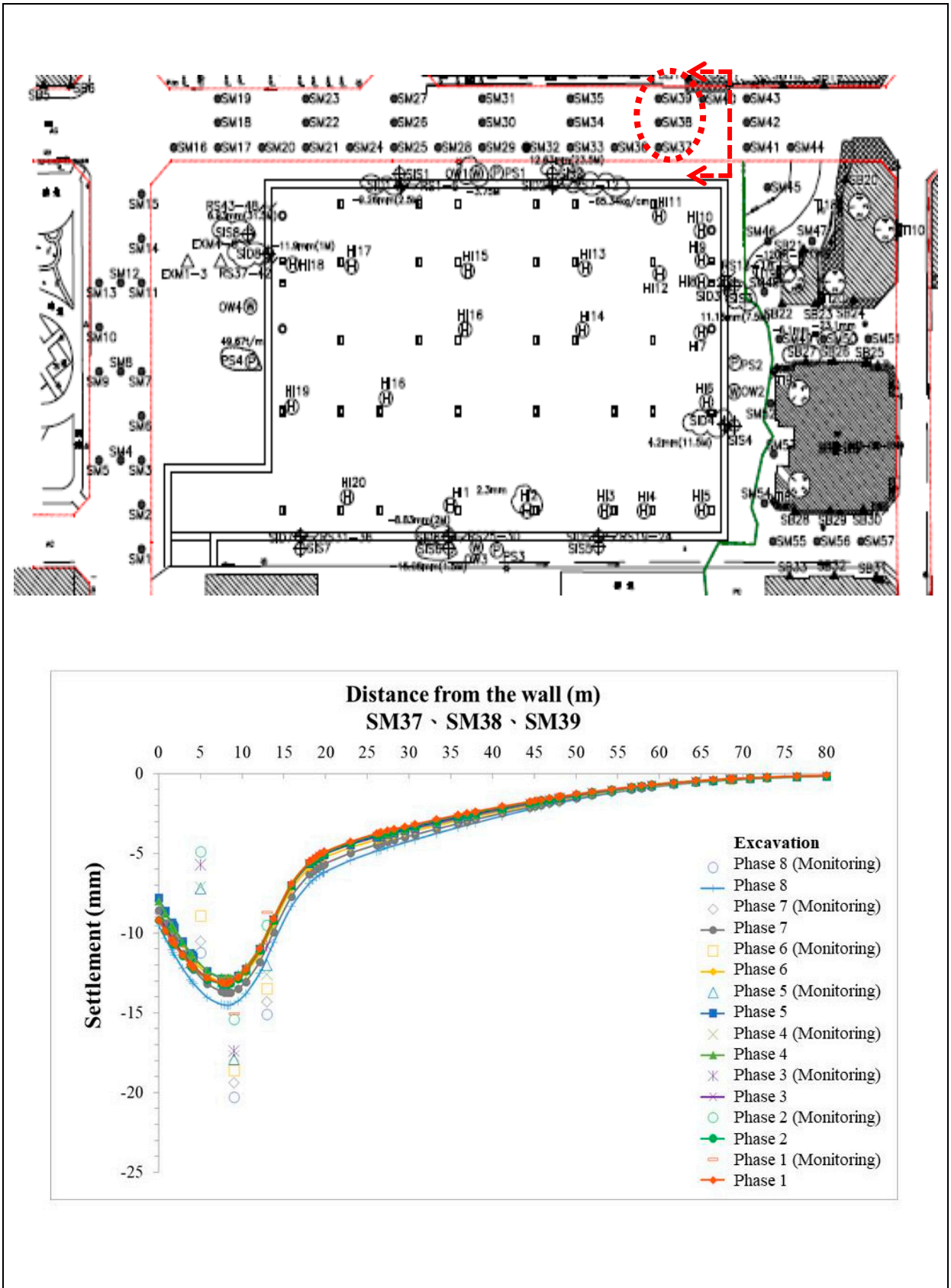
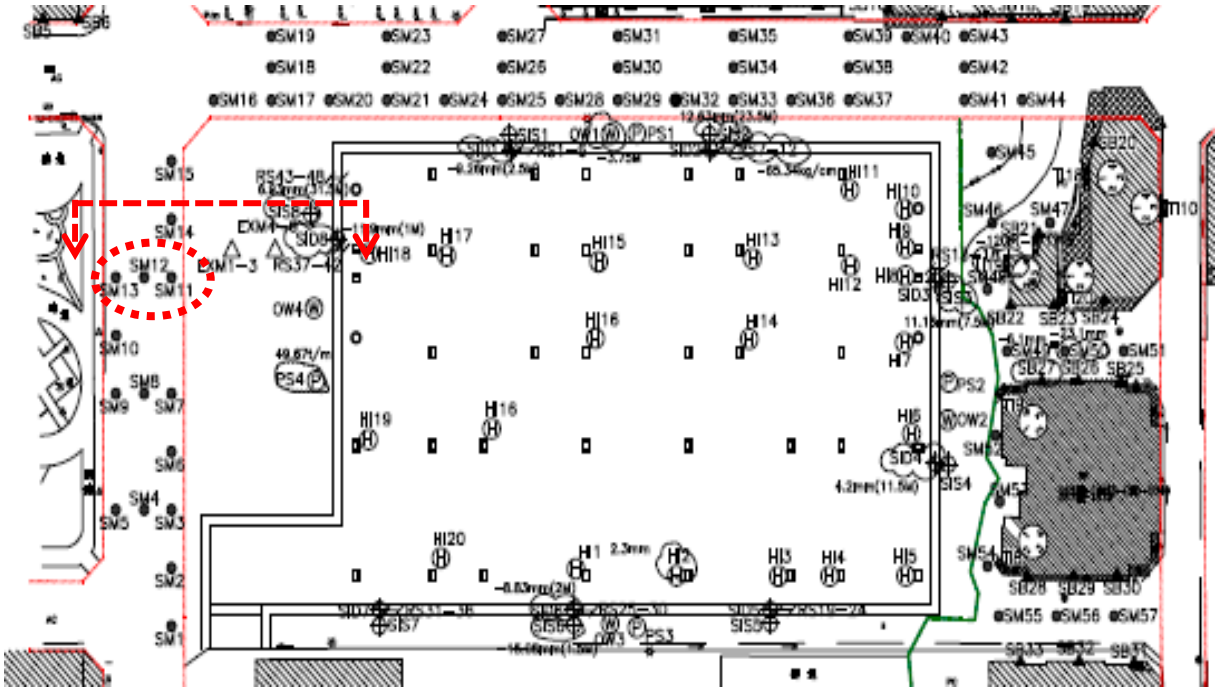


Figure S5. Comparison of Ground Subsidence Analysis and Monitoring Results for Each Excavation Phase on the Northwest Side



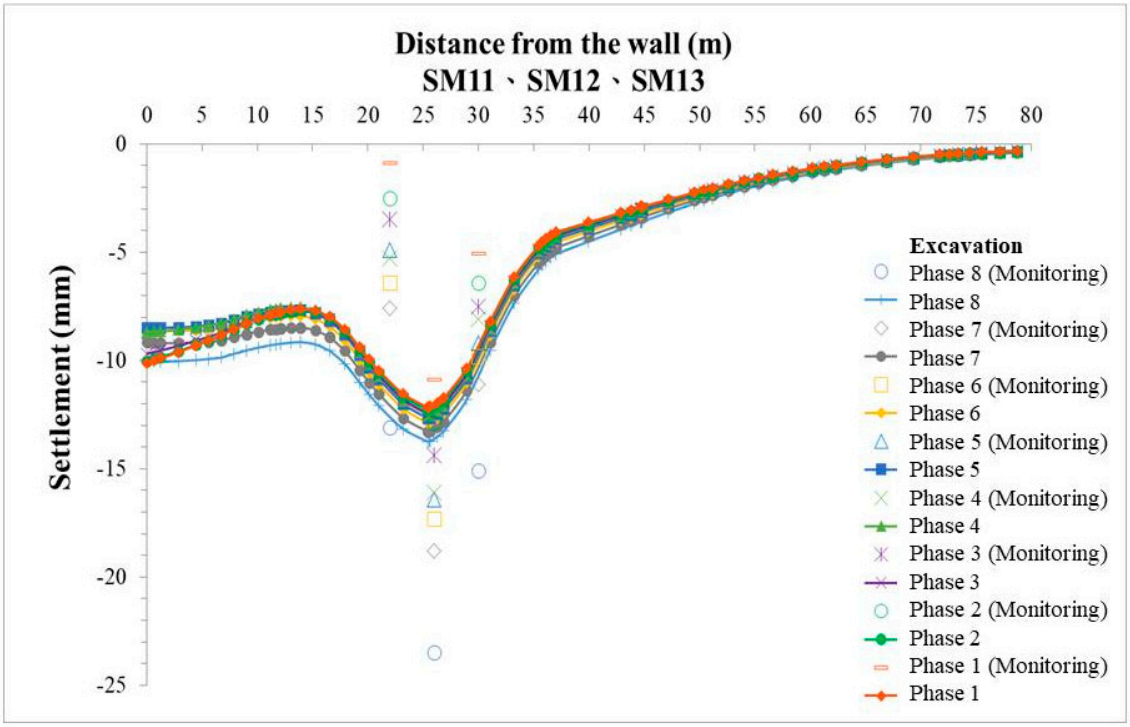


Figure S6. Comparison of Ground Subsidence Analysis and Monitoring Results for Each Excavation Phase on the Southwest Side

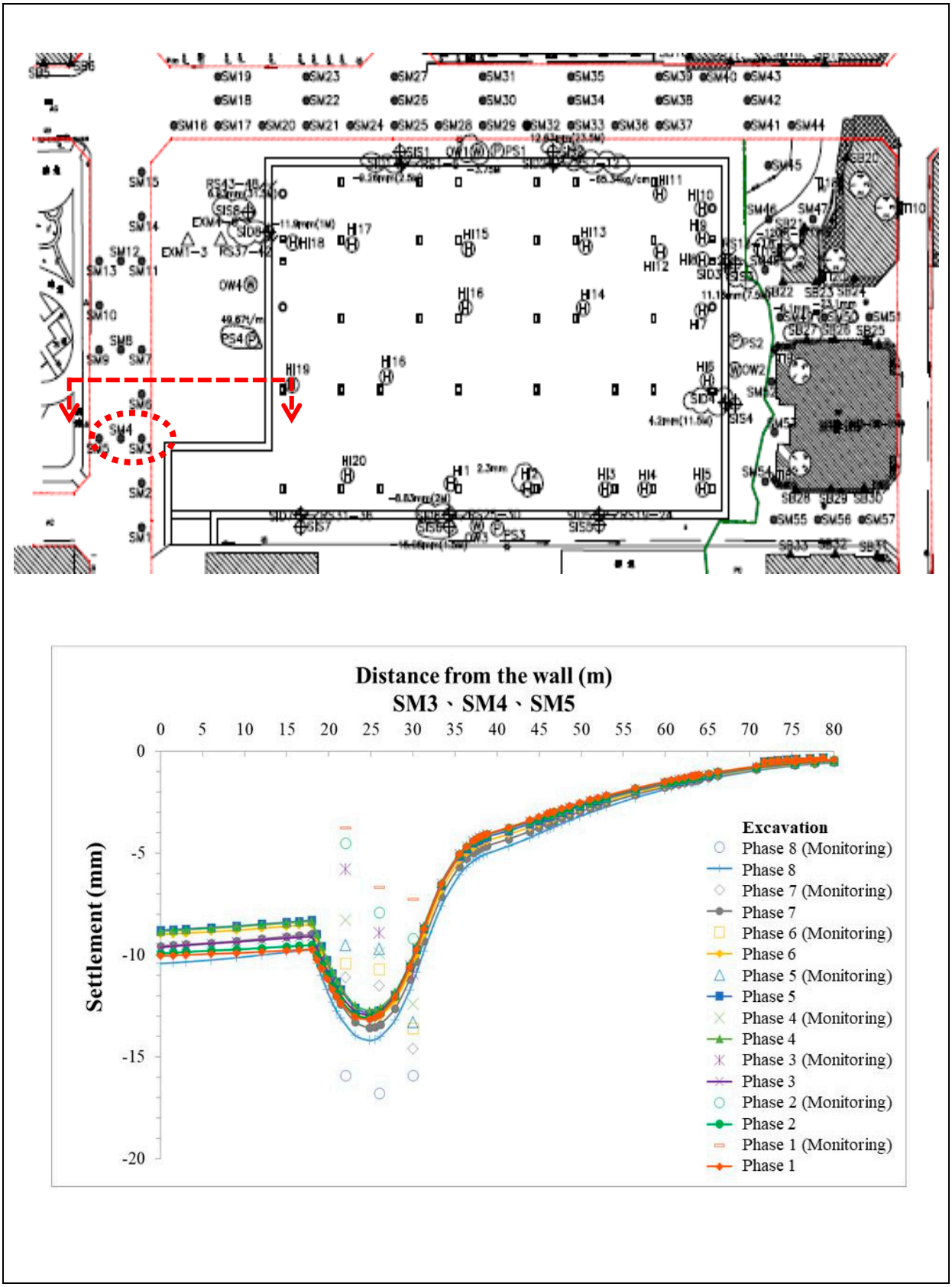
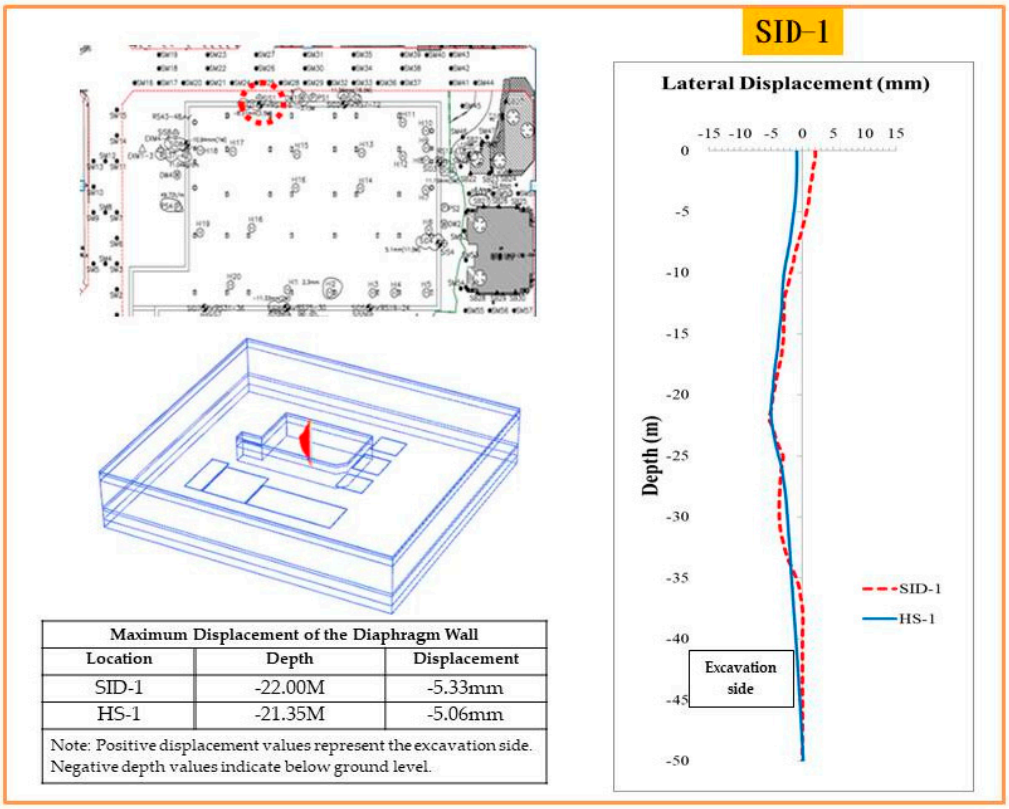


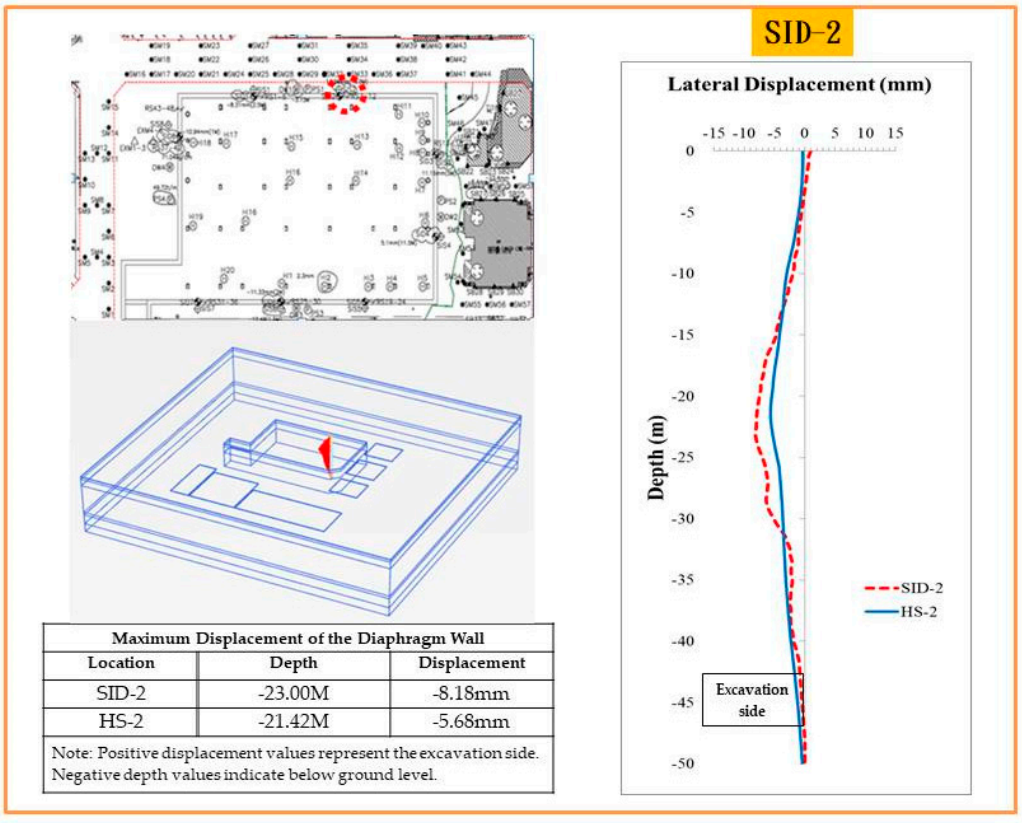
Figure S7. Comparison of Ground Subsidence Analysis and Monitoring Results for Each Excavation Phase on the Northwest Side



Maximum Displacement of the Diaphragm Wall		
Location	Depth	Displacement
SID-1	-22.00M	-5.33mm
HS-1	-21.35M	-5.06mm

Note: Positive displacement values represent the excavation side. Negative depth values indicate below ground level.

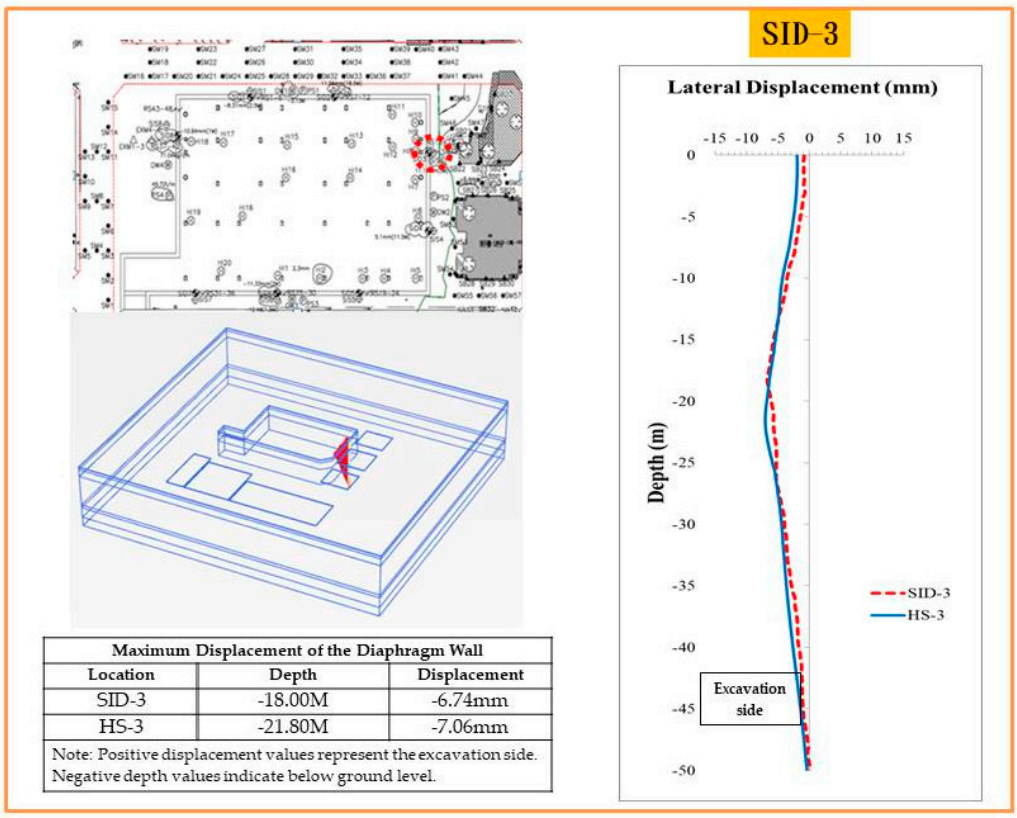
Figure S8. Comparison of Numerical Analysis Results with Monitoring Values from Monitoring Point SID-1



Maximum Displacement of the Diaphragm Wall		
Location	Depth	Displacement
SID-2	-23.00M	-8.18mm
HS-2	-21.42M	-5.68mm

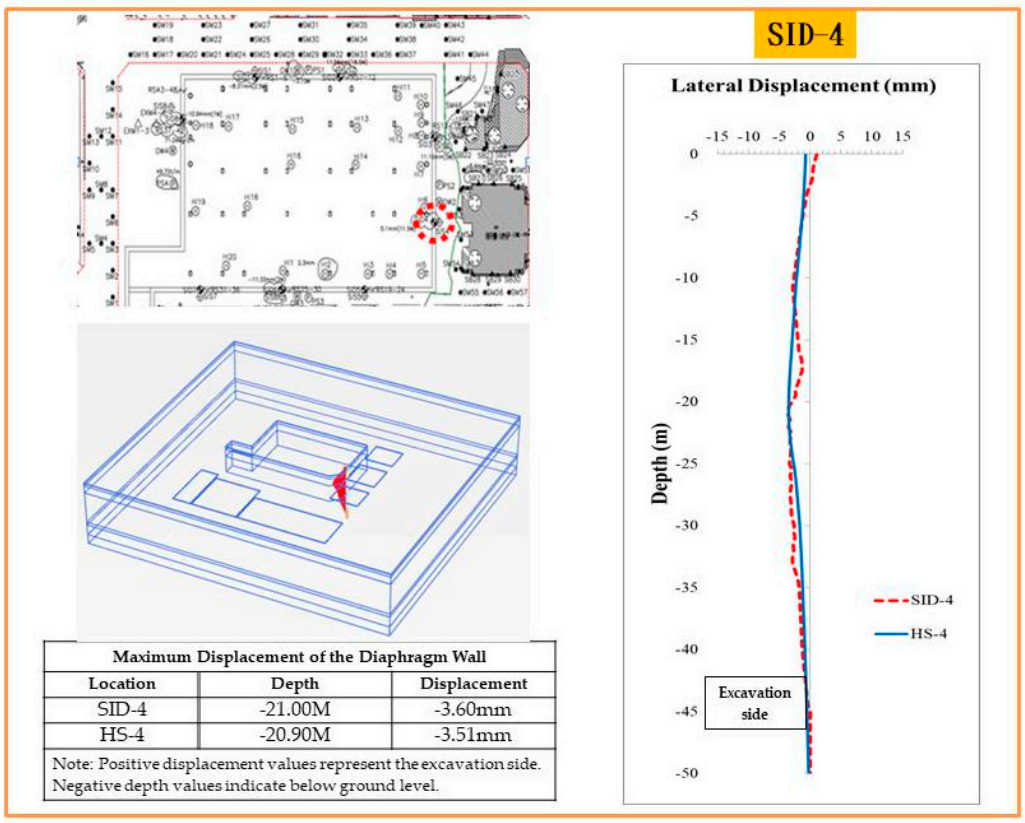
Note: Positive displacement values represent the excavation side. Negative depth values indicate below ground level.

FigureS9. Comparison of Numerical Analysis Results with Monitoring Values from Monitoring Point SID-2.



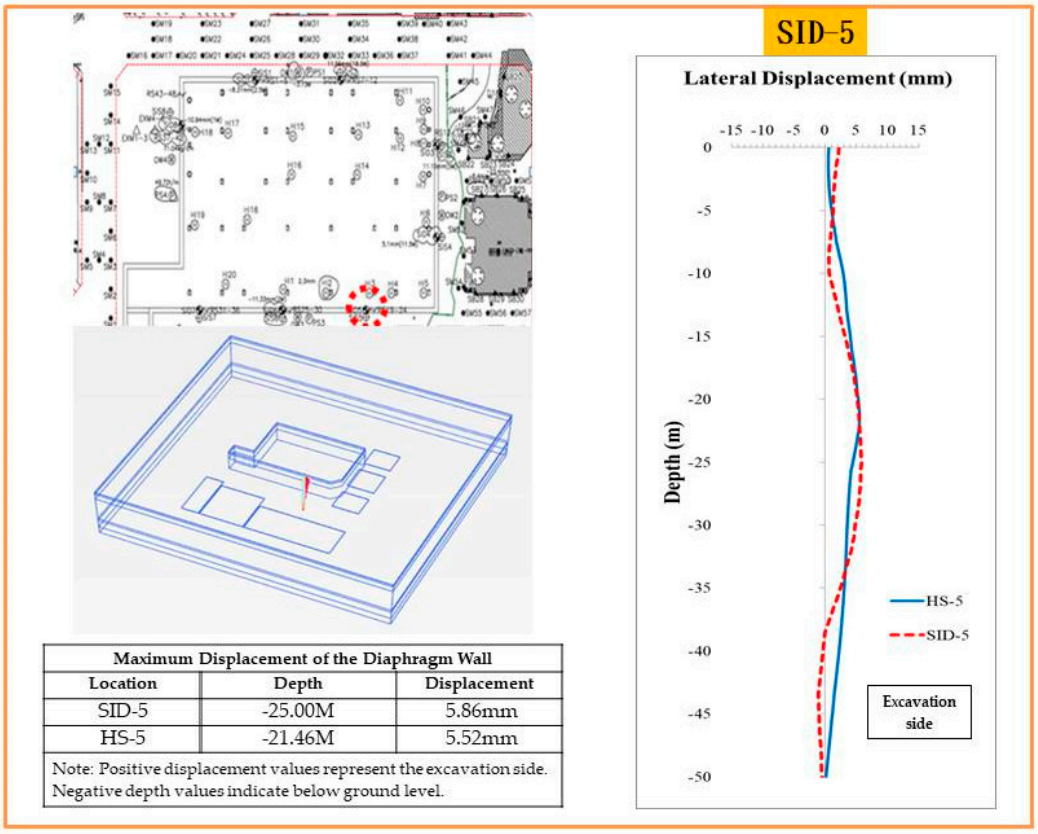
Maximum Displacement of the Diaphragm Wall		
Location	Depth	Displacement
SID-3	-18.00M	-6.74mm
HS-3	-21.80M	-7.06mm
Note: Positive displacement values represent the excavation side. Negative depth values indicate below ground level.		

FigureS10. Comparison of Numerical Analysis Results with Monitoring Values from Monitoring Point SID-3



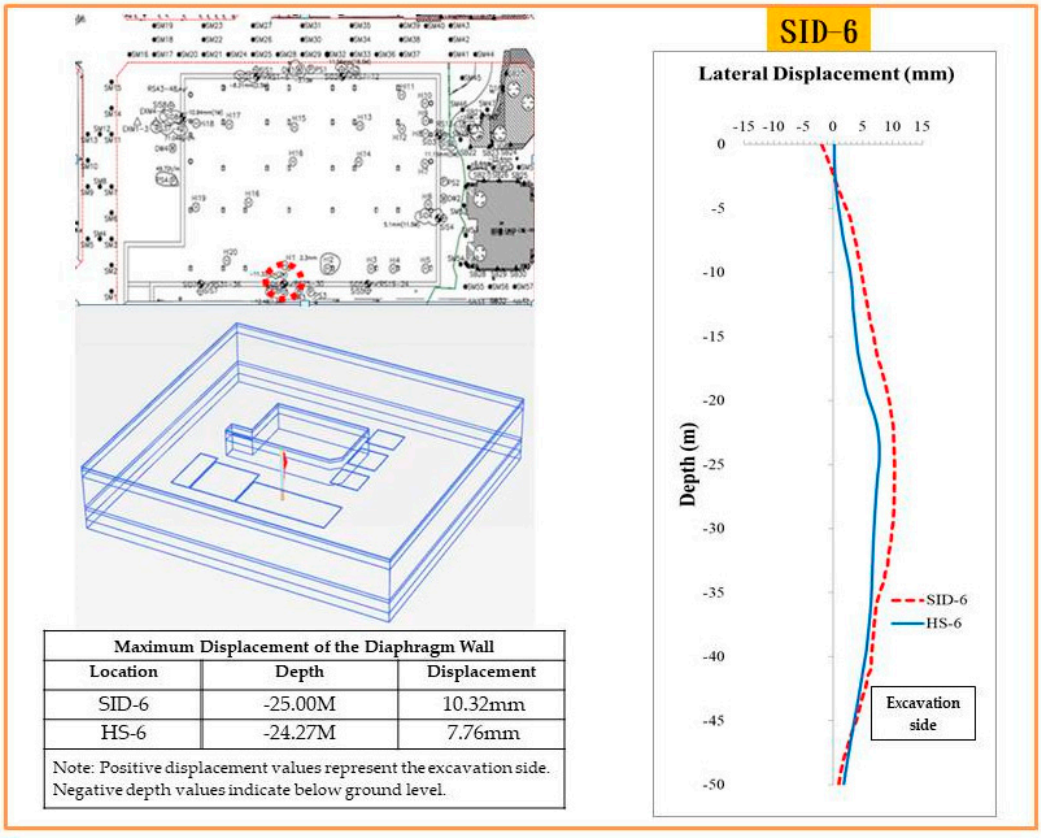
Maximum Displacement of the Diaphragm Wall		
Location	Depth	Displacement
SID-4	-21.00M	-3.60mm
HS-4	-20.90M	-3.51mm
Note: Positive displacement values represent the excavation side. Negative depth values indicate below ground level.		

FigureS11. Comparison of Numerical Analysis Results with Monitoring Values from Monitoring Point SID-4



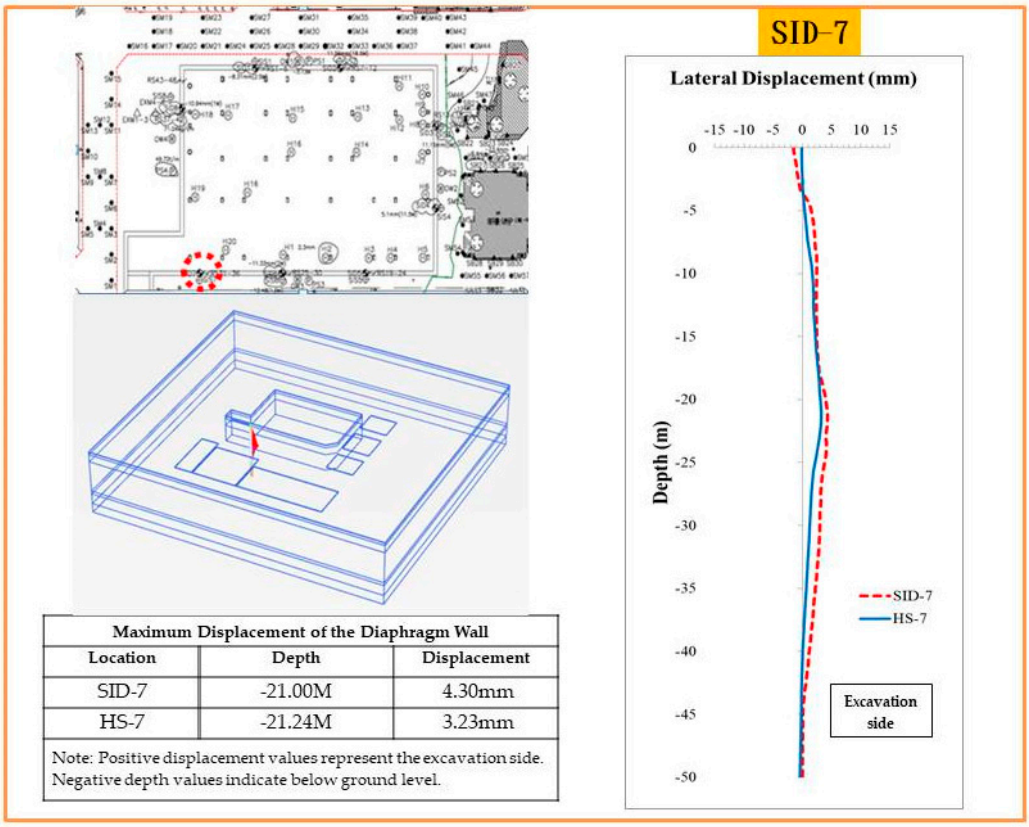
Maximum Displacement of the Diaphragm Wall		
Location	Depth	Displacement
SID-5	-25.00M	5.86mm
HS-5	-21.46M	5.52mm
Note: Positive displacement values represent the excavation side. Negative depth values indicate below ground level.		

FigureS12. Comparison of Numerical Analysis Results with Monitoring Values from Monitoring Point SID-5



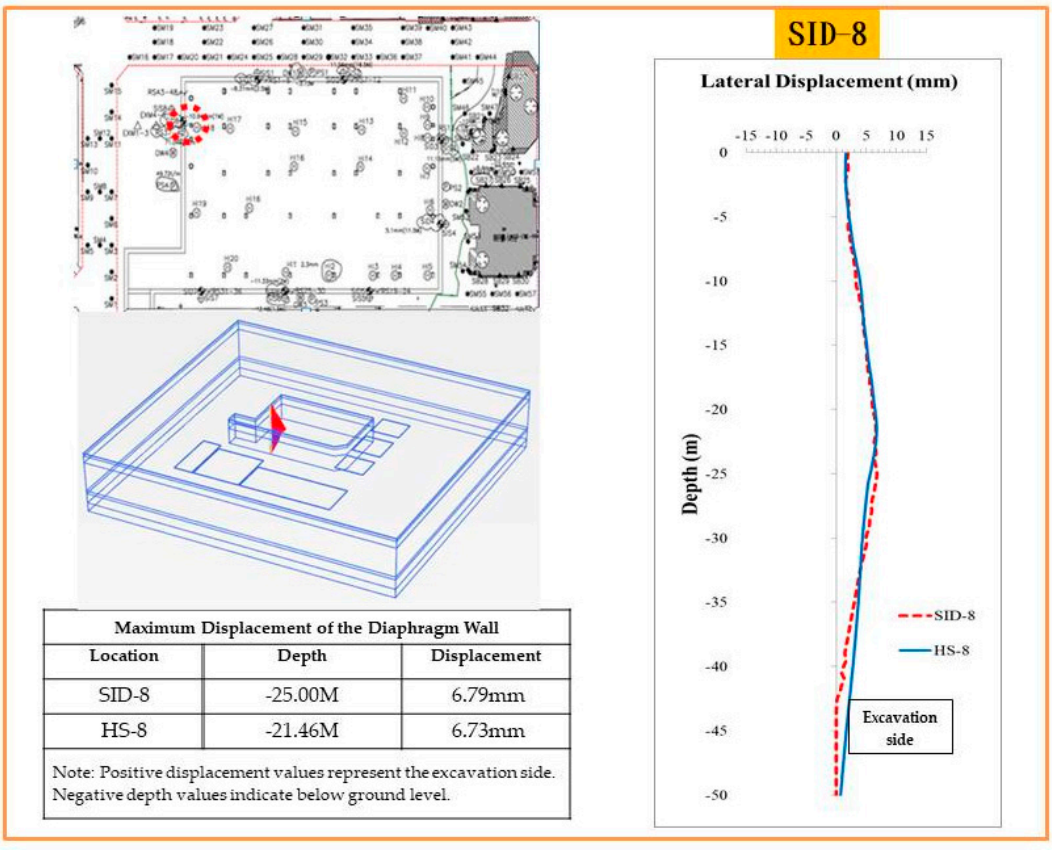
Maximum Displacement of the Diaphragm Wall		
Location	Depth	Displacement
SID-6	-25.00M	10.32mm
HS-6	-24.27M	7.76mm
Note: Positive displacement values represent the excavation side. Negative depth values indicate below ground level.		

FigureS13. Comparison of Numerical Analysis Results with Monitoring Values from Monitoring Point SID-6



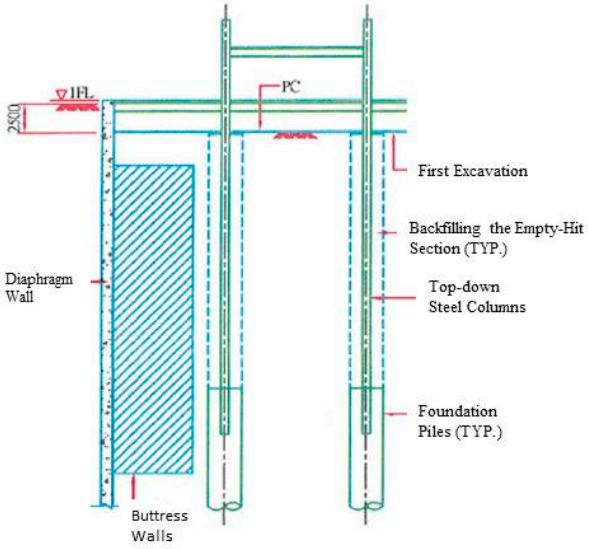
Maximum Displacement of the Diaphragm Wall		
Location	Depth	Displacement
SID-7	-21.00M	4.30mm
HS-7	-21.24M	3.23mm
Note: Positive displacement values represent the excavation side. Negative depth values indicate below ground level.		

FigureS14. Comparison of Numerical Analysis Results with Monitoring Values from Monitoring Point SID-7



Maximum Displacement of the Diaphragm Wall		
Location	Depth	Displacement
SID-8	-25.00M	6.79mm
HS-8	-21.46M	6.73mm
Note: Positive displacement values represent the excavation side. Negative depth values indicate below ground level.		

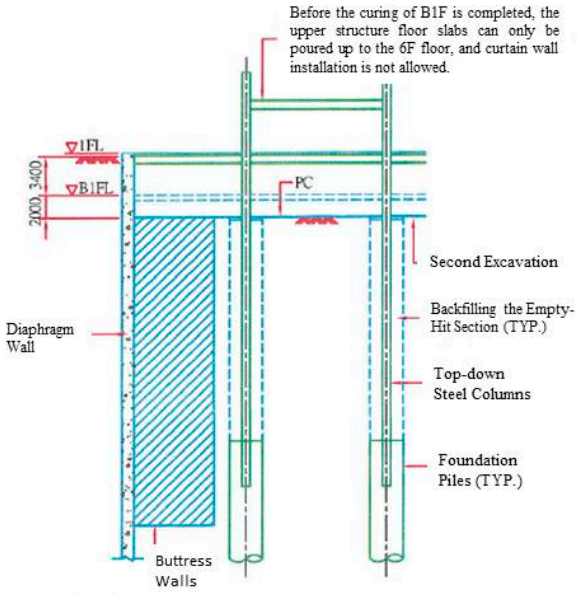
FigureS15. Comparison of Numerical Analysis Results with Monitoring Values from Monitoring Point SID-8



Explanation:

① Excavate the soil to GL-2.5M.
② Pour PC at a thickness of 10cm and construct the 1F steel beam structure.
③ After layout, make the template and complete the rebar installation, pour the 1F concrete.

Top-down Construction Steps 1- Diagram

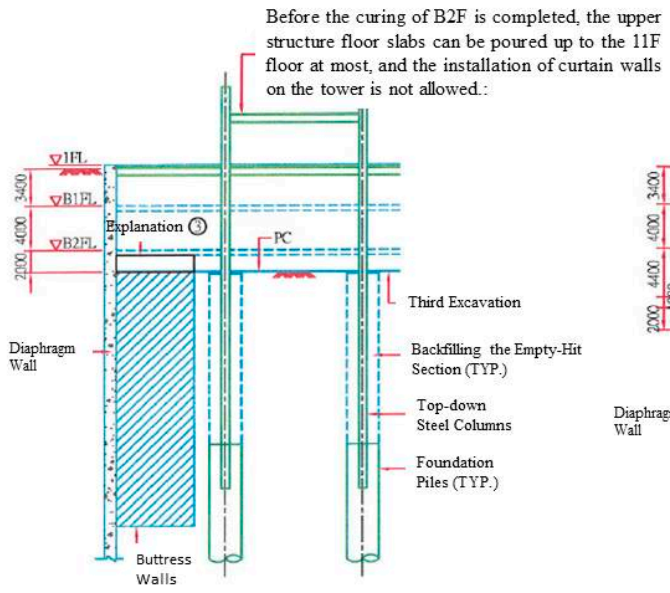


Explanation:

① Once the curing time has been reached, preparation for the second excavation begins.
② The second excavation goes down to approximately 2.0M below B1F while simultaneously removing the support walls.
③ Pour P.C. with a thickness of 10cm.
④ After the layout is made and the rebar is installed, pour the B1F concrete.

Top-down Construction Steps 2- Diagram

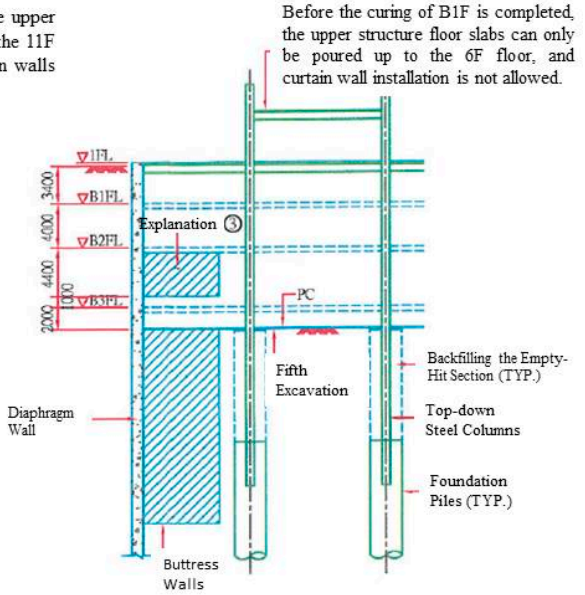
FigureS16. Schematic Diagram of the Timing Steps for Removing Buttress Walls (Step 1 to Step 2)



Explanation:

① Preparation for the third excavation begins immediately after the curing time is reached.
② The third excavation goes down to approximately 2.0M below B2F.
③ The buttress on the south toilet side (facing the rapid transit side) is removed down to the B2F slab base, and its rebar is integrated with the B2F floor by pouring them together (refer to the detailed diagram). The remaining buttresses are removed down to the excavation surface.
④ P.C. of 10cm thickness is poured.
⑤ After the layout is made, templates are created, and upon completion of the rebar installation, the B2F concrete is poured.

Top-down Construction Steps 3- Diagram

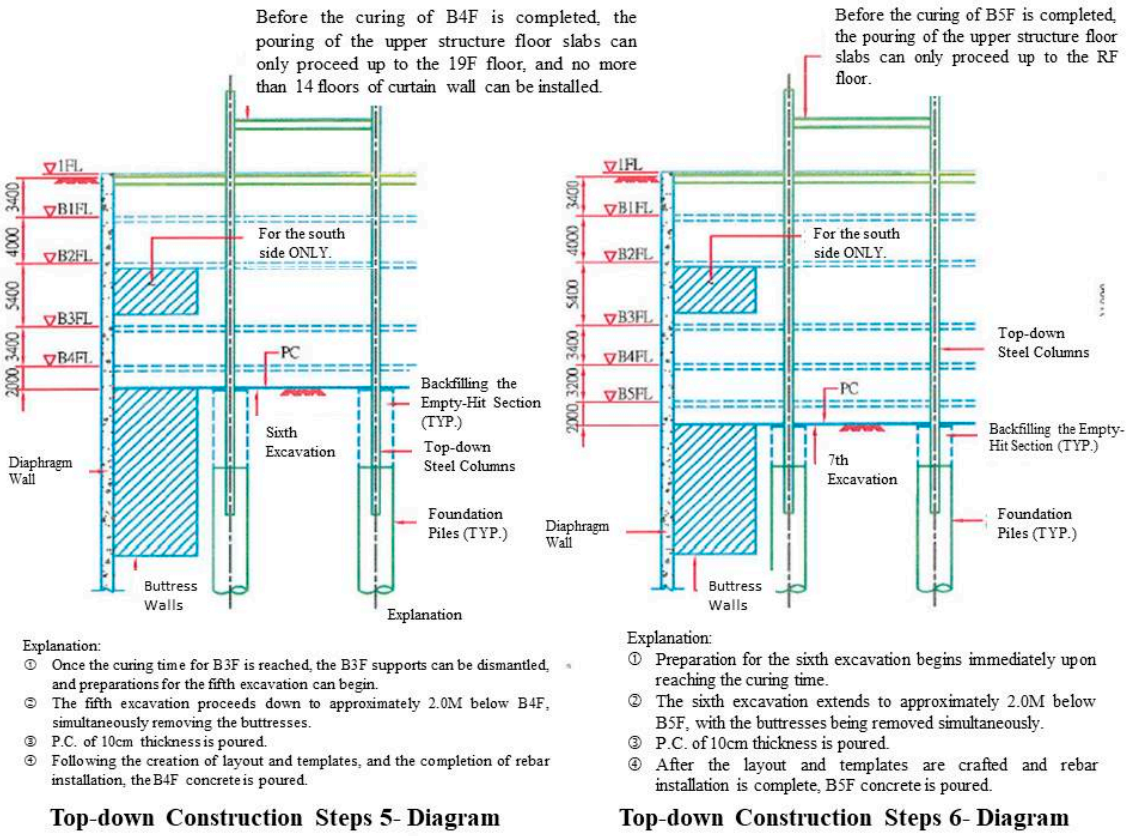


Explanation:

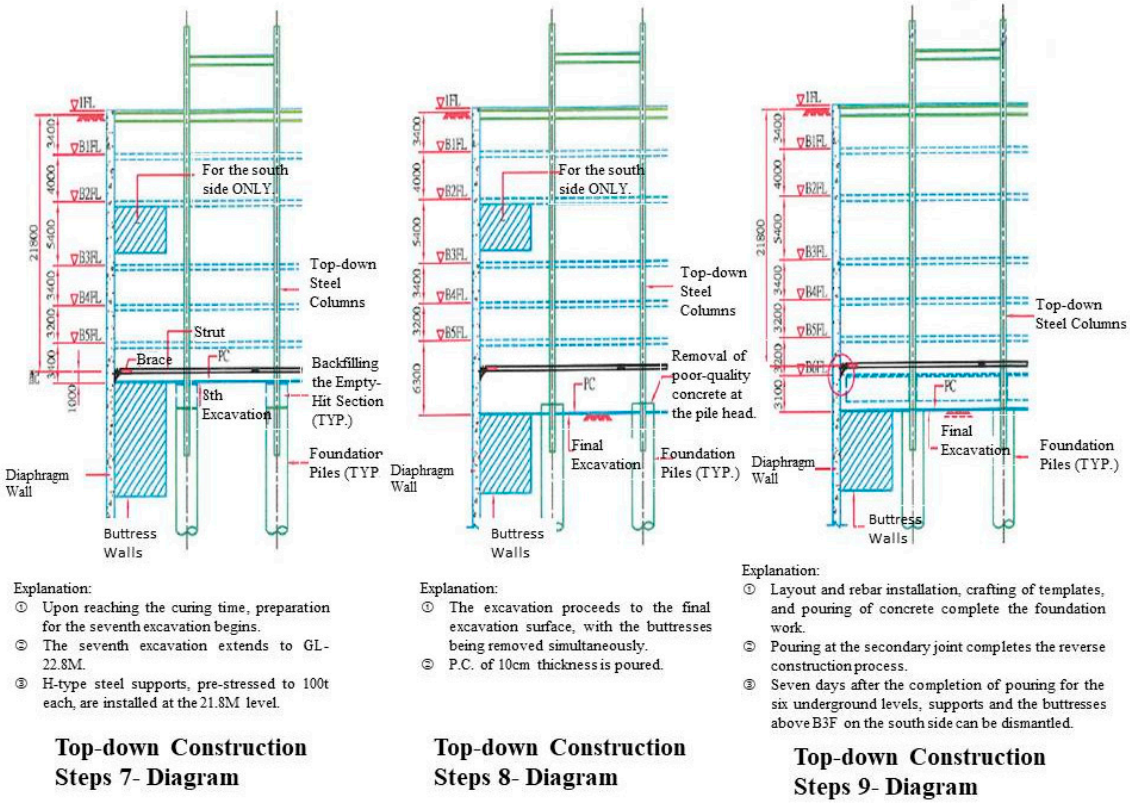
① Upon reaching the curing time, preparation for the fourth excavation commences.
② The fourth excavation extends to approximately 2.0M below B3F.
③ On the south side (adjacent to the rapid transit), the buttress is retained from B2FL to 1M above B3FL, while the rest is removed down to the excavation surface.
④ P.C. with a thickness of 10cm is poured.
⑤ After the layout, templates are crafted and, upon the completion of the rebar installation, the B2F concrete is poured.

Top-down Construction Steps 4- Diagram

FigureS17. Schematic Diagram of the Timing Steps for Removing Buttress Walls (Step 3 to Step 4)



FigureS18. Schematic Diagram of the Timing Steps for Removing Buttress Walls (Step 5 to Step 6)



FigureS19. Schematic Diagram of the Timing Steps for Removing Buttress Walls (Step 7 to Step 9)

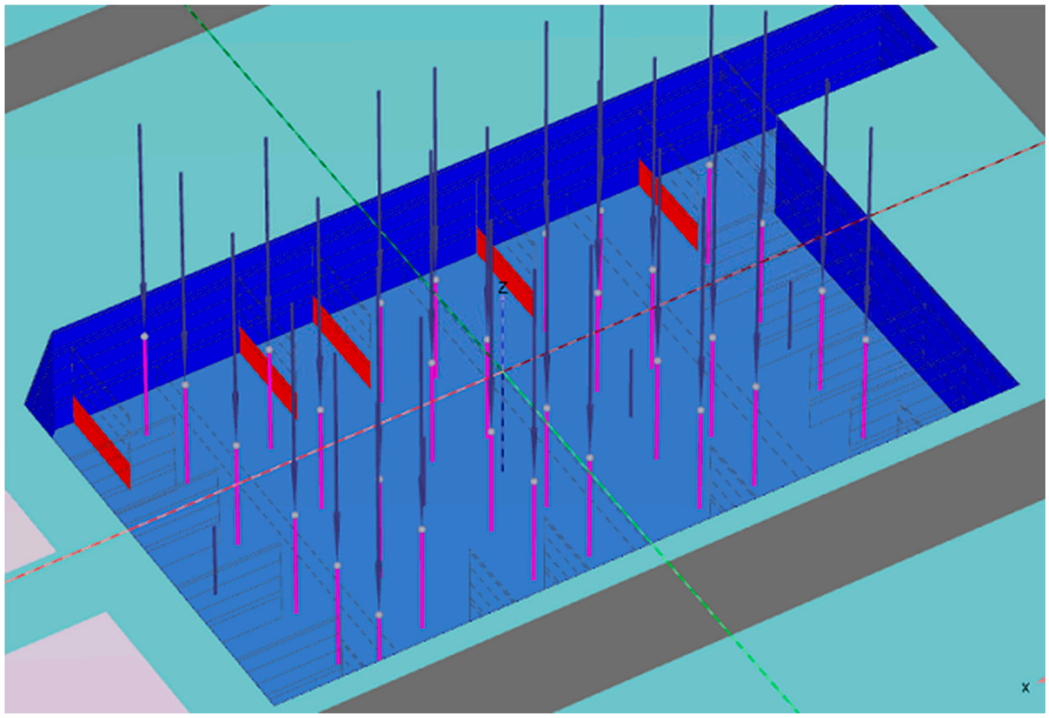


Figure S20. Plaxis 3D Simulation Diagram for Buttress Wall Removal Timing

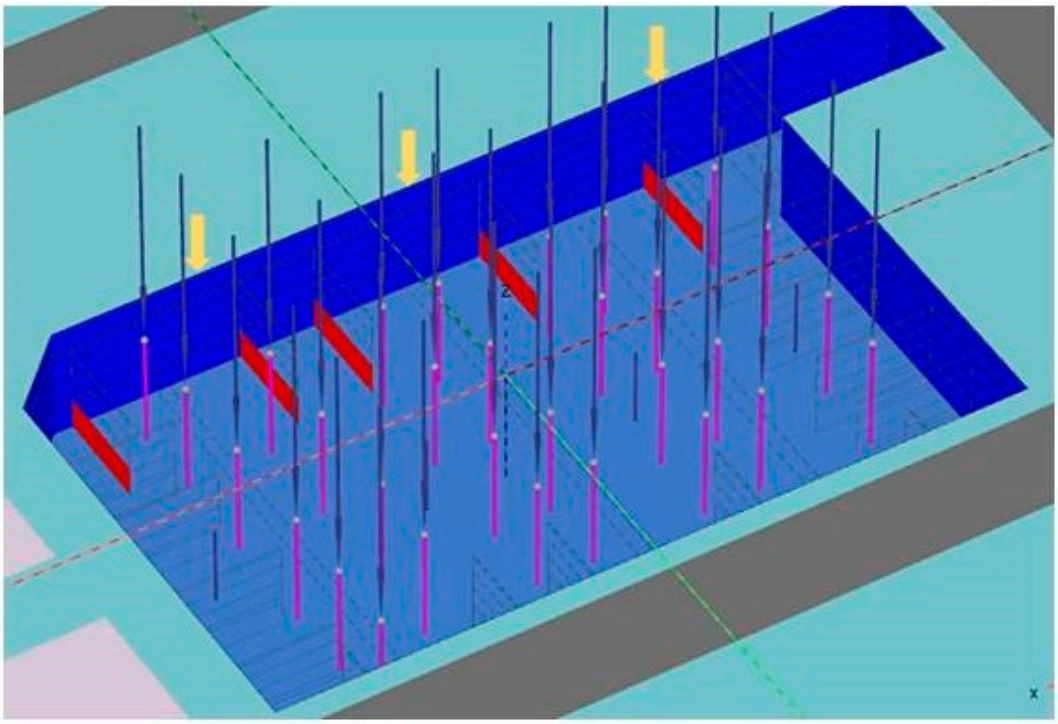


Figure S21. Plaxis 3D Analysis Location Diagram