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Effect of facing and construction sequence on the stability of reinforced soil wall

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ABSTRACT: A small-scale reinforced soil wall was constructed in a laboratory to investigate role of the wall facing and the effect of construction sequence on the wall. A full continuous facing wall and a block-type facing wall were introduced for test. These two different facing systems adapted different construction procedures. The model wall was built with geogrid reinforcement, sand, and facings on rigid surface. The model wall was instrumented with earth pressure gages, LVDTs, and strain gages. The experimental results have shown differences in wall behavior related to construction sequence and types of wall facing. It is found in this study that the reinforced soil wall system built with full continuous facing be the safest reinforced soil wall ever compared to the block-type facing wall. Thus, it is recommended that study for the wall system be necessary for further wide usage for the future.

1 INTRODUCTION

Recently, many types of reinforced soil wall with geogrid reinforcement and block facing have been proposed due to its simplicity of construction and economic construction procedure. However, wall deformations generated during the construction procedure are comparatively larger than those of conventional gravity retaining wall and excavated cut wall such as soil nailed wall (Jones, 1994). This is due to use of different construction procedure and construction materials. The reinforced soil wall is built usually from bottom to top. The soil nailed wall is built from top to bottom. Typically, the reinforced soil wall is vulnerable to deformations. In this study, a reinforced soil wall built with full continuous facing was investigated in order to check possibility of reducing wall deformation.

Cardoso and Lopes (1996) divided construction procedures of the reinforced soil structures into two typical types. The first one is the so-called common type of reinforced soil wall built from bottom to top with block-type facing, reinforcement and backfill soil. In this type of the wall, tension in the reinforcement is generated from the beginning of construction. On the other hand, construction of the other type of the wall may start with use of panel-type facing with aid of props in front of the wall first. After setting up the propped facing, the wall is backfilled and reinforced from bottom to top. Then the props are to be removed from the wall after backfilling. Therefore, the tension in the reinforcement is to be generated when the wall moves due to removal of the props. Different wall behavior can provide different pattern and amount of wall deformation.

In this study, a small-scale model wall reinforced with geogrid adapting different construction sequences was investigated in order to validate usage of full continuous facing wall for reducing wall deformation effectively compared to conventional reinforced soil wall.

2 DESIGN OF MODEL TEST

2.1 *Test apparatus and instrumentation*

A schematic diagram of the testing apparatus used for the tests is shown in Figure 1. The model wall was constructed by adapting two different construction sequences.

The testing apparatus consisted of external steel frames and internal soil retainer. The external steel frames include vertical and horizontal loading machines attached on them. The size of the external frames is 2.0m long, 3.0m high, and 0.8m wide. The soil retainer used for making the model wall to be filled with the Jumunjin sand was 1.2m long, 0.8m high and 0.8m wide. The bottom of the soil retainer was rigid steel slab. The vertical load is applied to the wall by a 196kN capacity of linear servo motor and screw gear. Either a constant loading rate or a constant pressure system is available in this loading machine. Total displacements of the wall were monitored by five LVDTs as shown in Figure 2.

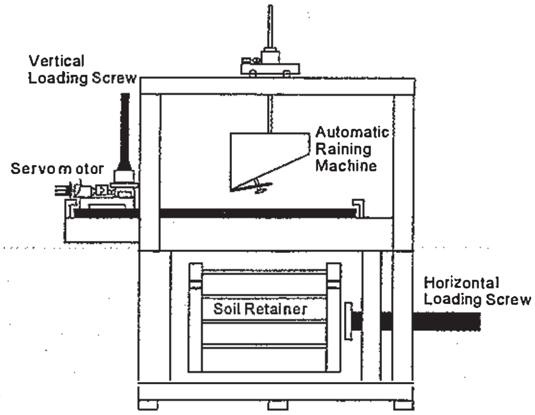


Figure 1. Test apparatus and loading system.

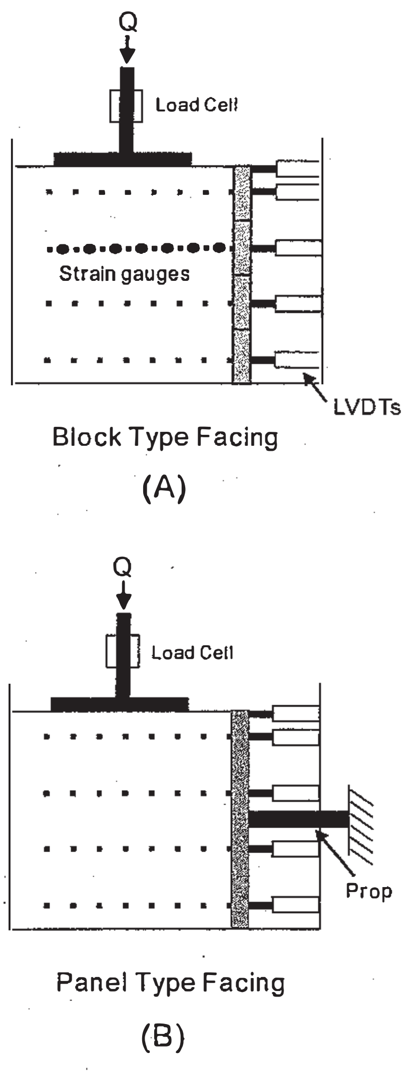


Figure 2. Sectional view of model walls: (a) block facing, (b) continuous full facing.

The vertical load that was applied to the model wall was measured by a load cell. Earth pressure gauges were also embedded behind the wall to monitor change in earth pressure in process of loading and wall deformation. Strain gauges were also attached on the surface of the reinforcement in order to monitor the generated tensile strains. The measured signals were transmitted to readout box and personal computer for analyzing and saving the data. The model wall was loaded vertically to failure. The failure of the wall was determined when the wall was deformed horizontally to 10% of the wall height (H=0.8m).

2.2 *Properties of backfill soil and reinforcement*

The soil used for the backfill of the model wall was selected as S. Korea's standard Jumunjin sand. Properties of the Jumunjin sand and of the reinforcement are shown in Table 1. The used reinforcement for all tests was obtained from commercial production (geogrid type). Dry Jumunjin sand was compacted to 77% of relative density by free falling method.

Table 1. Material properties of Jumunjin sand and geogrid reinforcement.

Jumunjin sand					Reinforcement		
G_s	γ_{max} (kN/m^3)	γ_{min} (kN/m^3)	D_r (%)	φ	Tensile Strength T_{max} (kN/m)	T^* (kN/m)	ε^{**} (%)
2.65	16.17	13.3	77	45	80	25	13

* T= tensile strength at 5% elongation of reinforcement;
** ε=elongation at failure of the reinforcement

2.3 *Design of model tests*

All tests were focused on investigation of effects of reinforcement length, facing types, and load intensity on the wall behavior, especially the wall deformation. The vertical load was applied to the wall after the wall completion. The variable parameters for loading were width of loading plate, location of loading plate, and loading intensities. The red data from earth pressure gauges were too irregular to be valuable data. Thus it was ousted. The used facings (0.05m thick) were made of recycled and pressed polyurethane board and have 5% of glass fiber. The size of the full continuous facing was 0.8m wide, 0.8m high and 0.05m thick. The size of the block facing was 0.8m wide, 0.2m high and 0.05m thick. The block facings were inter-connected using small rail and long hole made on the top and bottom of each facing board. However, each block facing moves freely by making the rail to have half-circular section. The reinforcements were connected to the facing using small steel hooks. Material characteristics of the facing are presented in Table 2. All tests were performed following the design parameters as shown in Table 3.

Table 2. Material characteristics of facing.

	Full cont. facing	Block facing
Young's modulus (kN/m^2)	6.27E6	6.27E6
Section area (m^2)	0.04	0.04
Moment of Inertia (m^4)	1.04E-5	N/A
Unit weight (kN/m^3)	5.88	5.88

Table 3. Design parameters for test.

Facing and reinforcement conditions			Loading conditions			
			Plate width (m)	Loading intensity (kN/m^2)		
Test no.	Facing type	Length (L)				
1	FHP	0.9H	0.6 (0.75H)	10.0	19.6	39.2
2	FHP	0.7H	0.6 (0.75H)	10.0	19.6	39.2
3	FHP	0.7H	0.3 (0.37H)	10.0	19.6	39.2
4	FHP	0.5H	0.6 (0.75H)	10.0	19.6	39.2
5	BP	0.9H	0.6 (0.75H)	10.0	19.6	39.2
6	BP	0.7H	0.6 (0.75H)	10.0	19.6	39.2
7	BP	0.7H	0.3 (0.37H)	10.0	19.6	39.2
8	BP	0.5H	0.6 (0.75H)	10.0	19.6	39.2

N.B) FHP: full continuous facing, BP: Block facing, H: wall height (H=0.8m)

The model wall was constructed by following two different construction sequences independently. The block-facing wall was constructed built from bottom to top with block-facing, extensible reinforcement and backfill soil. On the other hand, construction of the continuous full facing wall started with setting full facings and props up first. After setting the propped facing up, the wall is backfilled and reinforced from bottom to top. Then the props are to be removed from the wall after backfilling. Thus the construction sequences adapted in this test were drastically different in these two wall types. In the continuous full facing wall, the facing was not hinged at the bottom of the wall resting on a rigid foundation. Therefore the wall facing moves freely at the bottom of the wall.

3 ANALYSIS OF TEST RESULTS

3.1 *Wall deflections*

Figure 3. illustrates how the horizontal wall deflections are different with changing the types of wall facing and the construction sequences. The horizontal wall deflections generated in the block-facing wall were 10 to 17 times those of the full continuous facing wall immediately after the wall construction was completed. Furthermore, the horizontal wall deflections of block facing wall were 4 to 5.7 times those of the full continuous facing wall when the

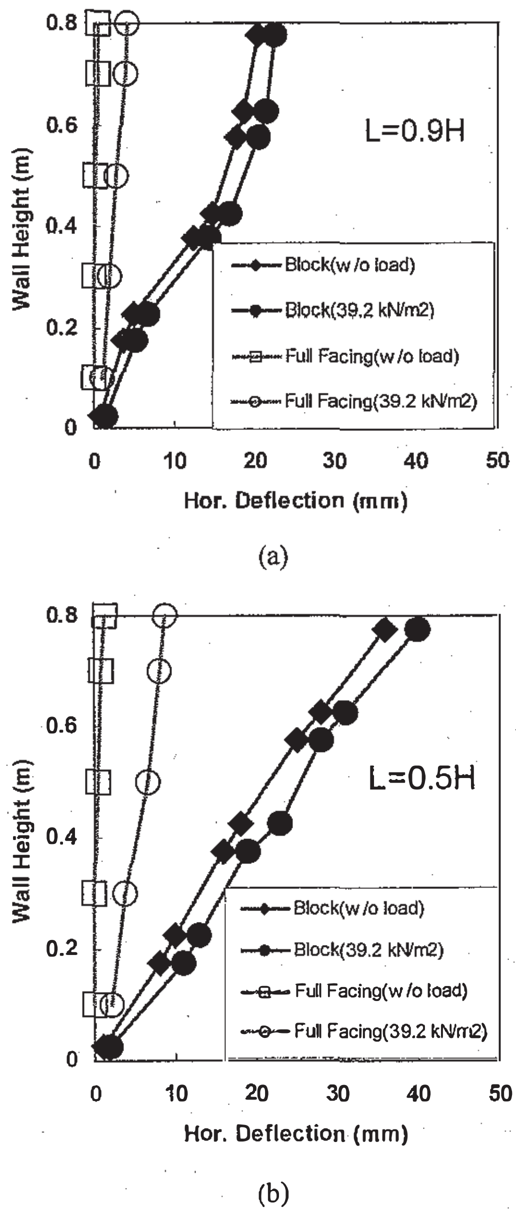


Figure 3. Comparison of horizontal wall deflections: (a) L=0.9H, (b) L=0.5H.

vertical load was applied up to 39.2 kN/m². Thus, difference in wall deflections between the two types of wall facing decreased when the vertical load applied. Nevertheless, the horizontal wall deflections of the full continuous facing were still smaller than those of the block-facing wall. Generated additional net wall deflections measured after the vertical loading applied increased similar proportion in both facing walls. However, the net increase of wall deflection in the block-facing wall tended to increase relatively smaller than those of the full continuous facing wall. This may be due to enough generation of wall deflection during wall construction when in case of the block facing wall.

3.2 *Tensilforce distribution in reinforcement*

The typical generated tensile forces in the reinforcement are shown in Figure 4. to Figure 7. for block facing and full continuous facing, respectively. Intensities of vertical loads were varied from 9.8 kN/m² to 39.2 kN/m² and were applied to top of the wall. As shown in the figures, the generated tensile forces in the reinforcement of the block facing wall were generally greater than those in the reinforcement of the full continuous facing wall. In the full continuous facing wall, the generated tensile forces in upper (two) reinforcement were greater than those in lower (two) reinforcement and tended to decrease with depth. In addition, in case of the full continuous facing wall, the maximum tension was found in reinforcement length (L) of 0.7H (not shown here). The generated tension in the reinforcement of the full continuous facing wall increased relatively very small when the wall was vertically loaded after the pros were removed, compared to the block-facing wall. On the other hand, the generated tensile forces in the block-facing wall were larger in lower reinforcement than those of upper reinforcement. In addition the maximum tensile forces in each reinforcements of the block-facing wall represented greater values in middle row of reinforcements than the upper most and lower most reinforcement. This may be due to the differences in mode of wall movement: the block facing wall moves in horizontal translation mode, but the full facing wall moves in rotational mode mostly.

In case of the full continuous facing wall, the locus of maximum tensile force in the reinforcements tended to be generated close to the facing rather than the Rankine failure surface when the reinforcement length (L) was longer than 0.7H.

4 SUMMARY AND CONCLUSIONS

This study has presented positive possibilities of reducing wall deflection when the reinforced soil wall is equipped with full continuous facing. In this study,

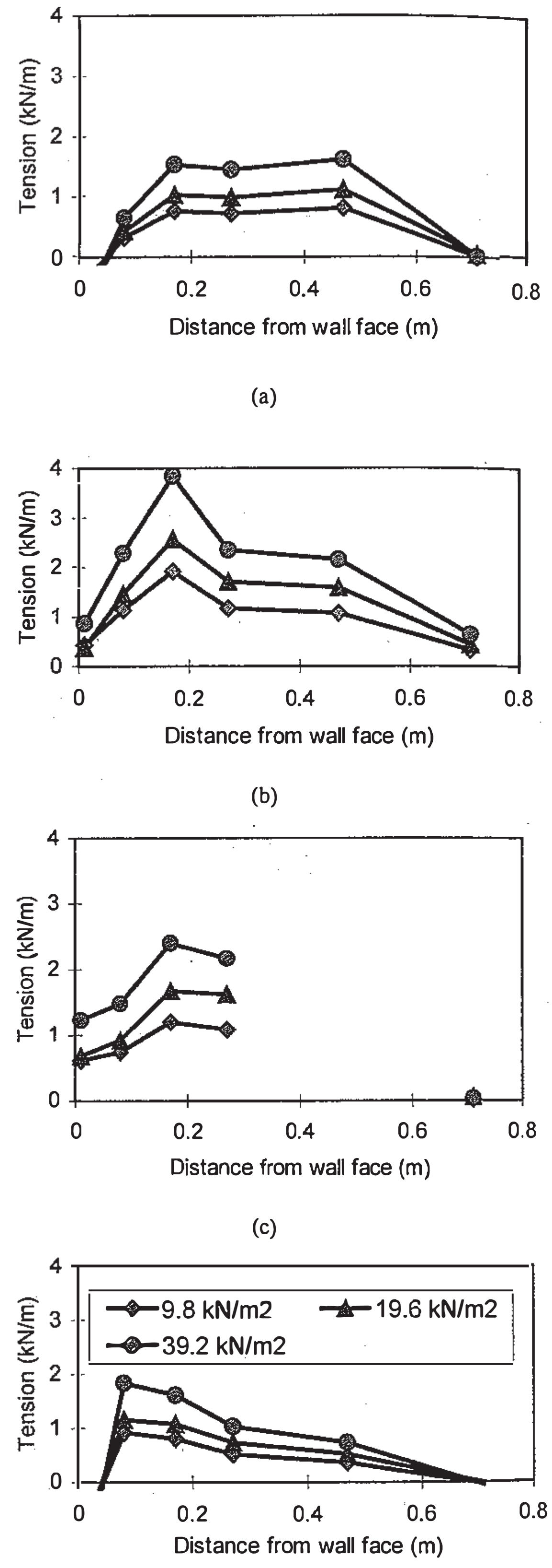


Figure 4. Typical generated tensile force distribution in case of block facing: (a) row 1 (top) to (b) row 4 (bottom).

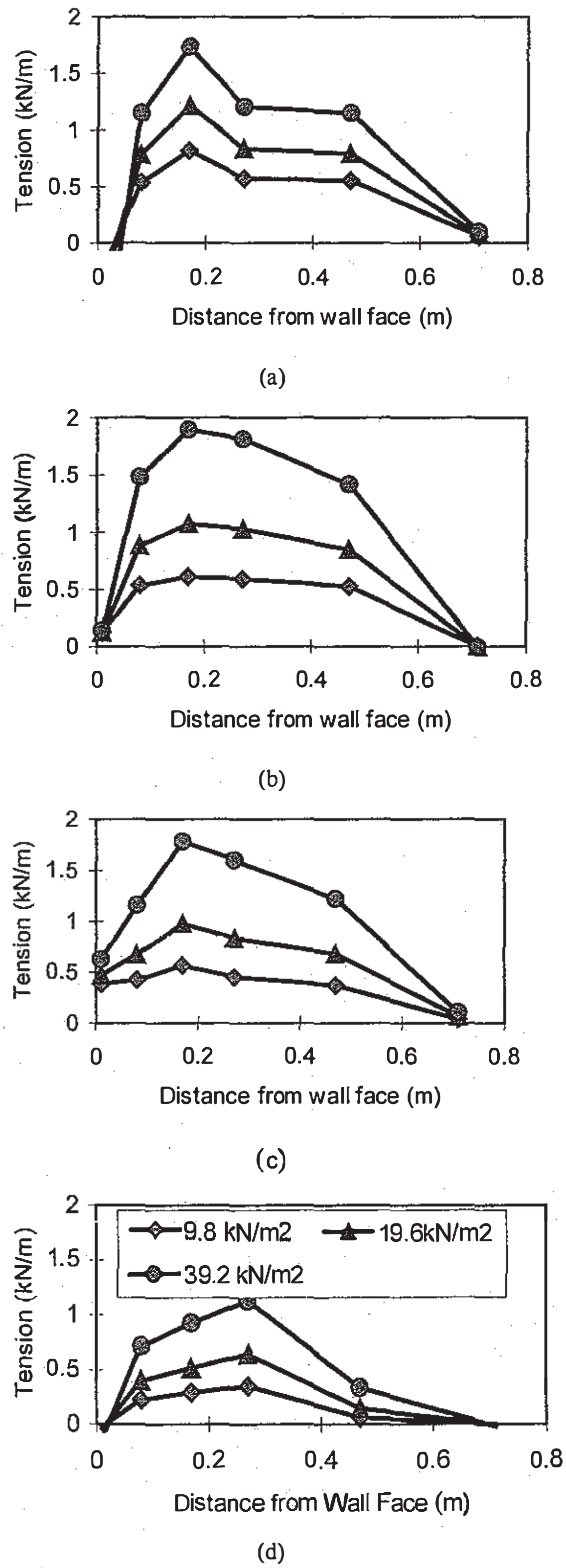


Figure 5. Typical generated tensile force distribution in case of continuous full facing: (a) row 1 to (b) row 4.

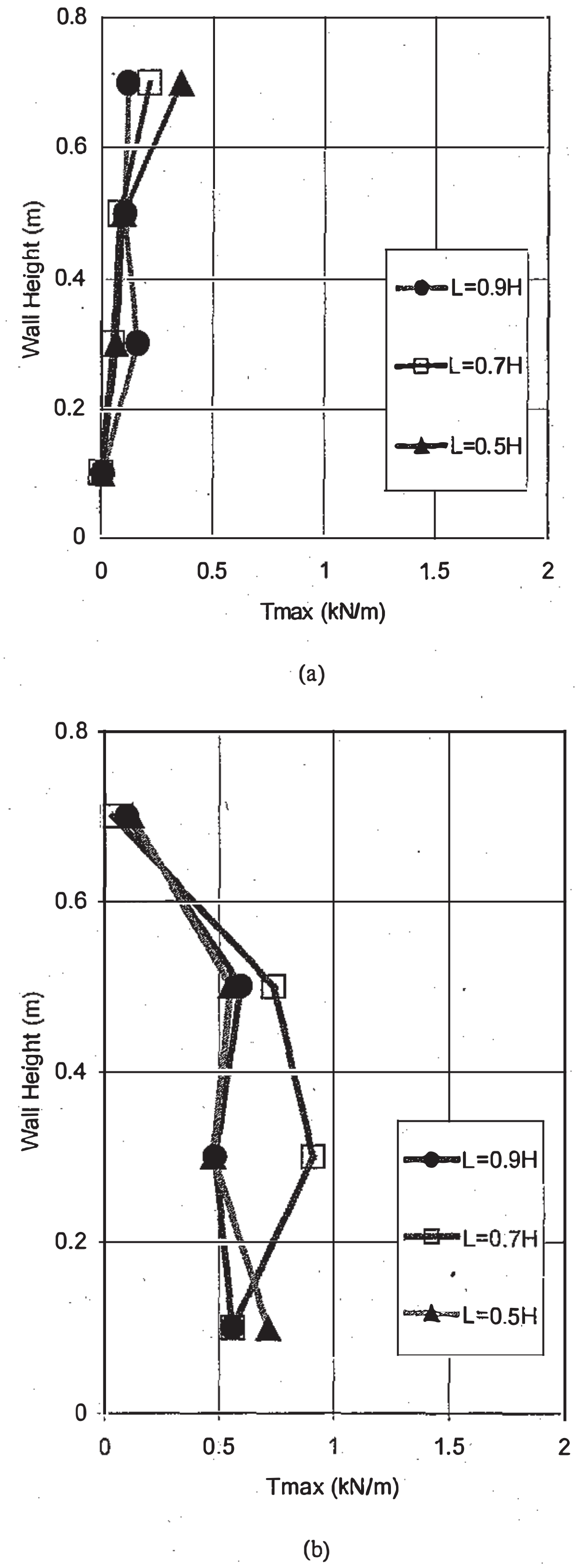
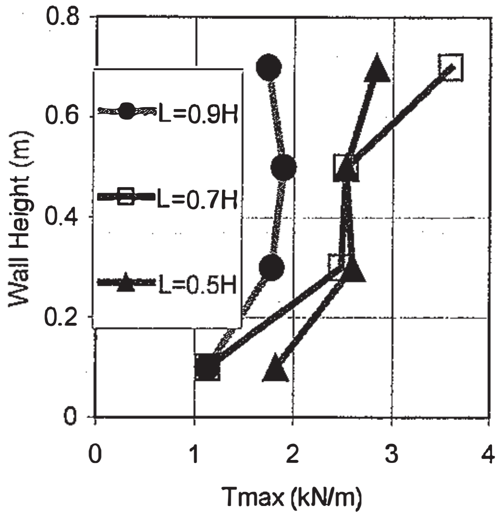
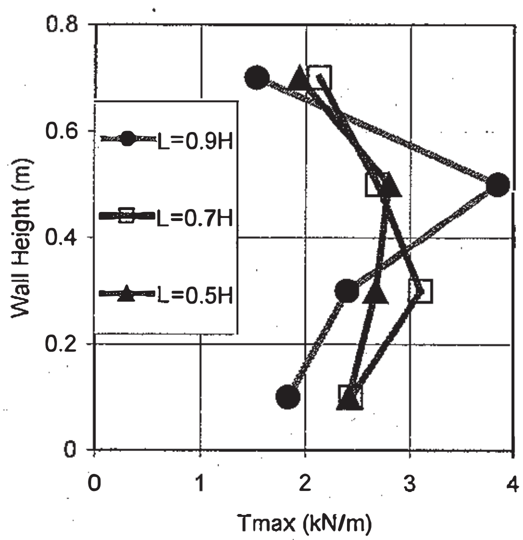


Figure 6. Comparison of maximum tensile force generated in reinforcement after completion of wall construction (without loading): (a) full continuous facing, (b) block facing.



(a)



(b)

Figure 7. Comparison of maximum tensile force generated in reinforcement after vertical loading: (a) full continuous facing, (b) block facing.

small-scale reinforced soil wall was constructed in a laboratory to investigate role of the wall facing and the effect of construction sequence on the wall. A full continuous facing wall and a block-type facing wall were introduced for test. These two different facing systems adapted different construction procedures. The model wall was built with geogrid reinforcement, sand, and facings on rigid surface. The model wall was instrumented with earth pressure gages, LVDTs, and strain gages. It is found in this study that the reinforced soil wall system built with full continuous facing be the safest reinforced soil wall ever compared to the block type facing wall since it can reduce wall deflection drastically compared to the conventional block-facing wall. Thus, it is recommended that study for the wall system, for example, full size of the full continuous facing wall, be necessary for further wide usage for the future.

5 ACKNOWLEDGEMENTS

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REFERENCES

Cardoso, A.S. and Lopes, M.L. (1996) The influence of the construction method on the behavior of geosynthetic reinforced walls-a numerical study, *Proc. The Int. Symp. On Earth reinforcement*, Kyushu, Japan, 351-355

Jones, C.J.F.P. (1994) Economic construction of reinforced soil structures, *Proc. Recent Case Histories of Permanent Geosynthetic-Reinfroced Soil Retaining Walls*, Ed. Tatsuoka and Leshchinsky, Balkema, Rotterdam, 103-115

Rowe, R.K. and Ho, S.K.(1997) Continuous panel reinforced soil walls on rigid founations, *J. Geotech. and Geoenv. Eng.*, Vol. 123, No. 10, ASCE, 912-920

Simac, P.E. et al. (1997) Segmental retaining walls, *NCMA Design Manual*, 2nd. Ed.

Tatsuoka, F. (1992) Roles of facing rigidity in soil reinforcement, *Key Note Lecture, Proc. The Int. Symp. On Earth Reinforcement*, Kyushu, Japan.