Research on Settlement Law of high salt sandy soil subgrade in Saline Lake area

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Abstract. The post construction settlement of the railway subgrade is affected by many factors usually. Based on the Xitieshan to North Hobson local railway as the engineering background, this paper discusses the settlement law of the high salt soil subgrade, the reasonable numerical model were used to fit the measured data, and compares the calculated results and the measured data, then the settlement of subgrade is summarized in this area. The research shows that the exponential function fitting model can better reflect the rule of roadbed settlement in the area, which can provide a reference for the design and construction of the same type of railway subgrade in the saline lake area.

1. Introduction

The problems of saline soil and subgrade are studied by the most researches at home and abroad[1-5]. However, due to the differences of the soil properties in different regions and the complexity of the deformation affected by the outside world, it is also need to sum up their own rules of settlement prediction model for specific projects. The research background in this paper is the new local railway from Xitieshan to North Hob Johnson Lakes region, the subgrade section of the project is located in the plain area of Saline Lake(DK36+620～DK45+250),which place the surface salinization is obvious here. The salt shell of this place is widely distributed, and the salt content is 15.03% ~ 30.73% by sampling, and the soil is mainly chlorinated saline soil. The groundwater depth in this area is relatively shallow, which is about 0.4 ~ 2.3 m. It has been detected as brine and has a high salinity.

During the construction of subgrade, there is about 0.3 m thick salt shell on the foundation surface. The original design is to remove the salt shell and use the heavy machinery to compact the foundation to achieve the compaction standard. And the permeable soil isolation layer is used to prevent capillary water from rising at 0.5 m above the surface. But during the actual construction period, it was found that the groundwater depth was relatively shallow due to the high water content and salt content in the area. After the salt shell was removed, the seepage was serious, and it could not be rolled normally, and the salt shell was hard, which made the construction difficulty increased. Therefore, the design is changed to not clear the salt shell directly to the compaction standard. The effect of this construction measure and the influence on the settlement of the subgrade remains to be further verified. In addition, when the soil subgrade filler using local materials, the high content of salt sand subgrade, subgrade soil salt-water under the effect of seasonal frost environment and the rainy season precipitation in the

plateau region, to further increase the complexity of the subgrade settlement as soon as possible, so it is very important to sum up the subgrade settlement prediction model in this area.

2. settlement observation scheme and measured data

The settlement observation selected the DK40+658 ~ DK40+708 subgrade section ,the height of subgrade filling was 5 m and the length of the observation section was 50 m. Along the length direction there have layout 5 settlement section, each section is located in the center of subgrade observation points and both sides of the road shoulder, by way of burying the settlement plate, we use the ruler and level to observe settlement data, the observation period for a week or ten days, figure 1 and figure 2 is the settlement observation point and plane cross-section layout of observation point. In order to eliminate the influence of roadbed construction on the settlement observation results, the site observation starts from the completion of subgrade filling, and the duration is September 22nd to August 17th in next year, accumulative total of 329 D. In order to facilitate comparison, the observation points of the subgrade center are selected from B1 to B5 for the convenience of comparison, and table 1 is the observation data of B1 settlement at the observation point.
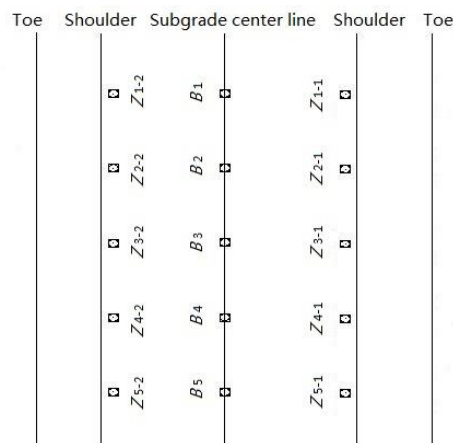

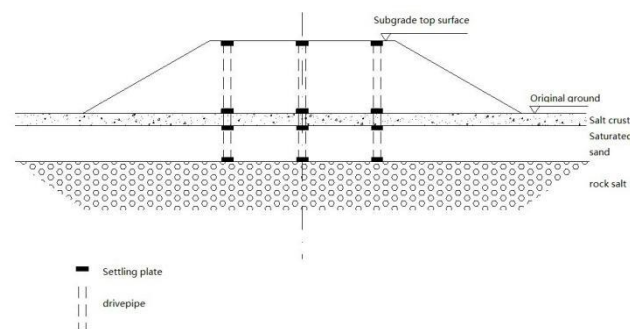Figure 1. The arrangement plan of observation point

Figure 2. The cross-sectional layout of observation point

Table 1. The field observation data of subgrade point B1(DK40+658)

Period of time	Date	Observation interval /d	Cumulative days /d	This settlement /mm	Accumulative settlement /mm	Sedimentation rate /（mm/d）
1	09-22	0	0	0	0	0
2	10-05	13	13	69	69	5.31
3	10-15	10	23	21	90	2.1
4	10-23	8	31	16	106	2

5	10-30	7	38	8	114	1.14
6	11-25	26	64	0	114	0
7	11-30	5	69	33	147	6.6
8	03-05	95	164	18	165	0.19
9	03-15	10	174	-4	161	-0.4
10	03-26	11	185	6	167	0.55
11	04-09	14	199	-2	165	-0.14
12	04-22	13	212	1	166	0.08
13	05-04	12	224	2	168	0.17
14	05-22	18	242	-1	167	-0.06
15	05-28	6	248	0	167	0
16	06-08	11	259	2	169	0.18
17	06-16	8	267	-1	168	-0.12
18	06-23	7	274	0	168	0
19	07-03	10	284	1	169	0.1
20	07-10	7	291	-2	167	-0.29
21	07-20	10	301	1	168	0.1
22	07-27	7	308	1	169	0.14
23	07-27	0	308	0	169	0
24	08-07	11	319	1	170	0.09
25	08-17	10	329	-1	169	-0.1

From table 1, it was found that the initial stage of settlement increased rapidly, and most of the settlement was completed at this stage. With the passage of time, the settlement rate gradually decreases, and the settlement observation data has gradually stabilized after March, and the cumulative settlement fluctuates up and down at 169 mm. During the 11-30~ 03-05 settlement data is missing, which is a winter downtime. From March to May, due to the seasonal frost heave and dry wet alternate environment, the observation data of individual settlement is negative, but there is little change. From June to August, due to the influence of rainy season precipitation and the effect of salt crystallization and dissolution, the settlement observation data are changing alternately. Therefore, it is necessary to further explore the settlement rule of salty sand subgrade in this area.

3. numerical fitting model

There are many methods of settlement prediction in practical engineering, and the application of curve fitting is more extensive, and many scholars have studied it in detail and deeply[6-10]. In order to preliminarily discuss the settlement rule of saline soil subgrade in this area, this paper applies the hyperbolic function model and exponential function model widely applied in engineering to predict settlement, and analyzes the fitting results, so as to select the best model.

The basic pattern of the hyperbolic function model is given by[6]:

$$S_t = S_0 + \frac{t - t_0}{\alpha_1(t - t_0) + \beta_1} \qquad (1)$$

Where S is the initial settlement (t_0 time); S_t is the settlement at the time of t; α_1 and β_1 are the parameters to be fitted. The initial point of this settlement observation is $t_0 = 0, S_0 = 0$, let $y_1 = \frac{1}{S_t}, x_1 = \frac{1}{t}$, formula (1) equals

$$y_1 = \alpha_1 + \beta_1 x_1 \qquad (2)$$

The undetermined parameters α_1 and β_1 can be obtained by using the parameter inversion analysis

The basic type of the exponential function model is[6]:

$$S_t = S_0 + \alpha_2 e^{\frac{\beta_2}{t-t_0}} \tag{3}$$

Let $y_2 = \ln S_t, x_2 = \dfrac{1}{t}$, by (3), we have

$$y_2 = \ln \alpha_2 + \beta_2 x_2 \tag{4}$$

The undetermined parameters α_2 and β_2 can be obtained by using the parameter inversion analysis in the same way.

4. Comparison and analysis of measured data and fitting data

Figure 3 to figure 7 is the result of the numerical calculation of the field settlement observation data and the fitting model, thus it can be seen that:

1) The technical standard of the railway subgrade in the Saline Lake District stipulates that the settlement of the subgrade shall not exceed 300 mm after the subgrade. At this time, the final settlement of the subgrade center observation point B1 ~ B5 under the two fitting models is less than that of the limit. The field test data show that the subgrade of salinized sandy soil in the local area is vermicular. Overall, from the beginning of observation to 170 d, the fitting settlement of the two models tends to the actual observation data, which indicates that the fitting model reflects the actual situation of the subgrade settlement well. Prediction of hyperbolic function model of settlement is higher than the exponential function model after 170d, the hyperbolic function model to forecast the final settlement of the maximum in B4 observation point, where the data is 270.27 mm, the exponential function model to predict the final settlement maximum also appear in the B4 observation point, where the data is 203.89 mm.
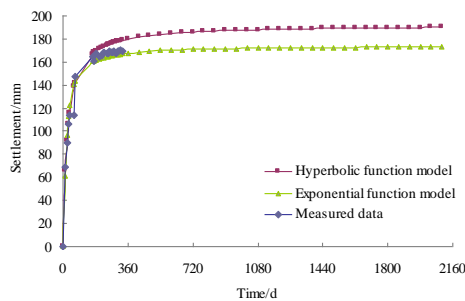

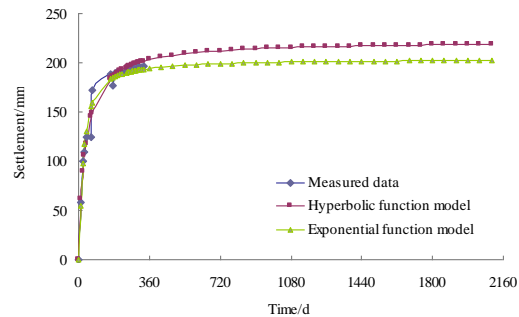Figure3. Settlement curve on point B1(DK40+658)   Figure4. Settlement curve on point B2(DK40+666)
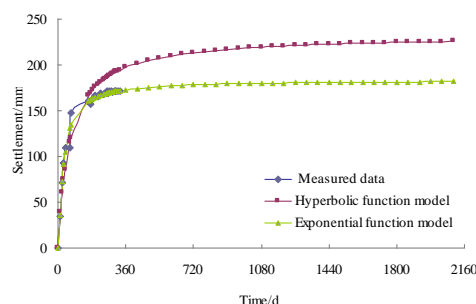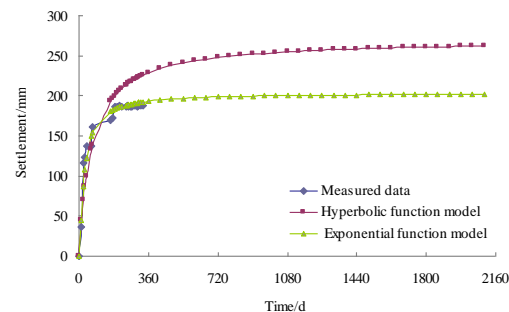

Figure5. Settlement curve on point B3(DK40+674)   Figure6. Settlement curve on point B4(DK40+682)
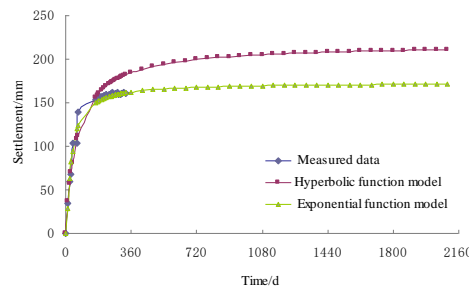
Figure7. Settlement curve on point B5(DK40+690)

2) The measured data are well correlated with the fitting data under the two models. It shows that the settlement tends to be stable, the hyperbolic function model is longer than the exponential function model, and the table 2 is the correlation coefficient R value under the two fitting models. Combined with the trend data and the data in the table, it is found that the two fitting models have higher fitting accuracy and reliability. In comparison, the exponential function model is better than the hyperbolic function model in terms of settlement curve or correlation coefficient.

Table 2. The correlated coefficient of different models

Observation point	Hyperbolic function model	Exponential function model
B1	0.9928	0.9873
B2	0.9893	0.9881
B3	0.9774	0.9933
B4	0.9454	0.9850
B5	0.9797	0.9910

3) Although the observation points of B1 ~ B5 were very close, but according to the measured data and the fitting results, due to the observational error, subgrade bottom salt shell thickness caused by different local bearing capacity differences, and different soil subgrade moisture content and salt content, so that each observation point fitting model parameters and predict the final settlement of the difference, as shown in table 3. This indicates that the settlement rule of subgrade is closely related to the above factors. It is necessary to further explore the influence of related factors on settlement by means of in-situ test or indoor test.

Table 3. The fitting parameters and final settlement under the different models

Observation point	Hyperbolic function model			Exponential function model		
	α_1	β_1	Final settlement /mm	α_2	β_2	Final settlement /mm
B1	0.0052	0.1296	192.31	174.1645	-13.508	174.16
B2	0.0045	0.1537	222.22	203.8124	-17.047	203.81
B3	0.0043	0.2775	232.56	183.5524	-21.477	183.55
B4	0.0037	0.2432	270.27	203.8939	-19.524	203.89
B5	0.0046	0.2976	217.39	173.1745	-23.345	173.17

5. Conclusion

In this paper, two nonlinear models are used to fit the settlement law of the salinized sandy soil subgrade in the local area. Research shows：

1) The settlement of the salinized sand soil subgrade increases rapidly in the initial stage, and then gradually becomes stable. According to the measured data and the model fitting results, it is found that the settlement can be stable after a long time.

2) By studying the settlement law and correlation coefficient of two kinds of fitting models, it is found that the exponential function fitting model can better reflect the rule of roadbed settlement in this area.

3) Because the exist of salt crust , and the influence factors of subgrade moisture and salinity as well as by the deformation caused by the seasonal frost area and so on, these factors make the settlement law become more complicated, so it is necessary to further explore the influencing factors on the engineering properties of saline soil subgrade through indoor test.

Acknowledgments

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