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A search for reliability of the mechanism of geotextile-reinforced soil wall

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ABSTRACT: Recently, Geotextile Reinforced Soil Wall is widely constructed instead of conventional retaining walls such as gravity type concrete walls due to the establishment of design manuals and the development of geotextile materials and methods. In Japan, Public Works Research Institute established the design manual in 1992. However, there are still unknown factors on the design which should be solved. This paper points out the comparison between design assumption and actual behavior which include earth pressure on the facing, tension generated by the reinforced materials etc.

1 INTRODUCTION

The reinforcing function of reinforced soil walls is achieved by a combination of the tension effect of the reinforcing material, the resistance effect of the facing, and the virtual retaining wall effect of the monolithic reinforced zone. In other words, [1] embankment with a steep slope is supported by a facing in which the reinforcing material links the resistance forces required to maintain embankment in stable condition, and [2] the reinforcing material provides tensile resistance force based on the friction resistance in the stable embankment to guarantee balanced conditions. And [3] the soil reinforced by the reinforcing material is integrated as the virtual retaining wall, and it acts as the retaining soil for the backfill soil behind it. In line with this concept, Jones C.J.F.P. (1984)[1) and Jewell R.A. (1984) [2) proposed a design method for reinforced soil walls or steep slope reinforced embankments reinforced with a geogrid, and defined [1] and [2] as the internal stability, and [3] as the external stability. Assuming that it was necessary to evaluate the overall sliding stability including that of the foundation ground to provide external stability, the design method was completed from a rigid plastic body. However, their design methods do not necessarily fully apply in Japanese design criteria, for examples, their design methods have not considered stability during earthquakes, the application of the safety factor in various stability evaluations differs from that in Japan. Therefore some experiences have been conducted on these issues. Fig.1 shows the evaluation modes for design of reinforced soil wall. This figure also shows evaluation of the stability of reinforcing material near facing as internal stability (partial stability), and an overall stability evaluation of a case where the foundation ground is weak sandy ground. Many structures are constructed based on design work done in accordance with the evaluation modes explained above, but measurements of various experiments have confirmed that their design assumptions do not necessarily fully explain actual behavior. The subjects such as the comparison between design assumption and reality and effects of facing in geotextile reinforced wall are described as following based on by some experimental researches.

2 COMPARISON BETWEEN DESIGN ASSUMPTION AND REAL BEHAVIOR

In fact, reinforced soil structures require a certain degree of deformation in order that resistance forces act between the soil and the reinforcement material (in the case of a soil wall, the facing is included). In other words, reinforced soil walls are flexible structures which can maintain their stability while undergoing deformation because they can follow the deformation. Consequently, their characteristics differ from those of conventional concrete retaining walls; namely on the condition that the foundation ground remains stable in a case where the bearing ground under a reinforced soil wall is soft, it is

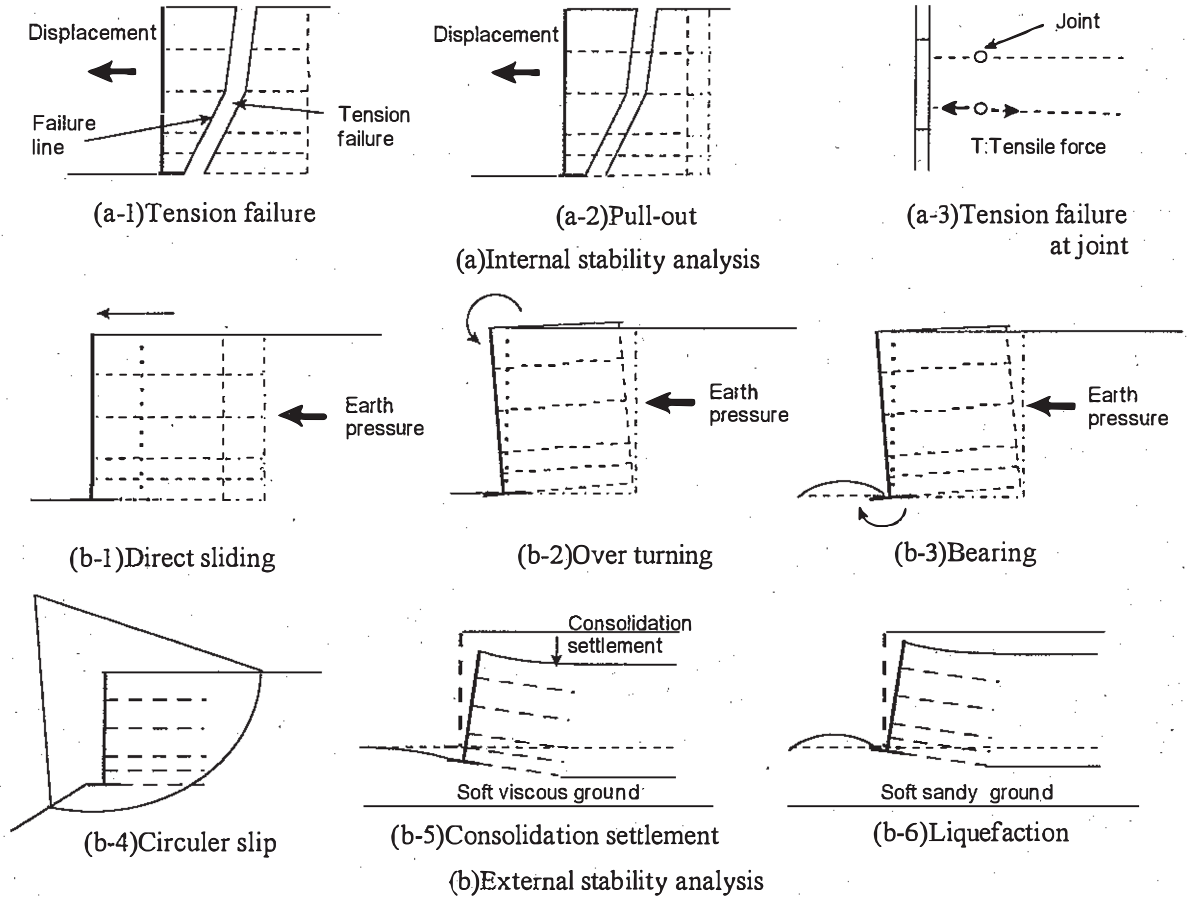
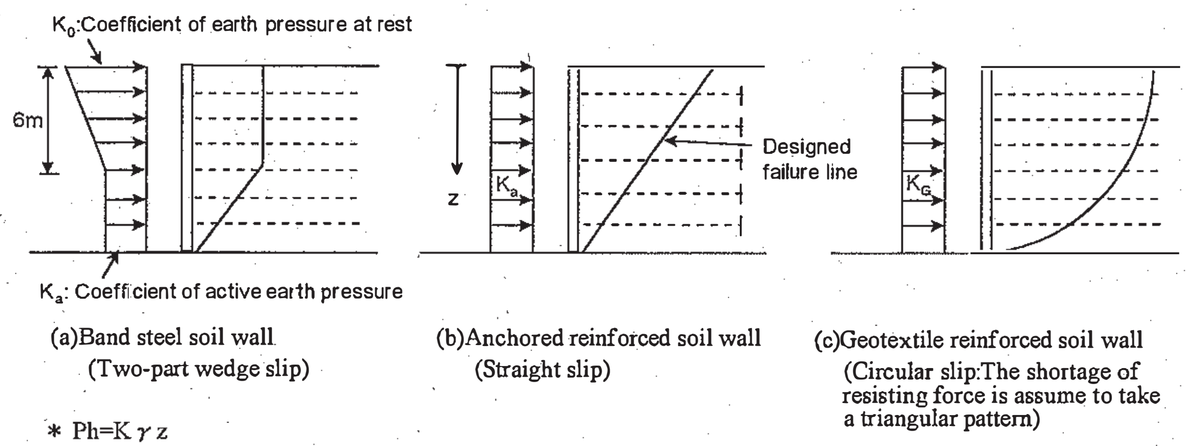


Fig.1 Failure patterns and analysis points on the design of reinforced soil wall



* $Ph=K\gamma z$

K: Coefficient of earth pressure, γ : Unit weight of backfill soil, z: Vertical distance from the top

Fig.2 Analysis concepts of required tensile strength

possible to construct a structure which remains stable while it follows deformation. This characteristic as a flexible structure causes actual behavior which differs from that assumed for design purposes explained in the above. The following is a summary of comparison between design assumption and its actual phenomena.

2.1 *Earth Pressure Acting on the Facing*

It is assumed that the earth pressure acting on the rear of the facing is distributed as shown in Fig.2 along with the slip surface. In the case of flexible facing on the other hand, the backfill soil reinforced close to the facing work is deformed and resistance

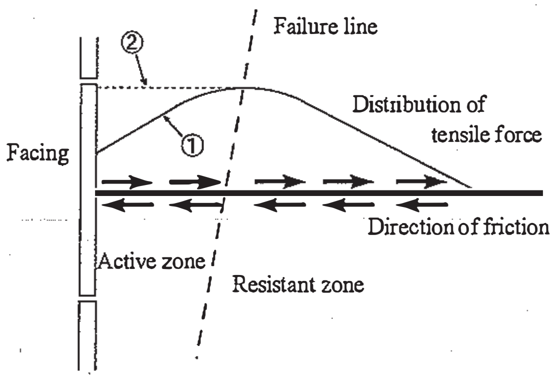


Fig.3 Tension distribution on the reinforcement

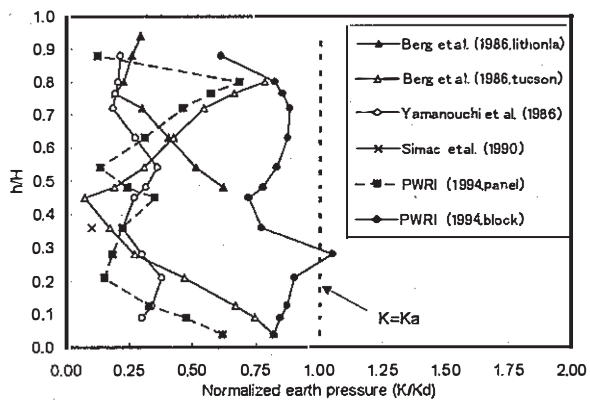


Fig.4 Results of horizontal earth pressure of wall

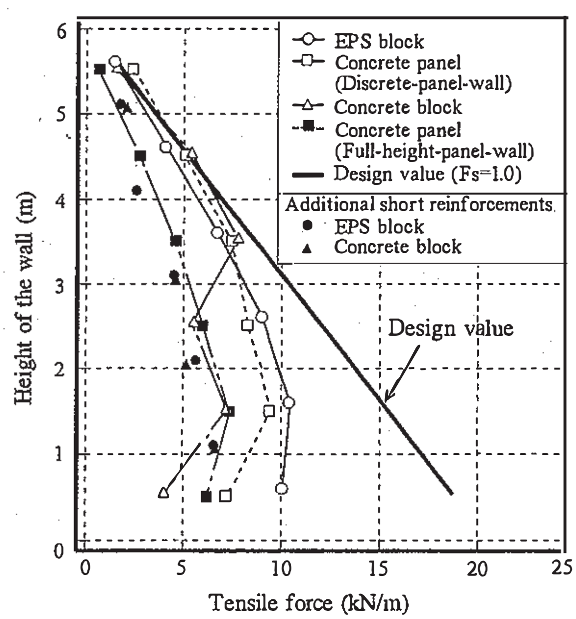


Fig.5 Distribution of maximum tensions experiments of geotextile reinforced soil walls(H=6m) at PWRI

force is generated by the reinforcing material. The tension distribution, which is presented schematically in Fig.3, results in a reduction of the earth pressure acting on the facing.

In this fig.3, when the friction stress in the active pressure area is distributed as in [1], the earth pressure is reduced, and when it is distributed as in [2], there is no friction stress between the soil and the reinforcing material, so the earth pressure is not reduced. Fig.4 represents the results of measurement results obtained in reinforced soil walls in demensionless earth pressure K/Ka vs h/H [3]

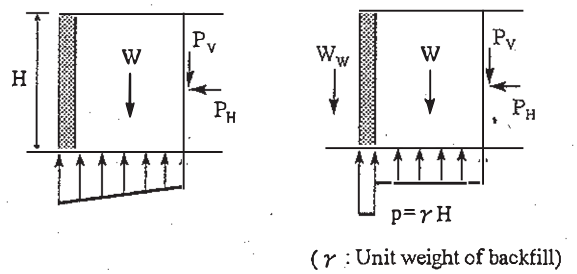
For design purposes, this earth pressure reduction mechanism is not sufficiently understood and is not used for safe side judgments right now.

2.2 *Tension Generated by the Reinforcing Material*

Fig.5 shows the distribution of tension of reinforcing material during a full-size experiment using a specimen with a height of 6 m at the Public Works Research Institute (hereinafter PWRI) [4]. In this experiment, a comparison was made of various facing categories: EPS, integrated concrete panels, divided concrete panels, and block type. In the design, the earth pressure acting on the facing was distributed in triangular form and the tension generated by the reinforcing material did, similarly, increase towards the bottom, but actual measurements have shown that the values of tension were either identical or smaller. The values of tension were particularly low towards the bottom.

2.3 *Subgrade Reaction and the Stability of the Bearing Ground*

The reinforced and integrated zone is assumed to have the same earth retaining effects as those provided by a gravity retaining wall, and ground reaction with the trapezoidal distribution shown in Fig.6 acted against the external force acting on it. Measurements of existing reinforced soil walls[5] and the experiment performed at PWRI explained in the above[4] have revealed that the distribution of subgrade reaction at the bottom surface of the reinforced zone is approximately the overburden pressure, and clearly indicate that large reaction force is generated at the bottom of the facing by the dead weight of the facing (Fig.7).



(a)Design assumption (b) Practical tendency

Fig.6 Assumption and practice of ground reaction

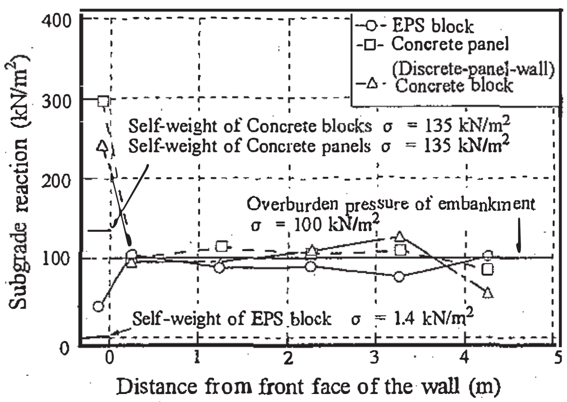


Fig.7 Distribution of subgrade reaction force (experiments of geotextile reinforced soil walls (H=6m) at PWRI)

In the design, the allowed bearing capacity was satisfied for this trapezoidal distribution ground reaction, but according to the results of a full scale reinforced soil wall on-site experiment using block type with a height of 8 m, the foundation ground consisted of relatively soft sandy soil at the surface and a soft clay layer deposited beneath the sand, conditions which do not satisfy bearing capacity conditions, but nevertheless, stability was clearly maintained. The value of the reaction force at the bottom edge of the facing was also greater than the dead weight of the facing as it was in the laboratory experiments (Fig.8).

Fig.9, Fig.10 and Fig.11 show the results of measurements of a full scale reinforced soil retaining wall conducted over a period of about 550 days. The results indicate that unlike an extremely stiff structure such as a concrete retaining wall, a reinforced soil wall will maintain stability while it deforms. It also suggests that as far as the overall stability including that of the foundation ground is concerned, because the main body of a reinforced soil wall is an embankment, it may be concluded that, as an embankment, it satisfies safety conditions based on its rotational slip.

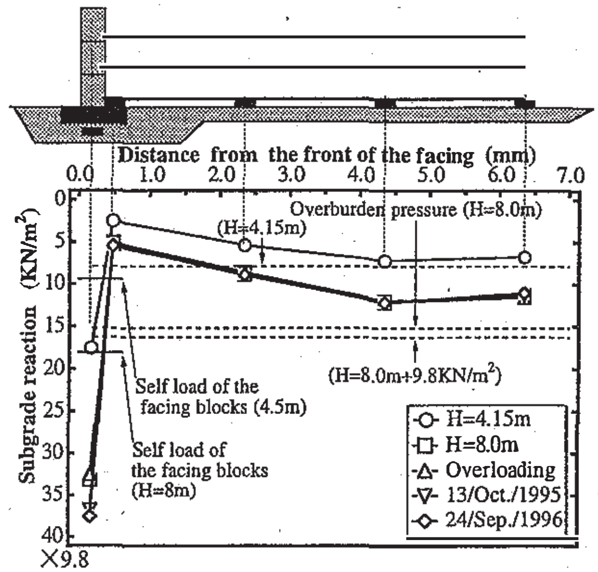


Fig.8 Distribution of ground reaction force (An experiment of geotextile reinforced soil walls (H=8m) at PWRI)

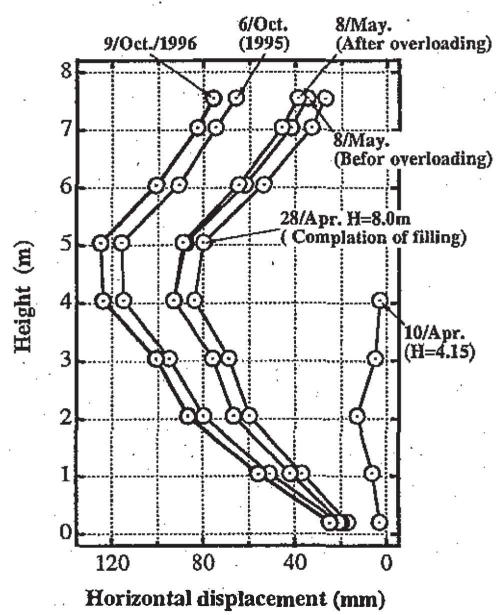


Fig.9 Distribution of horizontal displacement (An experiment of geotextile reinforced soil walls (H=8m) at PWRI)

3 EFFECTS OF THE FACING

In the current design method, it was assumed that the effects of the facing work of a reinforced soil wall included the prevention of leakage of the soil and support for the earth pressure acting on the facing. In contrast, Tatsuoka proposed that according to the

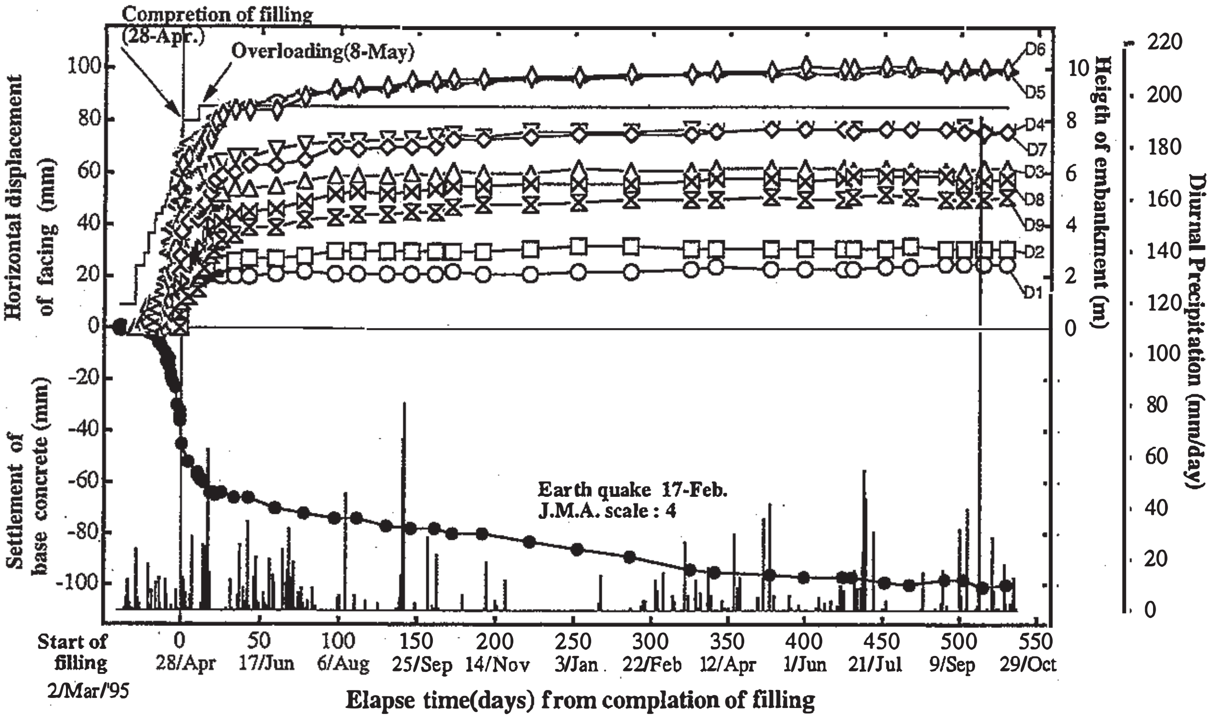


Fig.10 Horizontal displacement with Elapsed time
(An experiment of geotextile reinforced soil walls(H=8m) at PWRI)

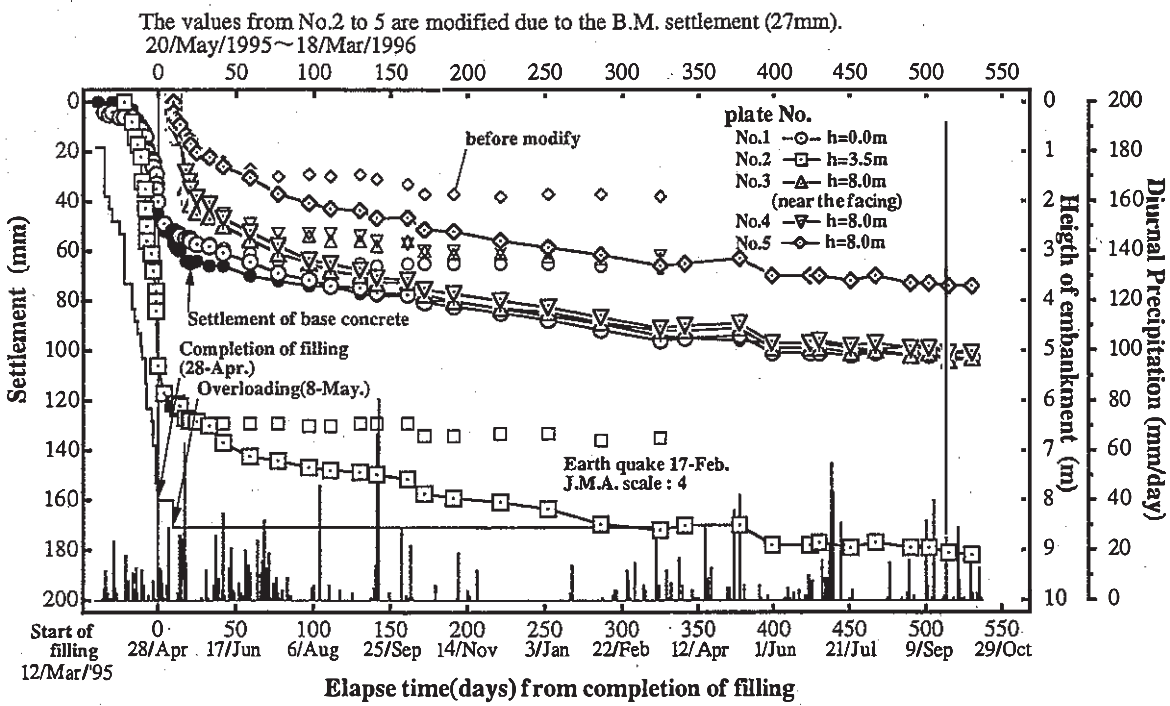


Fig.11 Settlement of embankment with elapsed time
(An experiment of geotextile reinforced soil walls(H=8m) at PWRI)

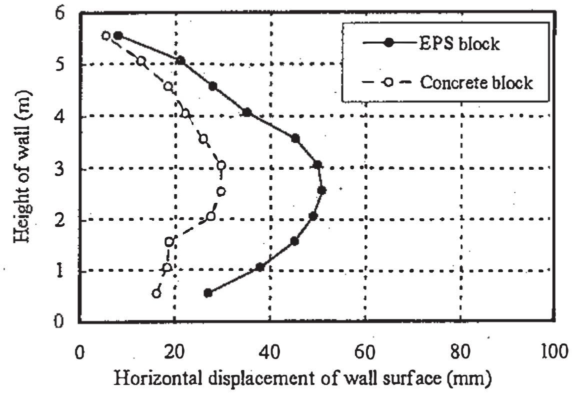


Fig. 12 Horizontal displacements of an EPS block and concrete block(experiments of geotextile reinforced soil walls (H=6m) at PWRI)

type of facing, the effects can be classified local rigidity, overall longitudinal rigidity, overall shearing rigidity, overall bending rigidity, and gravity comparison of the horizontal displacements of an EPS block and concrete block based on an experiment conducted by PWRI.

Although deformation was restricted by the facing, in case of EPS block the weight effect of the facing work was small regardless of the presence of longitudinal rigidity[4)]. And the tensile stress acting on the reinforcing material is shown to reach its maximum value near the facing. This trend has also been confirmed by a full scale experiments of reinforced soil wall using block facing.. And when designing a reinforced soil wall such as a block type wall, it is possible to reduce the tension acting on the reinforcing material by accounting for the weight resistance of the blocks and the friction resistance between the blocks. Similar proposals have been offered by Gotteland et al.[7)] (1993) and Leshchinsky[8)].

4 CONCLUSION

This paper is an outline focused on the reinforcement effect mechanism and design concepts of reinforced soil walls or reinforced embankments as geotextile reinforced soil structures. Based on numerous experiments, analyses, and on-site measurements, a design method has been created based on a concept of ultimate balance. But it has also been shown that this design method can not necessarily fully explain actual behavior.

While on one hand, real reinforced soil structures are flexible structures, one important question is how to predict the deformation, then control it through the design and execution stages. As the point of contact between the limit equilibrium method and the deformation analysis method, it is important to conduct model experiments which are able to analyzed by all researchers and designers who are concerned.

REFERENCES

1)Jones, C.J.F.P. 1984. *Design and construction methods. Proc. Symp. Polymer Grid Reinforcement*, ICE,London, pp. No.6.1,8p.

2)Jewell,R.A.,Paine,N. and Woods R.I. 1984. *Design Methods for Steep Reinforced Embankments, Symp. Polymer Grid Reinforcement*, ICE, London, pp.No.3.1,12p.

3)Yamanouchi,T., Fukuda,N. 1994.*12 State of the art of geosynthetic reinforced soil structures*, OXford & IBH Publ.Co.PVT.LTD. ed. Saxena, pp.305-335.

4)Tajiri,N.,Tsukada,Y.,Yamamoto,J.,Ochiai,Y.,Dobashi,K. 1995. *Comparison among full-scale failure experiments of geotextile reinforced soil walls with different types, 10th Geosynthetics symposium*, pp.37-46.

5)Nakajima,T.,Ooki,Y.,Oda,K.,Miyatake,H., Dobashi,K. 1995. *The fileld performance of a geotextile reinforced soil wall with concrete facings, 10th Geosynthetics symposium*, pp.47-56.

6)Tatsuoka,F. 1993. *Role of facing rigidity in soil reinforcing, Proc.Int.Symp. Earth Reinforcement Practice, Keynote Lecture, IS-KYUSHU'92, Fukuoka, Vol.2*, pp.831-870.

7)Gotteland,Ph., Grouc,J.P.,Jones, H.W.,Baraize, J. 1992. *Cellular walls associated with geosynthetics: A laboratory model study, IS-KYUSHU'92, Fukuoka, Vol.1*,pp.337-334.

8)Leshchinsky,D. 1993. *Geosynthetic reinforced steep slopes and walls: Effects of facing blocks, Proc. Geotech. Seminar Tokushima u.*, pp.95-133.