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NUMERICAL ANALYSIS OF CONSOLIDATION SETTLEMENT AND CREEP DEFORMATION OF ARTIFICIAL ISLAND REVETMENT STRUCTURE IN A LARGE-SCALE MARINE RECLAMATION LAND PROJECT

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ABSTRACT

In order to analyze the influential factors of soft foundation settlement in a marine reclamation land project, the consolidation settlement and pore pressure dissipation of the entire area are numerically simulated using Soft-Soil-Creep Model, in which the PLAXIS finite element software for professional geotechnical engineering is applied and empirical data of Japanese Kansai's airport project are used. Moreover, the figures of settlement and pore pressure results in the different basic period are drawn, and the corresponding analysis conclusions are ob-tained based on the comparison among the results from the computational parameters of depth. In addition,, the influence rules of various parameters on settlement results is concluded through running the parameter sensitivity analysis in Soft-Soil-Creep Model, and the experience and conclusions can be for reference in the design and con-struction of similar large-scale marine reclamation land project. Also the empirical value method of the creep index has not been applied widely. Further research needs to be done.

Keywords: marine reclamation land; Soft-Soil-Creep model; consolidation settlement; pore pressure; micro-structure; numeri-cal analysis.

INTRODUCTION

Plentiful soft soil layers that water content is higher are distributed in Chinese coastal areas, such as soft soil sedimentary of coastal facies in Tianjin, Dalian, Qingdao and so on. The soft soil is mainly made up of fine-grained soil whose major kind is muddy soil. A In terms of the engineering properties of soft soil, it has high water content, low strength, low coefficient of permeability and obvious rheological property. It is the most common to the rheological phenomenon of soft soil, which is the primary soil in the construction of marine reclamation land project. Microstructure of marine sedimentary soft soil is complex, and its engineering properties have a very close relation-ship with certain types of microstructure. Therefore, the long-term influence of microstructure of soft soil, consolidation and soft soil creep must be taken comprehensive consideration.

Soil microstructure means size of soil particles, shape, surface characteristics, the link way and the arrangement between the particles in the soil and so on. Under the external environmental in-fluence, a variety of soil exhibited features reflect on change of all its intrinsic microstructure, so microstructure of soil plays an important role in the changing of the soil nature.

From the 1920s, Terzaghi pointed out that micro-structural necessity of the soil needed to con-sidering when the geological nature of the clay is in the in the evaluation, which linked marine sedimentary soft soil to engineering properties of soil. From then on, a new study field of soil mi-crostructure was founded. It is And Casagrande proposed a composite model containing silt and clay by Terzaghi's model, which described sensitive characteristics of soil structure of marine sed-iments. So the relationship between micro-structural characteristics and mechanical properties of soil is systematic studied. And the essential factors affecting the deformation and force of the mi-cro-structural itself characteristics are revealed, which are important for mechanism analysis of consolidation settlement, permeability and shear deformation.

Foundation settlement usually includes the initial settlement and the post-construction settle-ment (primary consolidation settlement and secondary consolidation settlement). Terzaghi Consol-idation Theory assumed that the total normal stress does not change along with time in the process of consolidation, thus consolidation settlement can be only approximately figured up. However, Biot Equation

[1, 2] can calculate both initial consolidation settlement and consolidation settlement and horizontal displacement. However, the secondary consolidation settlement is not taken into account in the above the two theories, which leads to be larger different from actual settlement value. In fact, for most soft soil, secondary consolidation deformation has a large proportion of the total deformation, so the part of soil deformation cannot be neglected. Therefore, most scholars proposed consolidation theories considered rheological property, which made calculation of set-tlement value consider secondary settlement.

In twentieth century 30's, Bingham put forward material rheological theory, which marked ap-pearance of rheological subject. Subsequently our country scholar Chen Zongji put rheological the-ory into the use of consolidation theory, and built consolidation theory considering rheology and deduced consolidation equation as well as the solution of equation based on it [4]. Based on the spread of study of soft soil settlement problem of finite method, Folque presented a consolidation model of unsaturated soil considering rheological question and got the solution of constitutive equation of model [5,8]. Tang Bin et al [9] adopted finite producer to analyze consolidation of soft soil foundation based on rheological characters; Mamoru Mimura et al [6] studied number one runway of Kansai International Airport and contrasted local actual monitoring value with finite numerical calculation value of consolidation settlement post construction. The two results are al-most similar. In this paper, Consolidation settlement and creep analysis calculation are proceeded to marine reclamation land project using Soft-Soil-Creep Model as well as plane finite method, in which the PLAXIS finite element software for professional geotechnical engineering is applied and empirical data of Japanese Kansai's airport project are used. Then the sensitivity analysis is carried out for some factors which affect soil consolidation and creep. Furthermore, the corre-sponding analysis conclusions are obtained which can be for reference in the design and construc-tion of similar large-scale marine reclamation land project.

BASIC PRINCIPLE OF CONSOLIDATION

Excess pore pressure of soil gradually dissipates, internal water consent slowly outflows, and effective stress gradually increases. Such a phenomenon is called soil consolidation. In project practice, soft soil not only produces consolidation settlement before excess pore water pressure absolutely dissipates, even though consolidation has finished (excess pore water pressure com-pletely dissipated) and certain settlement deformation still exists in the soft soil. Therefore, the whole soil settlement should be considered the combined effect of soft soil creep and settlement.

Basic consolidation equation [3] in the PLAXIS was obtained by Biot Theory. Darcy Law is adopted in the seepage problems, which was based on small strain theory and presumed that soil skeleton was of elasticity deformation. Based on Terzaghi Principle, stress of soil was divided into effective stress and pore pressure:

$$\sigma = \sigma' + m(P_{steady} + P_{excess}) \tag{1}$$

Where $\boldsymbol{\sigma} = (\boldsymbol{\sigma}_{xx}\ \boldsymbol{\sigma}_{yy}\ \boldsymbol{\sigma}_{zz}\ \boldsymbol{\sigma}_{xy}\ \boldsymbol{\sigma}_{yz}\ \boldsymbol{\sigma}_{zx})^T$; m = $(1\ 1\ 1\ 0\ 0\ 0)^T$, and m includes the vectors of unit normal stress and zero shear stress component. And $\boldsymbol{\sigma}$, $\boldsymbol{\sigma}'$, P_{excess}, P_{steady} represent respectively total stress vector, effective stress, excess pore pressure, the final steady-state solution in consolidation. Also, the constitutive equation can be expressed in the form of increment. $\dot{\sigma}'$, $\dot{\varepsilon}$, represent respec-tively the increment of effective stress and increment of strain. So the constitutive equation can be written as

$$\dot{\sigma}' = \underline{M}\,\dot{\varepsilon} \tag{2}$$

$$\varepsilon = (\varepsilon_{xx}\varepsilon_{yy}\varepsilon_{zz}\gamma_{xy}\gamma_{yz}\gamma_{zx})^T \tag{3}$$

Where, M is the material stiffness matrix.

SOFT-SOIL-CREEP MODEL

The Soft-Soil-Creep model is applied to simulate the consolidation settlement of foundation and the secondary consolidation settlement of the total area in the numerical calculation. Neher and Vermeer et al [10] proposed the Soft-Soil-Creep model, which is a three-dimensional creep model expanded by one-dimensional creep model based on standard 24h load test. The main pa-rameters contain natural severe γ, saturation severe γ_{sat}, horizontal permeability coefficient k_h, vertical permeability coefficient k_v, cohesion force c, internal friction angle φ, dilation angle ψ, fixed compression indexλ^*, modified swelling index κ^*, fixed creep index μ^*.

Buisman first put forward the following equation of creep equation under constant effective stress:

$$\varepsilon = \varepsilon_c - C_B \log\left[\frac{t_c + t'}{t_c}\right] \tag{4}$$

Subsequently, Butterfield proposed a new style as follow.

$$\varepsilon = \varepsilon_c - C\ln\left[\frac{\tau_c + t'}{\tau_c}\right] \tag{5}$$

where ε_c is the total strain when primary consolidation finished, and t_c is the time that primary consolidation finishes. Moreover substitution of τ_c in the sixth equation into t_c in the fifth equation, t' = t - t_c can be obtained which is the time of effective creep. In summary, combining with schol-ars' research results of creep model, such as Jianhua Yin et al, ε_c can be expressed with the fol-lowing style:

$$\varepsilon_c = \varepsilon_c^e + \varepsilon_c^c = -A\ln\left[\frac{\sigma'}{\sigma_0'}\right] - B\ln\left[\frac{\sigma_{pc}}{\sigma_{p0}}\right] \tag{6}$$

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where $\boldsymbol{\sigma}_0'$, $\boldsymbol{\sigma}'$, $\boldsymbol{\sigma}_p^0$, $\boldsymbol{\sigma}_p^c$, $\boldsymbol{\sigma}_p$ represent respectively the initial effective stress before load, the effective stress of finial load, the preloading consolidation stress before loading, finial consolida-tion stress, and the preloading consolidation stress.

$$\frac{\tau}{\tau_c} = \left[\frac{\sigma'}{\sigma_{pc}}\right]^{\frac{B}{C}} \tag{8}$$

At last, creep equation can be obtained as follow:

$$\dot{\varepsilon} = \dot{\varepsilon}^e + \dot{\varepsilon}^c = -A\frac{\dot{\sigma}'}{\sigma'} - \frac{C}{\tau}\left[\frac{\sigma'}{\sigma_p}\right]^{\frac{B}{C}} \tag{9}$$

Where:

$$A = \frac{C_r}{(1+e_0)\ln 10} \tag{10}$$

$$B = \frac{C_c C_r}{(1+e_0)\ln 10} \tag{11}$$

$$C = \frac{C_\alpha}{(1+e_o)\ln 10} \tag{12}$$

Basic stiffness parameters and the meaning as follow:

1. fixed compression index

$$\mu^* = \frac{C_\alpha}{(1+e_0)\ln 10} \tag{13}$$

where $C_c = \frac{e_1 - e_2}{\lg p_2 - \lg p_1}$ represents the compression index.

2. modified swelling index

$$\kappa^* = \frac{3(1-\nu_{ur})}{(1+\nu_{ur})}A = \frac{3(1-\nu_{ur})}{(1+\nu_{ur})\ln 10}\frac{C_r}{(1+e_0)} \tag{14}$$

where C_r represents swelling index, υ_{ur} represents unloading - reloading Poisson's ratio;

3. fixed creep index

$$\mu^* = \frac{C_\alpha}{(1+e_0)\ln 10} \tag{15}$$

where C_α represents creep index.

ANALYSIS OF PRACTICAL PROJECT

PROJECT SITUATION

Field area of marine reclamation land project of Airport Industrial Park was 21 km^2. After field of project formed, the elevation of top ground was 3.1 meters. Rectangular artificial island was reclaimed. And its length was 6621.1 meters and the width was 3328.3 meters. Moreover the for-mation of artificial islands revetment and land of Airport Industrial Park includes dredging, water rubble mound, underwater explosive ramming, overland advance backfilling and so on. Also, stra-tum structure of the site consists of marine sediment, sediments of alternative sea and river and continental sediment, which is 50 ~ 80 meters of covering. Among them, marine sedimentary lay-ers contain silt, silt clay, silt clay, silt sand, belonging to plastic flow - soft plastic state and local more fine sand. And sediments of alternative sea and river sediment includes clay and silt clay, belonging to plastic - hard plastic state and local folders fine sand. And continental sedimentary layers include clay, silt clay, belonging to hard plastic state, a strong bedrock weathered rock is primary in basic rock. The revetment structure is only taken as the examples in this paper (Fig.7), settlement and excess pore pressure distribution law of different positions were analyzed.

THE MICROSTRUCTURE ANALYSIS OF SOIL

In the paper, the scanning electron microscopy method was used in the analysis way of soil mi-crostructure, with the vacuum freeze-drying method for sample preparation. Therefore, the instru-ment specification of scanning electron microscope was 20 kv and its magnification is 10,000 times. For field area, representative soil samples were tested and studied. Scanning electron micrographs were obtained under certain magnification (Fig.1~6). The relationship between micro-structural characteristics and mechanical properties of soil was systematic studied.

Tab. 1.soil sample depth of microstructure analysis

number	sample name	sample depth
①	silt	3.0 m -3.5m
②	mucky silt clay	9.0 m -9.5m
③	silt clay	29.1 m -29.3 m
④	silt clay	33.1 m -33.3 m
⑤	Silt clay	47.1 m -47.3 m
⑥	clay	17.1 m -17.3 m

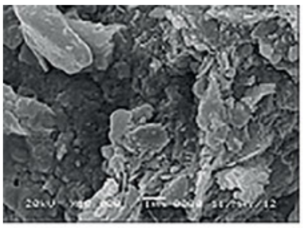


Fig. 1. SEM figure of soil sample①

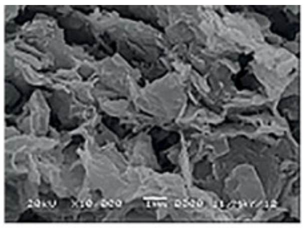


Fig. 2. SEM figure of soil sample②

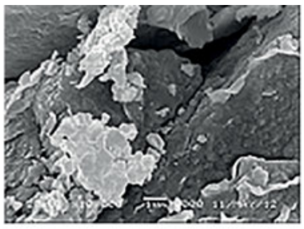


Fig. 3. SEM figure of soil sample③

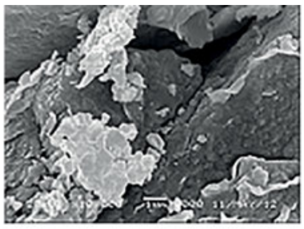


Fig. 4. SEM figure of soil sample④

Fig. 5. SEM figure of soil sample⑤

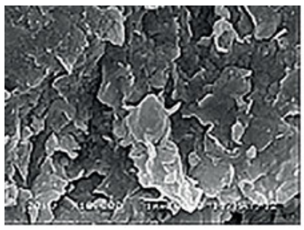


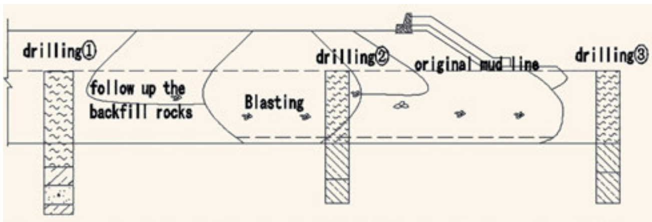
Fig. 6. SEM figure of soil sample⑥

It can be seen from above figures:

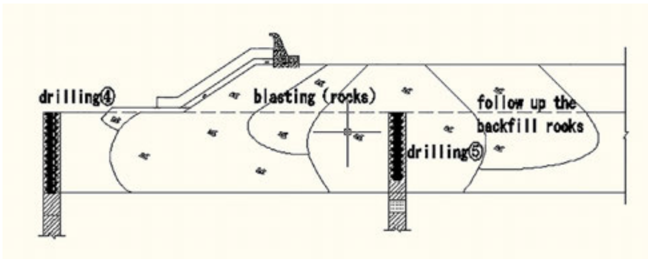
1. Soil sample 1 is gray-black in the whole. In the view of high-power electron micrograph, the soil sample takes the flocculation as the skeleton, which connected together to the flocculation by the clay chain. The porosity is mainly intergranular pore, but some large pore exists in it, which indicate that the intensity of the silt is low. However compressibility and rheology sensitivity of the silt is high.
2. Soil sample 2 presents pewter above side, however the other sides are black. Also, the middle of soil sample exist fracture. In the view of high-power electron micrograph, a soil sample also is flocculent link structure taking the flocculation as the skeleton. The porosity is mainly in-terparticle pore. Compared with the silt, the pore reduces and the pore size is small, which indicates that the intensity of the soil sample is low.
3. The soil sample 3 shows pale brown, layering and intermediate mixed with partial sand whose strength is higher by identified. From a high-power electron micrograph, soil samples see tablets or powder set for the skeleton. Certain distance between the particles exists. The distance of particle is connected with clay chains that are formed with clay tablets or clay domain, which forms soil structure of large pores between the particles.
4. Soil sample 4 shows yellow sand in the whole, the soil sample is coarser than the former soil sample and its hardness is higher. soil samples stacked together by clay particles to be clay domain, and then clay domains aggregate together into regular or irregular aggregates that further aggregated together to form a larger group of clay (block) .
5. Soil sample 5 shows yellow sand in the whole, which is the most coarse and the highest hardness in all soil samples by identified; in the view of high-power electron micrograph, the soil sample is the same with soil sample 5.
6. Soil sample 6 shows cyan, the whole show stone gray. In the view of high-power electron micrograph, the soil samples also sets clay tablets or powder form sheet for the skeleton, clay tab-lets to face-face contact based, and the porosity is relatively small, belonging to marine sedimen-tary soil of low compressibility.

CALCULATION PARAMETERS AND MODEL

PLAXIS, the software of finite element analysis in geotechnical engineering, was used for cal-culation. The 2D subsidence analysis model was established, in which second-order six-node tri-angular elements were used. The maximum height of model is 80 meters and the width is 425 me-ters. East revetment was divided into 3,280 elements and 6,677 nodes. However, west revetment was divided into 3,018 elements and 6,153 nodes as Fig.8. As kinds of soil in engineering are var-ious, the paper lists some typical calculation parameters of soil used in calculating (Tab.2), where bedrock, sand and backfilling stone using Mohr-Coulomb model and the entire clay use SSC mod-el.



East revetment

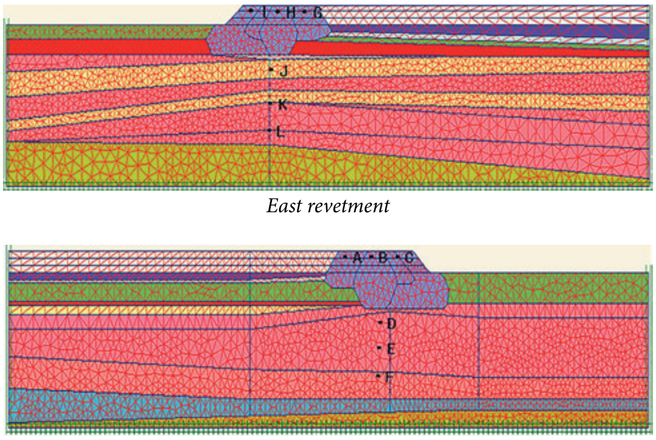


West revetmentt

Fig.7. cross-section drawn of typical revetment structure

Tab.2. Typical physical and mechanical parameters of soil

Soil name	Soil constitutive model	Stauration bulk density γ /(kN/m3)	Void ratio e	Cohesion C/(kPa)	Internal friction angle Φ/(℃)	Permeability Coefficient k/(m/d)	Compression index λ	Swelling index κ	Creep index μ	Poisson's ratio ν	Stiffness E/(MPa)
Clay	SSC	16.6	1.64	13.1	12.4	0.00025	0.105	0.021	0.0042	-	-
Silt clay	SSC	19.0	0.91	38.8	13.7	0.00023	0.052	0.0105	0.0021	-	-
Silt	SSC	19.6	0.78	41.8	17.6	0.00019	0.046	0.0093	0.0019	-	-
Fine	M-C	19.0	-	0.0	27.0	2	-	-	-	0.35	50
Rock	M-C	20.0	-	0.0	38.0	8	-	-	-	0.28	150
Strong weathered rock	M-C	20.5	-	0.0	38.0	8	-	-	-	0.3	180



East revetment

West revetmentt

Fig.8. finite elements model of revetment

ANALYSIS OF CALCULATION RESULTS

The results of above calculation are as shown in Tab.3 and Fig.9. And we can see residual settlement laws of different basic period after the completion as follow: with time going by, the settlement of east and west revetment gradually increases. After the completion 100a, the maxi-mum settlement in the area of east revetment is 0.638 meters and west revetment is 0.586 meters. Therefore, the reason for the difference settlement value between east revetment and west revet-ment is that physical and mechanical properties of soil under revetment are different. The soil un-der east revetment is thin silt clay, but the soil of west revetment is thick silt clay. After adopting the Rubble, a small amount of silt still exists. So the settlement of west revetment is slightly supe-rior to settlement of east revetment.

Tab.3. residual settlement after construction in the different reference period

	settlement in (m)			
sectional position	5 years	10years	20years	100yea
west revetment	0.183	0.295	0.389	0.638
east revetment	0.151	0.256	0.343	0.586

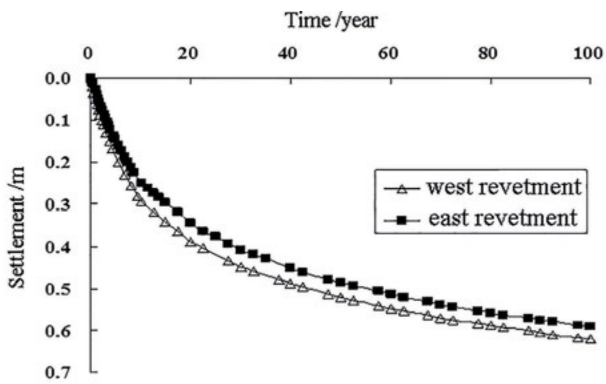
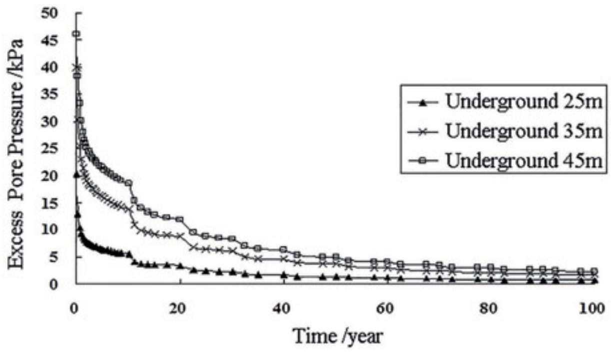
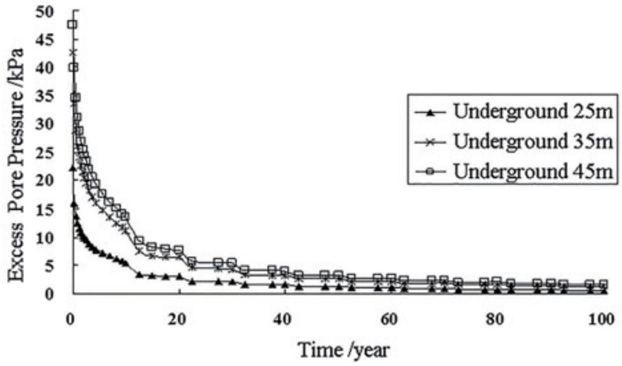


Fig.9. the comparison of settlement trend of revetment after construction

Through comparing the dissipation of pore water pressure at depth of 25 m, 35m and 45 m, it can be seen that excess pore water pressure of deep foundation slow dissipates and the area still will be slow sinking, but the trend becomes slow. Moreover, the model adopts one-way drainage, and left, under, right boundary is not drained. Because of the path of seepage is from bottom to top, so one of crucial main factors of dissipated speed of pore pressure is the length of the seepage path. Also another influential fac-tor is the permeability coefficient (Sand permeability coefficient is 2 ~ 7 m/d, permeability coeffi-cient of backfill rock is 8 m/d): closed to area of sand and rock, pore pressure dissipation obviously speeds up. According to Geological Survey Report, besides sand layer, permeability coefficient of soil is $10e^{-3}$~10^{e-4} m/d, so the speed of soil dissipation at the same depth of soil is approximate. Besides, a special case appears in the revetment. As filling area is large and the filling follows the rocks, coefficient of permeability is much larger than mucky soil before filling, which accelerates drainage, leading to dissipate fast at pore water pressure of revetment.



East revetment



West revetment

Fig.10.The dissipation of excess pore water pressure

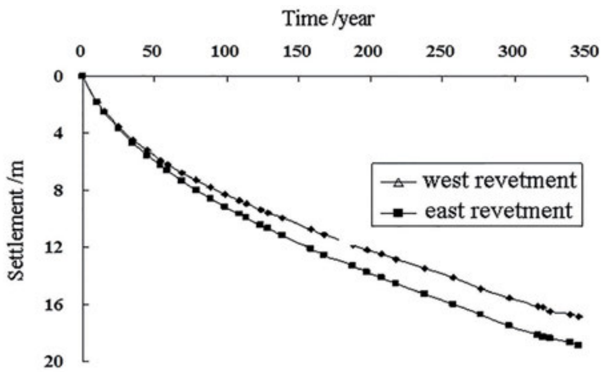


Fig. 11.The comparison of after construction settlement of east revetment

According to the above results of table and figures, it can be concluded that excess pore water pressure of the area of revetment dissipates faster. After the completion 100a, excess pore water pressure in shallow soil layer is tend to zero, and the consolidation settlement of soil finished in the main, but the deep soil still exists some excess pore water pressure without dissipation, excess pore water pressure without dissipated has a about 8% proportion of the total excess pore water pres-sure.

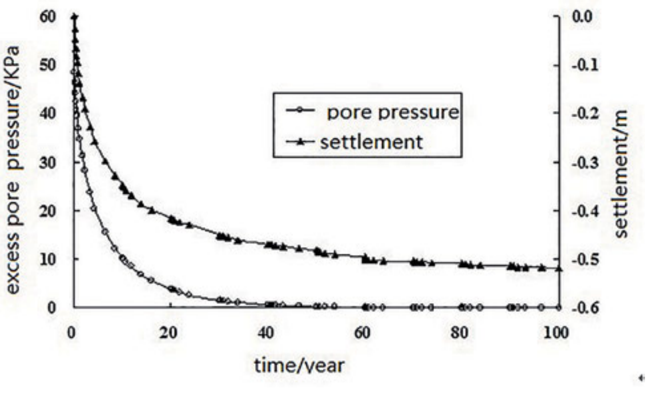
Now, existing measured data is settlement value of east revetment from August 19, 2011 year to August 5, 2012 year. To verify the accuracy of the numerical simulation analysis results, the set-tlement after the completion of east revetment filling 346 d was done through the numerical simu-lation. As fig.11 showed that actual measured settlement is 16.2 cm, but the value of numerical simulation is 18.9 cm. Therefore, we can know that the result of numerical simulation is approxi-mate to actual measured value, which is more conservative.

THE SENSITIVITY ANALYSIS

To accurately choose geotechnical model is a premise for geotechnical soil mechanics doing quantitative and qualitative analysis. Constitutive model and the parameters have an effect on the rationality of soil settlement analysis. Considering discrete type of geotechnical soil parameters, for the settlement numerical analysis of marine reclamation land project, the sensitivity analysis was done, which the change of main soil mechanics parameters had an effect on settlement.

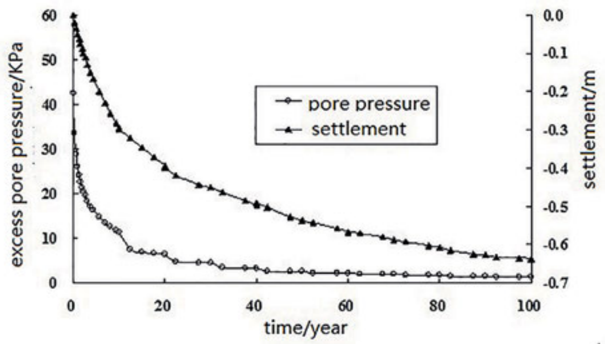
THE INFLUENCE OF MODEL SELECTION

Soft soil model is a model of Cam-Clay, which especially is applied to primary compression of clay soil of normal consolidation, which can't explain rheological phenomenon (main performance is creep and stress relaxation). However, certain creep existed in the soil and the secondary com-pression some extent followed with primary compression. SSC model is just applied to the solution of soil rheological problem. Therefore, comparing the settlement result of SS model with SSC model, we can see that creep characteristics of soil had an effect on the final settlement (Fig.12).



a) Result of SS model

Fig.12.The comparison of SS model and SSC model settlement curve



b) Result of SSC model

Fig.12.The comparison of SS model and SSC model settlement curve

As Fig. 12.showed that primary consolidation had mainly finished when pore pressure slope tended to zero. And from now to hundred years after construction, the growth of SS model set-tlement is small, also the curve are very smooth. While the increase of SSC model settlement is very obvious, also the trend of increase will last hundred years, but the slop of curve become small, at last the settlement is tend to be steady at some time.

Tab.4 the comparison of settlement results of two creep model

location	model	S_1/m	S/m	S_2/m
east bank	SSC	0.492	0.586	0.094
	SS	0.501	0.518	0.017
west bank	SSC	0.539	0.638	0.099
	SS	0.512	0.525	0.013

Notes: S1 is the settlement that excess pore water pressure tends to zero, S is the total settlement of hundred years after construction, and S2is the settlement of creep.

As Tab. 4 showed that the settlement of east revetment creep had a 16 % proportion of the set-tlement after construction based on the result of SSC model, but west revetment occupied 15.5 %, which indicated when excess pore water pressure tended to zero, creep deformation still existed after primary consolidation had mainly finished, which corresponds to objective theory. However, for SS model, without the error of finite element calculation, there wasn't creep deformation after excess pore water pressure dissipated, which doesn't correspond to objective theory. Thus it is sure that the SSC model is rational to calculate creep deformation of soft soil.

THE INFLUENCE OF CREEP INDEX

The numerical analysis of two dimensional settlement referred to the experiential data from Japanese Kansai airport [7]. Creep index was taken 1/25 of compression index. In order to analyze influence of creep index on residual settlement, the sensitivity analysis of creep index was done. In the case of modified creep index taking 1/20, 1/25, 1/30 of modified compression index, Fig.13 shows that settlement of west revetment changes in the different reference period. As can be seen, the final residual settlement decreases along with the decrease of the creep index, and the curves become slow.

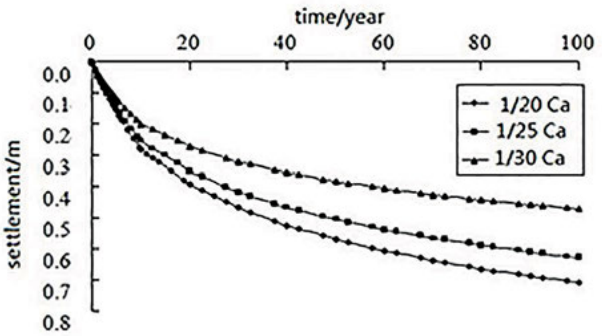


Fig. 13.alteration of modified creep index impact on residual settlement

Tab.5. OCR effect on residual settlement

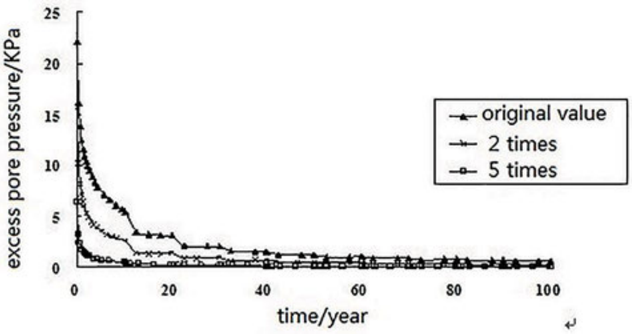
OCR value	settlement of different base period(m)				
	location	5 years	10 years	20 years	100 years
original value	West bank	0.183	0.295	0.389	0.638
	east bank	0.151	0.256	0.343	0.586
+25%	west bank	0.135	0.224	0.313	0.583
	east bank	0.120	0.205	0.280	0.491
+50%	west bank	0.122	0.194	0.265	0.483
	east bank	0.106	0.172	0.231	0.389

THE INFLUENCE OF OVER CONSOLIDATION RATION

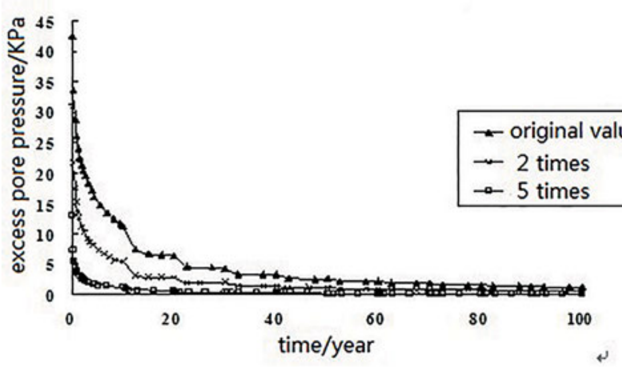
Only the OCR value was changed to analyze the effect on settlement trends and final result. Under other conditions constant, the OCR value respectively increased by 25 %, so the re-sults were obtained in Tab. 5. We can see that the greater the OCR value, the shorter the steady time of settlement, the smaller the final settlement became.

THE INFLUENCE OF PERMEABILITY COEFFICIENT

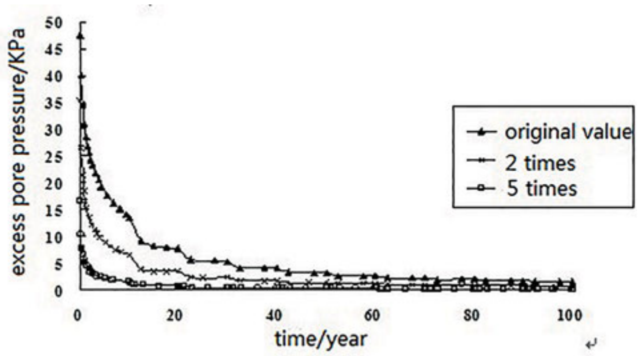
Only the permeability coefficient of soil was changed to analyze the influence on the speed of pore pressure dissipation as well as the final settlement. Under other conditions constant, the soil permeability coefficient was expanded to 2 times and 5 times of the original value. Thus the in-fluence of permeability coefficient was obtained in Fig. 14 and tab. 6



a) excess pore pressure at underground 25m



b) excess pore pressure at underground 35m



c) excess pore pressure at underground 45m

Fig.14.The comparison of permeability coefficient expanded to the original 2times and 5times

Tab.6 permeability coefficient effect on settlement

permeably coefficient	Settlement of different base period (m)				
	location	5years	10s	20s	50s
1time	West bank	0.183	0.295	0.389	0.514
2 times	West bank	0.209	0.325	0.436	0.519
5 times	West bank	0.296	0.412	0.501	0.522

Fig.14 and Tab. 6 showed that the greater permeability coefficient, the faster pore pressure dis-sipation, while the shorter the steady time of settlement. Although the final settlement value slightly increased, the difference is small.

CONCLUSION

1. The microstructure of soil samples 1, 2 showed flocculent link structure, and some lager voids are found between the basic elements, an unconsolidated flexible framework is constructed. While, there is no connection between elements, which leads to the voids are instability, so they intend to be unstable and low strength under the compression forces. The microstructure type of the deeper silt clay is the clay matrix structure, and its skeleton particles are mainly connected with clay-based, so it's easy to see that the strength of the clay and the silt clay is stronger than the silt and the silt clay. Macro colors of silt clay at

three different depths show a decreasing trend with the incremental depth. Comparison of the three SEM figures, we can see that the voids decreased gradually with increasing the density and structural. Therefore, the strength of three became stronger gradually.

2. The largest settlement in the area of revetment is about 0.6 ~ 0.7m after 100 years of com-pletion of Land reclamation project. From the analysis of the charts of consolidation degree and excess pore water pressure dissipation, after the completed 100a, the deep inside soil still exists a small amount of pore water pressure without dissipation, and the field area will slowly be sinking, however, the trend will become gradually slow.
3. Based on Soft-Soil-Creep model of PLAXIS and its finite element program, trends of set-tlement of soft ground can be depicted accurately and the creep can be also predicted more accu-rately. It can provide the basis for the settlement that is set aside to make sure the reclamation ground elevation after construction meets the design requirements.
4. The results of sensitivity analysis of calculation parameters indicate that the greater the OCR value, the shorter the steady time of settlement, while the final settlement became small with it. The greater the permeability coefficient, the faster pore pressure dissipation, and the shorter the steady time of settlement. Although the final settlement value slightly increased, the difference is small.
5. The modified creep index takes 1/25 of compression index in the settlement of numerical analysis which refers to the empirical data of Japanese Kansai Airport engineering (Ca / Cc = 0.04 ± 0.01). In order to promote the use of the determination method for the key parameters of creep, more extensive research must be carried out in related fields.

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