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# Geosynthetic-reinforced soil retaining wall using clay on a very soft ground for Hokuriku bullet train yard in Nagano

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ABSTRACT: Now in Nagano, the Japan Railway Construction Public Corporation is constructing the Hokuriku bullet train yard approximately about 100m wide and 2km long using Geosynthetic-Reinforced Soil Retaining Walls with rigid facing (GRS-RWs). This construction has two special features, of the retaining wall being built on a very soft ground, and clay being used as the backfill material. The results of analysis and execution of GRS-RWs are reported in this paper.

## 1.THE SITE OF NAGANO TRAIN YARD

Hokuriku bullet train line is under construction to link Tokyo with Nagano in about 1 and 1/2 hours. Hokuriku bullet train yard in Nagano is located 10km north-east of Nagano station. The position of train yard is shown in Fig.1, plan of the site in Fig.2, and cross-section of the embankment in Fig.3. The train yard is designed approximately 100m wide and 2km long. The embankment is designed 2m high from G.L. West side of this embankment was built by GRS-RWs and east side is slope . It is planned to expand from Nagano to Hokuriku area through the east side in future.

This train yard is on a very soft ground formed by Chikuma River. The geological map is shown in Fig.4 . This area is constituted of soft clay layer, over 20m deep, in Quartenary Alluvium deposit. We can see layers, from top to down: first Alluvium clay (Ac1 to Ac4: with peat and some thin sand layer), second Diluvial clay (Dc), and third Diluvial gravel(Dg). In these layers, soft(peat or clay) layers stretch 20m deep from G. L. The characters of this

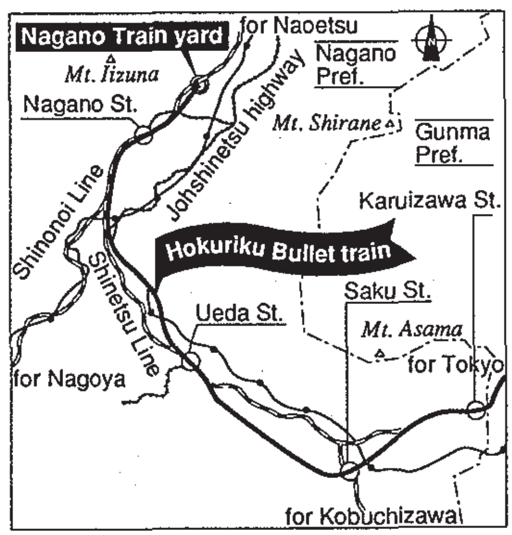


Fig.1 position of train yard

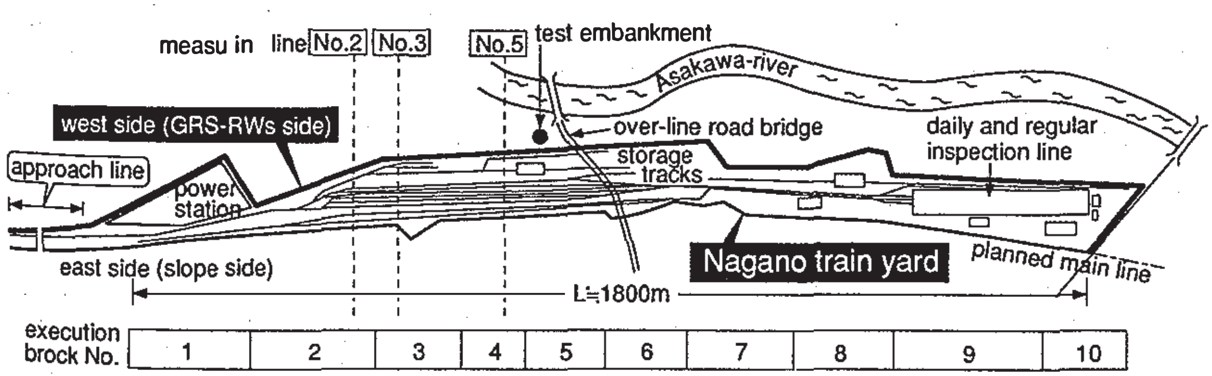


Fig.2 plan of the site

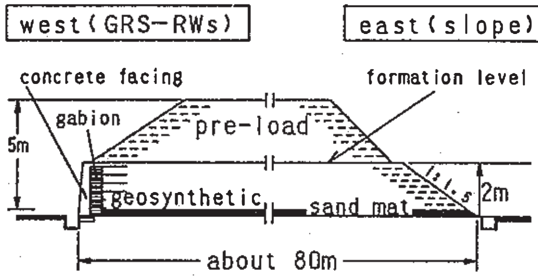

Fig.3 cross-section of the embankment

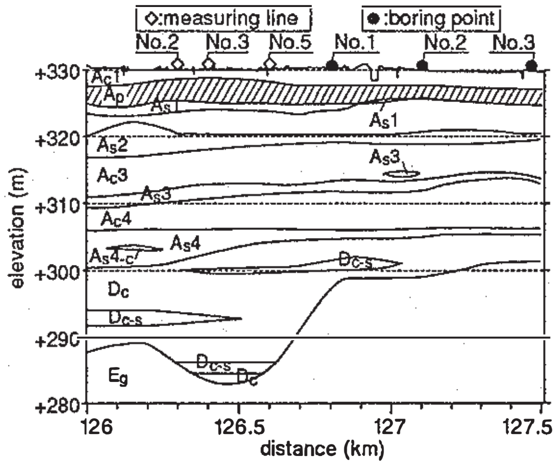

Fig.4 geological map

layer are N value: 0 to 3, natural water content: 40 to 200%, unconfined compressive strength: 20 to 80 $kN/m^2$, and random range of various values. We need to consider consolidation settlement.

## 2. THE CHARACTER OF GRS-RWS

We used much clay (weathered tuff) as the backfill materials for the first time in Japan to hold down pore water pressure of embankment. We selected as the reinforced materials composite geosynthetics, using clay as backfill materials is shown in Fig. 5. This geosynthetics form three layers, first and second layers are non-woven geosynthetics, second layer is woven geosynthetics. The geosynthetics give two effects i.e. reinforcement and drainage. Woven geosynthetics have reinforcement effect, and non-woven geosynthetics do drainage effect.

## 3. THE EXECUTION OF GRS-RWS

After investigation and planning, we knew that the area of train yard sank approximately 1m due to the embankment, and consolidation settlement took 6 to 17 months to attain 90%. So we examined consolidation settlement. Pre-loading method, and sand drain method are generally known as the method for consolidation settlement . As pre-loading method has an economic advantage and it can hasten consolidation of the peat layer, we preferred the pre-loading method.

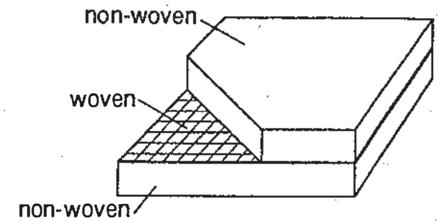

Fig.5 composite geosynthetics

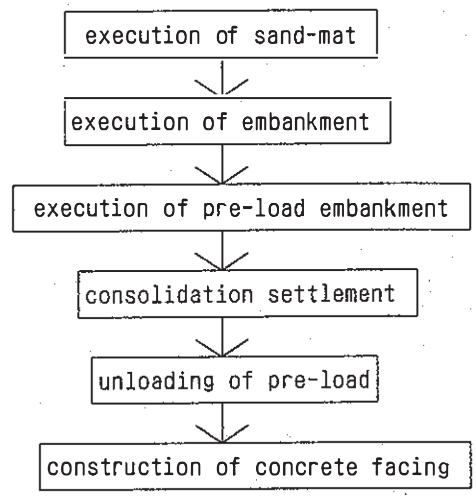

Fig.6 process of execution

We have been constructing the embankment, dividing it into 10 parts since December 1993. Fig.6 shows the process of execution. The site features are that we used accelerated consolidation taking time until consolidation settlement finished before executing concrete facing for reason of a very soft ground(see step 4 in this process).

In Fig.7 is shown execution at the site and Fig.8,9 are both views of finished embankment and pre-load embankment, but here we do not execute the concrete facing. At first, we executed the sand-mat before the embankment and at center of the embankment we used the rock waste to improve drainage of the ground and stability of truck because this site was a very soft ground . Cross-section of the GRS-RWs is shown in Fig.10. The geosynthetics 1.5m long and 0.3m high are used, and long geosynthetics are used in the fifth layer up to internal friction angle line. We executed 2.5m high GRS-RWs considering settlement and the pre-loading embankment 2.5m high, slope rate: 1:1.5. Therefore total height of the embankment was 5.0m. Reinforced concrete wall as retaining wall with rigid facing, is to be built after removing pre-loading embankment and achieving final settlement.

## 4. RESULT OF MEASURING

We set 15 measuring lines every 100m for execution management. We showed measured values of the measuring line No.3 mainly. But we didn't

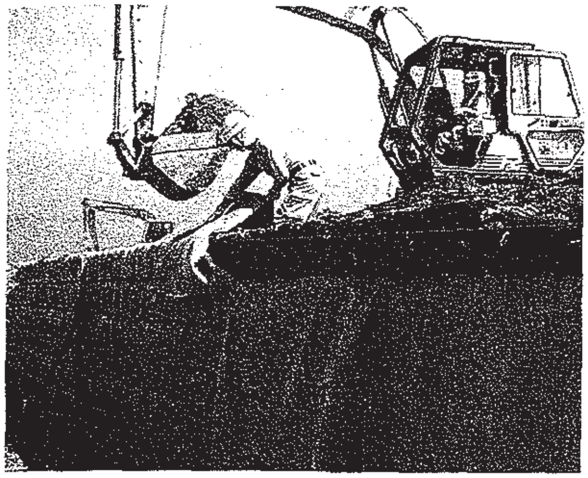

Fig.7 execution of GRS-RWs

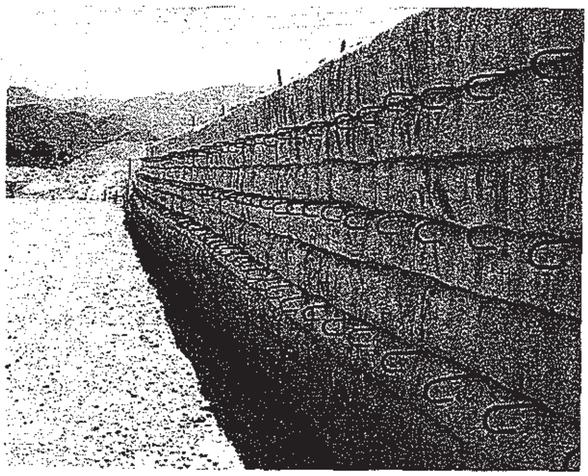

Fig.8 view of finished embankment and pre-load embankment

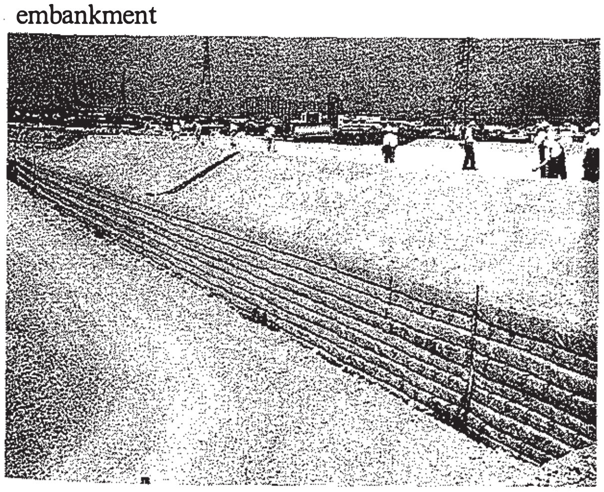

Fig.9 view of finished embankment and pre-load embankment

measure horizontal displacement on this line, and we showed only horizontal displacement on the measuring line No.5. Settlement of the ground surface on the measuring line No.3 is shown in Fig.11.

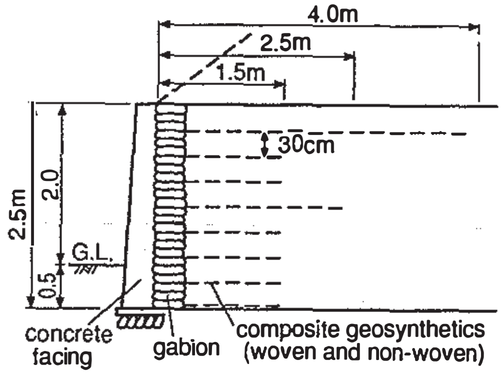


Fig.10 cross-section of GRS-RWs

At the center of the embankment approximately 1m consolidation settlement occurred in about 6 months. Settlement progressed faster than forecast. And we can see a decrease of settlement after removing the charge embankment. Settlement of each layer curve on the measuring line No.3 is shown in Fig.12. We can see that settlement goes as fast as settlement of Ap layer, accounting for large part of consolidation settlement. Cross-section of settlement on measuring line No.3 is shown in Fig.13. Horizontal displacement of GRS-RWs end on the measuring line No.5 is shown in Fig.14. We can see settlement range from 0.35 to 1.0m but the ground surface shifts horizontally little and the point at 2m to 3m deep from G.L. shifts as much as 0.15m. It seems that lateral flow of GRS-RWs are restricted by the geosynthetics of the bottom layer.

## 5. F. E. ANALYSIS

In our field, we do the F. E. analyses to estimate the embankment settlements. These analyses employ a Soil/Water coupling analysis program with constitutive equation of Sekiguchi and Ohta model, so-called "DACSAR".

Fig.15 illustrates the model of ground. The analyses area is a very soft ground about 30m deep. The

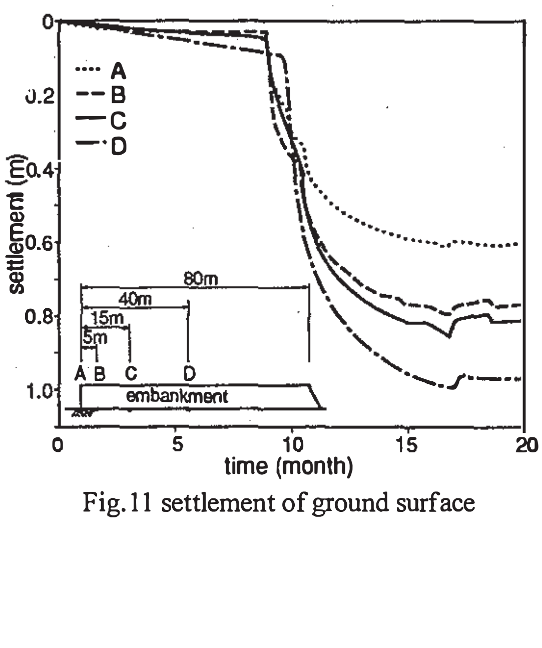


Fig.11 settlement of ground surface

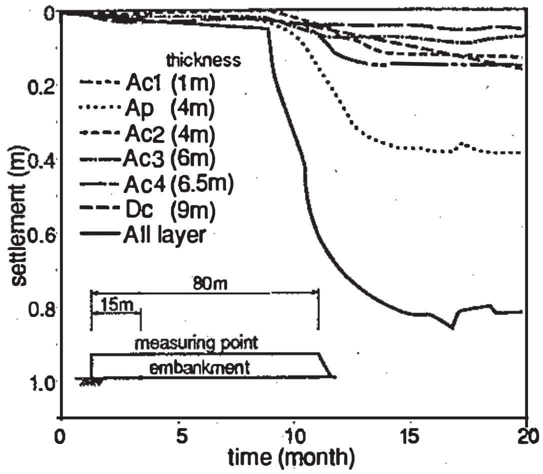

Fig.12 settlement of each layer

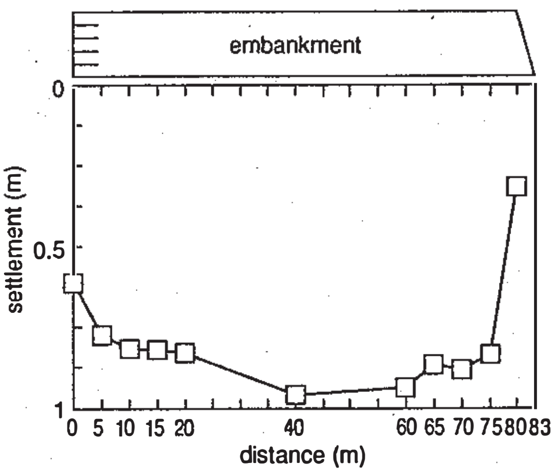

Fig.13 cross-section of settlement

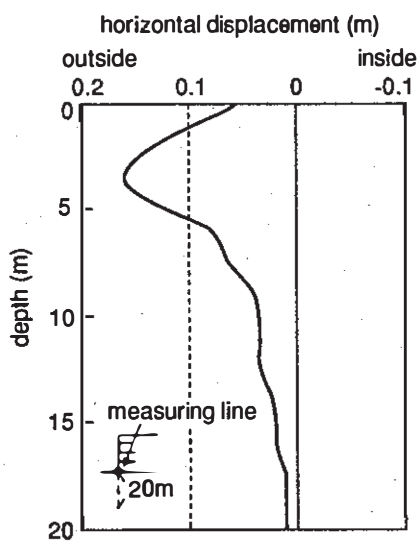

Fig.14 horizontal displacement

second and third layers are peat or clayey peat. For analyses, we conducted many samplings and soil tests in laboratories, and produced a model of ground using the result of soil tests and three geologic columns(see Fig.4, boring point No.1-3).

An analysis model is shown in Fig.16. The model

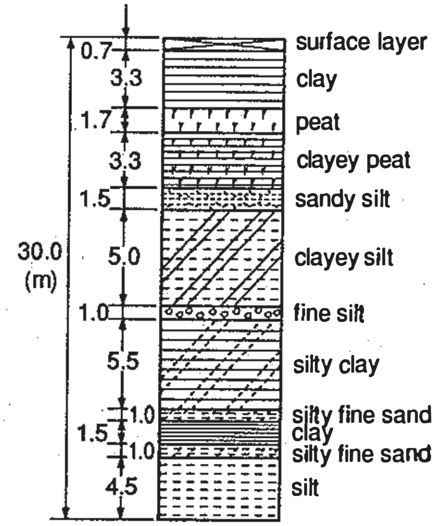

Fig.15 model of ground

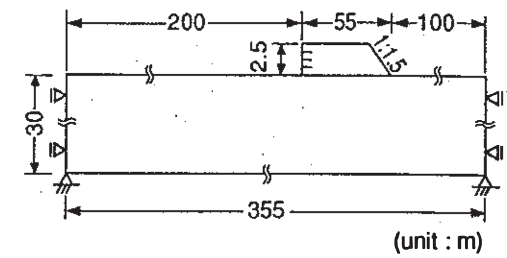

Fig.16 analysis model

size of GRS-RWs for analysis was 2.5m high and 55m wide. And the size of ground analysis model is 355m wide(to eliminate the effect of geometric boundary condition)and 30m deep(to get full bearing capacity). The geometric boundary conditions are fixed in x-direction and y-direction at the bottom, and x-direction on the right and left side. The hydraulic boundary condition is set both at top surface and at bottom surface.

The reinforced materials are composite geosynthetics, using clay as backfill materials. We use truss elements for geosynthetics in our analyses . In F. E. M. analyses, for the effect of drainage we create drainage boundary at position of truss elements. In this model, geosynthetics 1.5m long and 0.3m high are used, and long geosynthetics are used in the fifth layer the same as at the site. Analyses continued until the concrete facing was constructed . We aimed at understanding the GRS-RWs deformation and ground deformation.

Analysis flow is shown in Fig.17. We analyzed the flow in five steps.

## 6. INPUT PARAMETERS

The constitutive equation of the ground is an elasto-viscoplastic model and we calculate some parameters from soil test in the laboratory. Other parameter we can not get from soil test are obtained using two methods we described next. One of the

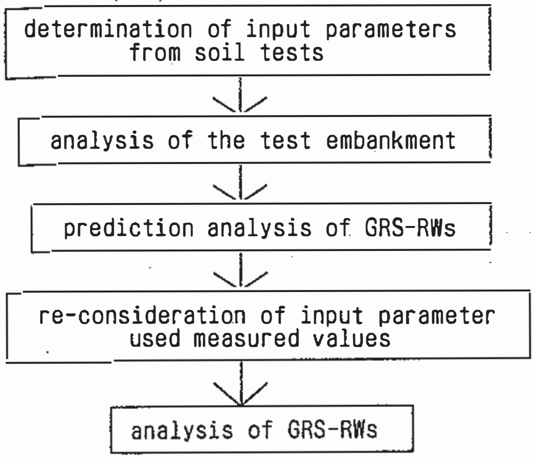


Fig.17 analysis flow

methods is obtain from plasticity index, the other to obtain from mechanical tests. We compare two kinds of parameters, and select better fit values. Parameters of the first layer are very difficult to selecte, and we cannot get results of soil tests. So we select elasticity materials and determine some parameters for elasticity from borehole horizontal loading tests, for example Young's modulus, Poisson's ratio. We show major parameters of the ground in Fig.18, using the values of full lines. In the field, the test embankments are constructed before constructing regular embankments. We analyze this test embankment because we compare them by fitting calculated parameters. Fig.19 shows analyzed and measured values. The analyzed values are in good agreement with the measured values. And we decided to adopt these parameters in our next analyses.

Parameters of GRS-RWs materials are calculated from soil tests in laboratories, for example physical test and mechanical tests(triaxial CU test and direct shear test). We use linear truss material for a model of geosynthetics, because it has a linear strength-strain relation in uniaxial tension tests, and we determine drainage using permeability tests. Input parameter: EA is 667(kN). We created the hydraulic boundary condition on the geosynthetics for hydraulic effect of non-woven geosynthetics.

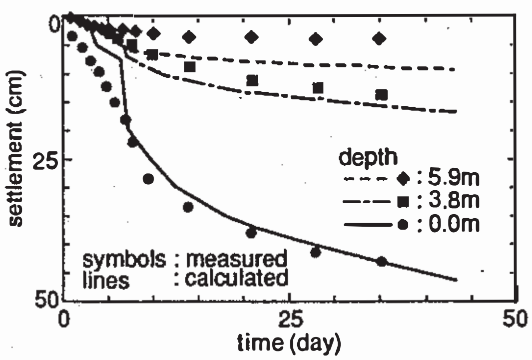


Fig.19 settlement of test embankment

## 7. RESULT OF ANALYSIS

We analyzed the measuring line No.2. Because we expected to spend long time for this analysis, we selected the measuring line No.2 finished faster near the measuring line No.3. On this line width of embankment is 55m, and depth of peat layers is about 5m. At first we made prediction analyses at this site. As a result, we got little consolidation settlements as compared with measured and spend long period to finish consolidation. We decided to take some parameters based on soil tests in laboratory as stated in Section 6, but found it very difficult to decide consolidation parameters. We changed two consolidation parameters, $\alpha$ (secondary consolidation index) and $v_0$ (velocity of initial volume strain) to be based on measured values of settlement(finished in about 6 months).

We show results of analyses in Figs.20,21. Fig.20 gives settlement-time curve at the center of embankment, on the ground surface and bottom of peat layer. And Fig.20 is shown in comparison with measured values. Fig.21 shows settlement of ground surface as viewed in cross-section.

## 8. CONSIDERATION AND CONCLUSIONS

In Fig.20 are shown settlement time scanning

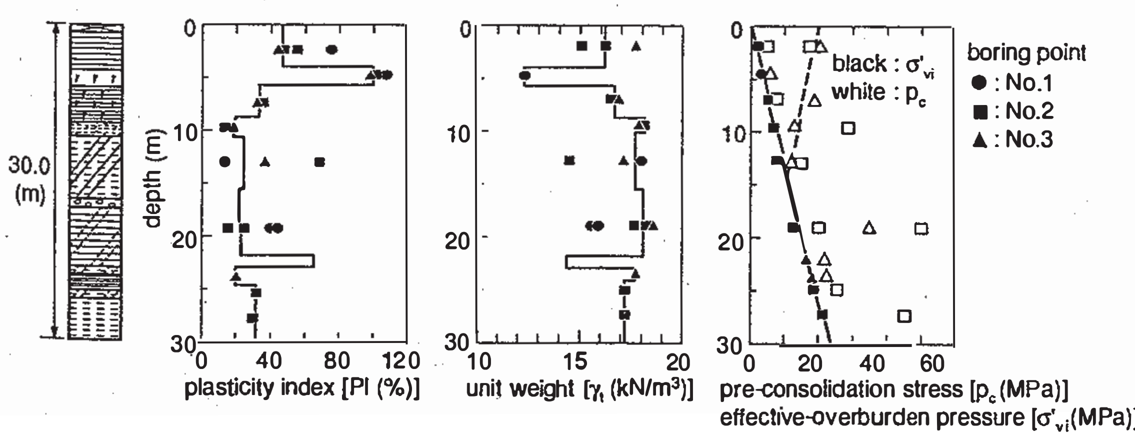


Fig.18 major parameters of the ground

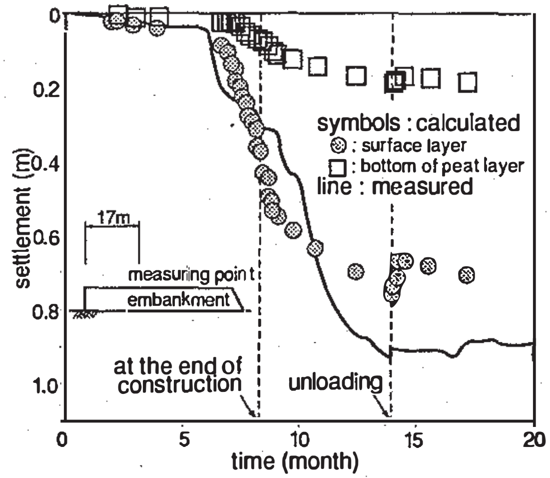

Fig.20 settlement of embankment

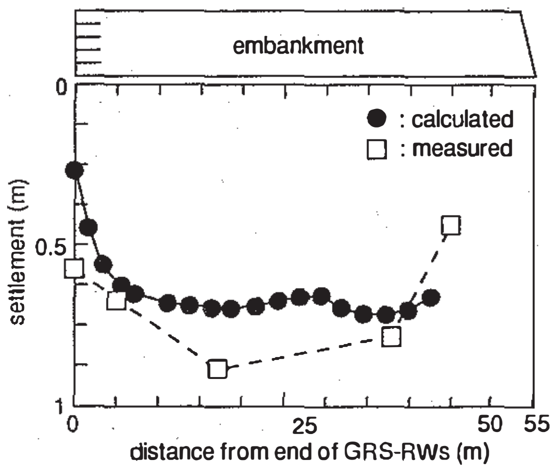

Fig.21 cross-section of settlement

curves of ground surface and the bottom of peat layer. Consolidation settlement of peat layer is about 0.5m and this value is about 10% of total peat layer depth. The result is the same as measured(see Fig.12). In this figure is made a comparison of calculated and measured values. The calculation curve simulates the measured curve very well. It shows a difference of about 0.1m. The reason, we consider, is that we cannot estimate the sand-mat and surface layer material character i.e. strength or permeability for analyses. The predicted settlement was about 0.3m(for about 15 months). We understand that the major factor of this difference is consolidation parameter(i.e. secondary consolidation index). Peat is a highly compressible material. And this character(i.e. permeability, strength) changes with history. We must determine input parameter(i.e. especially peat) considering the stress history in detail. In Fig.21 is shown settlement of ground surface as viewed in cross-section. The calculated value was small in settlement at the end of embankment. We suspect it is a mistake in estimation of surface layer material. We analyzed two cases: hydraulic condition created on the geosynthetics and non-created. But the result shows no difference between the two cases.

We need to re-consider character of surface layer and effect of side road, and hydraulic effect of non-woven geosynthetics for F. E. analysis. Then, we will do same analyses considering these condition and explore character of GRS-RWs using clay.

9. CONCLUDING REMARKS

Now, we are going ahead well with construction of the train yard in spite of difficulties that caused large settlement (about 1m) . We will finish the job within the estimated work period before Nagano Winter Olympics in 1998 .

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