Geosynthetics, J. Kuwano & J. Koseki (eds)

Lessons from construction of geosynthetic-reinforced soil retaining walls having full-height rigid facing for the last 10 years

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ABSTRACT: The Railway Technical Research Institute, Japan originally developed geosynthetics and the geosynthetic-reinforced soil retaining wall with full-height rigid facing in late 1980s'. During its development, model tests as well as prototype tests were conducted, through which, the design method for practical use of *geosynthetic-reinforced soil retaining wall* (here in after referred to as "GRS-RW") was established. At the initial stage of development of GRS-RW, it was mainly used for expansion of platforms of railway stations as well as to sliding lines of railways, and GRS-RW was gradually begun to be applied to the trunk lines of the railways as well, ensuring its reliability as the structure for use of railways. Even in Kobe earthquake in 1995, GRS-RW proved that it has an excellent seismic stability against earthquakes compared to the conventional retaining wall, although GRS-RW received several light damages during the earthquakes, which were found not at all fatal to GRS-RW. Through this experience, GRS-RW has gradually been applied as the embankment structure not only to the conventional lines of Japan Railway (JR) and the Shinkansen Lines but also to the construction of roads in Japan.

In this paper, reflecting the past 10 years' experiences in construction of GRS-RW, existing problems with GRS-RW and future problems to be solved are discussed below, introducing several experiments obtained through construction of GRS-RW.

1 INTRODUCTIUON

It has been more than twenty 20 years since the development of the geosynthetics with relatively short and flat shape, and the full-height reinforced rigid soil retaining wall. In 1991, 64 companies, consisting mainly of general contractors, gathered. There, GRS-RW was named as Reinforced Road with Rigid Facing Construction System (hereinafter referred to as "RRRCS"). And an association named RRR Construction System was established in 1991 with the purpose of further expansion and development of RRRCS. With this arrangement, application of GRS-RW to railways as well to roads has steadily been increasing.

In Kobe earthquake in 1995, GRS-RW proved its excellent seismic stability against earthquakes. With this experience, application of GRS-RW not only to the conventional and Shinkansen Lines but also to the roads construction has been rapidly increasing. At present, the evaluation as well as the design method for big earthquakes, i.e., L_2 (level 2 earthquakes) has been established, and more than 480 construction works by use of GRS-RW have been executed, and its total construction quantity in length has reached 80 km.

2 FEATURE OF THE GRS-RW

The main feature of GRS-RW is that, it is combined with geosynthetics and full-height rigid facing. Figure 1 shows general view of GRS-RW. And Fig. 2 shows general construction procedures of GRS-RW,

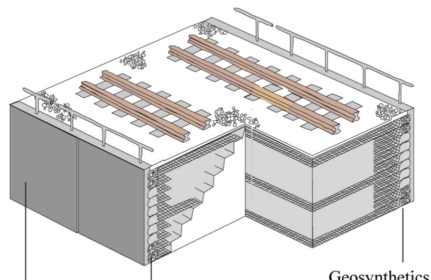

Figure 1. General view of GRS-RW.

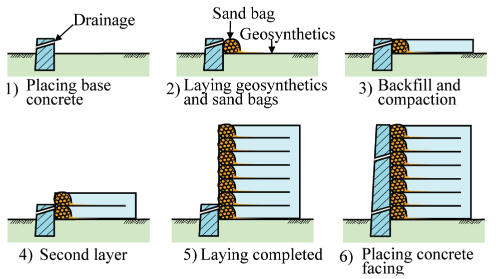

Figure 2. General construction procedures of GRS-RW.

which include: (1) laying the reinforcing materials (geosynthetics), (2) putting temporary counter-weighting materials (gabions (sand bags) or welded wire nets) to assist self-standing of the reinforced embankment until the concrete walls are constructed, and covering them with the reinforcing materials (geosynthetics), (3) repeating these procedures until we reach the required height of the embankment, letting the embankment reach its allowable deformation, and (4) placing the cast-in concrete to cover the reinforcing materials (geosynthetics) together with the temporary counter-weighting materials to form GRS-RW.

In the design of GRS-RW, following three (3) technical issues are studied.

(1) Study on inner stability of the reinforcing materials with respect to its strength and required length to decide the appropriate arrangement of the reinforcing materials.
(2) Study and check for the stresses acting on GRS-RW caused by earth pressure to decide the quantity and quality of concrete to be placed and the required reinforcing bar arrangement.
(3) External stability study on the total stability of GRS-RW, including the study on the foundation ground, whether it should be improved or not.

Other merits (features) of GRS-RW, which are brought mainly from its structural features of rigid combination of reinforcing materials with GRS-RW, are summarized below.

(1) As already described above, GRS-RW is constructed step-wisely, placing the cast-in concrete, to form full-height rigid facing walls after construction of the reinforced embankment, letting the reinforced embankment reach its allowable deformation. Accordingly, if we follow this construction method, we can allow deformation of the reinforced embankment to the technically acceptable level, which may not be achieved if we follow other reinforced embankment methods, in which walls and backfilling embankment are simultaneously constructed. This suggests that if we follow the proposed construction method, we can take flexible countermeasures against the deformation of foundation ground as well as against the deformation due to rolling compaction. These merits allow us less improvement in foundation ground; even in the case we need it. As a result, the proposed construction method brings us economical merit of reduction in construction cost as well.

(2) Another feature of this construction method is that GRS-RW and reinforced materials are rigidly combined each other, forming a solid body. Due to this, GRS-RW constructed following the proposed construction method, can resist the heavy loads acting on GRS-RW by all the reinforced materials. Thus, for example, GRS-RW can directly support such heavy loads as foundation of electric poles of railways and lighting facilities of roads etc (refer to Fig. 4).

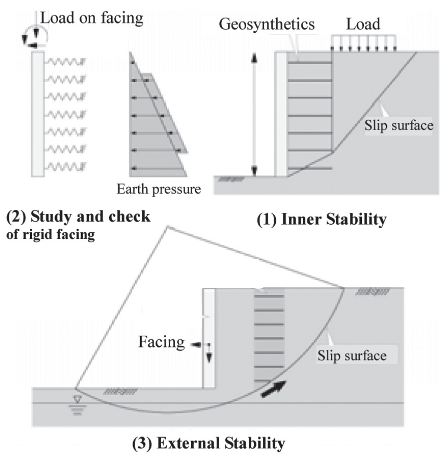

Figure 3. Outlines the above-stated 3 studies.

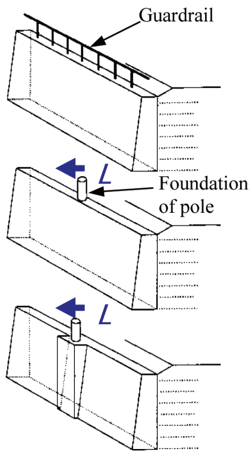

Figure 4. Merits of continuous rigid facing.

3 SEVERAL EXAMPLES OF CONSTRUCTION WORKS MAKING USE OF THE FEATURE OF GRS-RW

(1) Example 1: Construction of GRS-RW, Allowing Settlement by Stage-wise Construction

This example has been taken from the construction works of Nagano Trains Base of Hokuriku Shinkansen The foundation ground at the construction site is very soft, and alluvial clay is deposited to the depth of about 30 meters. Especially, the clayey and humid soil layer with the N value of almost zero, having the depth of 5 to 10 meters in total, located directly below the surface layer, consists of very soft foundation ground with the void ratio of 5 and unit weigh of 12 kN/m^3. Under the above-stated site condition, the required embankment for the said base with the height of 2.0 meters was constructed by use of reinforced embankment materials, applying pre-loading embankment of 3.0 meters in height to accelerate the settlement of the embankment. Figure 5 shows standard cross-section of the embankment. Figure 6 shows several construction stages of the embankment, and Fig. 7 shows completed pre-loading embankment for acceleration of settlement of the embankment. Figure 8 shows the relationship between the measured settlement of the embankment and lapse of time obtained. As is seen form Fig. 8, the settlement of the embankment at its cross-sectional center reached as big as about 1.0 meter, and 0.5 meter even on the slope of the embankment.

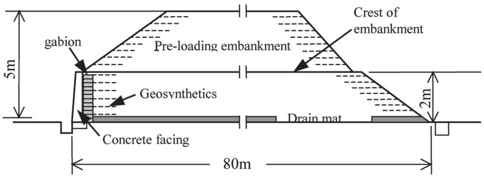

Figure 5. Standard cross-section of the embankment.

These results suggest that it is possible to construct GRS-RW even on the soft foundation ground without serious problems, utilizing the merit of step-wise construction, by placing the cast-in concrete to form rigid full-height walls, after deformation of the reinforced embankment has converged to its allowable limit.

(2) Example 2: Construction of Attached Structures (Soundproof Walls, Foundation of Electric Poles and Lighting Poles etc.) on GRS-RW

Figure 9 shows several pictures of electric poles, whose foundations are rigidly combined with GRS-RW. This kind of views can be commonly seen on the railways. However, here, we would like to introduce another example of GRS-RW, which was used for construction of a new tollgate on a highway, taking the advantages of GRS-RW introduced in Example 1 above. This construction work included raising the existing tollgate

Figure 6. Construction stages of the embankment.

Figure 7. Completed pre-loading embankment.

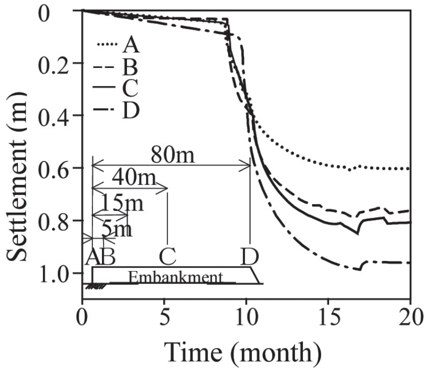

Figure 8. Settlement of the embankment.

of the highway, which was temporarily functioning as the terminal of the highway, whose location was decided according the originally planned route. Following the further extension plan of the existing highway, it was planned to raise the existing tollgate to the required height, allowing free traffic pass by use of the existing on-off ramps. And to keep the required space of the tollgate to be improved, construction of additional structure was needed. To fulfill this requirement, it was considered necessary to construct a cantilever structure by expanding the top portion of the existing walls (refer to Fig. 10). As a result, GRS-RW, which makes it possible to support the loads on the cantilever structure, was applied to satisfy the requirement. Figure 11 shows completed wall as well as its cantilever portion.

Figure 9. Foundation of pole combined with rigid acing.

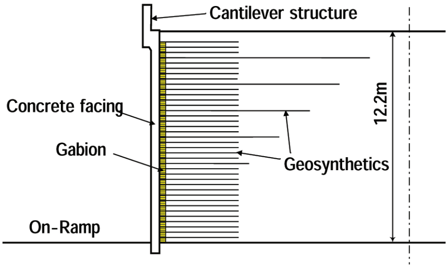

Figure 10. Cross section of the GRS-RW used for construction of a new tollgate on a highway.

Figure 11. Completed wall with cantilever portion.

4 IDENTIFIED PROBLEMS WITH GRS-RW AND PROBLEMS TO BE SOLVED IN THE FUTURE

As discussed above, construction of GRS-RW has steadily been increasing, because of its advanced technical features as explained above. In Kobe earthquake in 1995, no GRS-RW was collapsed during the earthquake, thus, GRS-RW proved its seismic stability against earthquakes. With this achievement, GRS-RW has been constructed in four hundreds eighty (480) different places in Japan, amounting to the total construction length of eighty (80) kilometers, during which, no collapse of GRS-RW and accidents have been observed. However, for further improvement of GRS-RW, we would like to summarize the existing problems with GRS-RW and problems to be solved in the future below.

(1) Presently, construction of GRS-RW is regulated by the technical specification that the reinforcing materials should be placed with the space of every 30 cm on the compacted soil layers. If we follow this specification, there will be a fear that we might have GRS-RW with excessive safety factor, which will result in excessive provision of the reinforcing materials. Accordingly, as the future problem with the reinforcing materials, it may be needed to pay more attention to its spacing (vertical height between the reinforcing materials) as well as to the design method of the reinforcing materials.

(2) Construction of GRS-RW essentially needs to place the cast-in concrete to make GRS-RW and the reinforcing materials into a solid body. Presently, construction of GRS-RW is usually started at the front portion of the reinforced embankment, which is constructed at the initial stage of the construction of GRS-RW. However, this construction procedure is not always economical, and sometimes it brings increase in construction cost of GRS-RW. Accordingly, instead of GRS-RW, use of pre-cast concrete walls is sometimes observed, and it contributes to reduce the construction cost to some extent. However, use of pre-cast concrete walls also requires placing the cast-in concrete to make the precast concrete wall and the reinforcing materials in to a solid body. These facts suggest that there exists further need of improvement in construction of GRS-RW.

5 CONCLUSIONS

Construction of GRS-RW has steadily been increasing due mainly to the following two reasons, i.e., (1) it can be constructed stage-wisely, i.e., it can be constructed after completion of the reinforced embankment, and (2) GRS-RW can support the loads of various attached structures.

It is important to make further improvement in design as well as in construction of GRS-RW, aiming at provision of cheaper and safer GRS-RW, maintaining its required performance as the structure.

REFERENCES

Kojima, K., Sakamoto, N., Tateyama, M. and Maruyama, O. “Geosynthetic-reinforced soil retaining wall using clay on a very soft ground for Hokuriku bullet train yard in Nagano”, IS-KYUSHU’96, 1996.11.

Tatsuoka, F. (1992). “Roles of facing rigidity in soil reinforcing”, Keynote Lecture, *Proc. Earth Reinforcement Practice, IS-Kyushu ’92* (Ochiai et al. eds.), Vol. II, pp. 831-870.

Tateyama, M., Tatsuoka, F., Koseki, J. and Horii K. (1995). “Damage to soil retaining walls for railway embankments during the Great Hanshin-Awaji Earthquake, Earthquake”, Geotechnical Engineering, Ishihara (ed.), Balkema, pp. 49-54, 1995.1.