Technique study on dynamic consolidation of collapsible loess foundation

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Abstract. With large-scaled but poor engineering properties of loess in western China, especially the badly collapsibility, to deal with the collapsibility is necessary for high quality of highway construction. This paper aims at the site conditions of collapsible loess foundation in Tong-Huang express way of the second enterclose of Xi'an to Yan'an. By means of the real engineering test of dynamic compaction test, combined with the indoor experiment study and field test analysis, we got the related practical parameters of collapsible loess foundation. Testing result shows that those sections treated with dynamic consolidation is at high stability, and the dynamic consolidation can be applied in similar foundation treatment.

Introduction

Collapsible loess is a kind of undervoltage of unsaturated soil, with large pores and vertical joints. Under the naturalmoisture,it is with low compressibility and high strength. Once flooded under certain pressure, the soil structure would be destroyed quickly, and at the same time significant additional deformation has a great harm to the engineering program will show out.

Researches show that dynamic consolidation is an economical method to deal with the collapsed loess, and also the high function of weak compressibility loess. Effect of dynamic consolidation is obvious and the effect depth can be about 4.0-5.0m

Engineering project

Tong-Huang expressway, the second enterclose of Xi'an to Yan'an is an important section of national expressway network Bao-Mao G-65W in Shanxi. Started from western Xin district in Tongchuan, combined with Xi'an to Tongchuan expressway, towards Xin district at northwest, and goes through Guanzhuang, Anli, Shizhu, Yanchi, Wangjiahe, Jinsuo, stops at Hejiafang, and combined with the linking of Banjiegou and Huangling to Tongchuang, the first-class highway.

The 48.2km route is designed at 100km/h. Most loess along this route is of loose structure. According to the engineering situation of this highway, do researches for deformation characteristics of collapsible loess soil. Loess naturally has some features, such as, the structural strong, being under compaction state, having tiny elastic deformation and mainly being compaction deformation, including compressive deformation and collapsible deformation. Collapsible deformation is rapidly developing after immersion, which is greatly harmful to the engineer. The collapsible deformation of collapsible loess behaves as mutability, discontinuity, and inconvertibility. Coefficient of collapsibility is one of the major parameters for the evaluation of loess foundation at moment.
Determination of the coefficient of collapsibility:
Firstly, please get the field soil sample. Then using cutting ring cut it into some soil samples, according to 《Test methods of soils for highway engineering》 (JTG E40-2007). Finally, please make single line collapsibility test. The results are shown in Table 1.

Table 1 Coefficient of collapsibility under different load levels

Region	Pressure (10^2kPa)									Density	Moisture content
	0.5	1	2	3	4	5	6	7	8	(g/cm^3)	(%)
Yanchi	0.09	0.23	0.34	1.49	5.65	7.20	7.28	7.15	5.89	1.51	12.8
Wangjiahe	0.02	0.17	0.28	1.32	3.47	5.01	5.65	4.65	4.89	1.51	16.3

We reach decisions from Table 1

(1)Coefficient of collapsibility depends on the initial water content. And the coefficient of collapsibility is decrease going with the increase of initial water content.

(2)Initial water content has tiny impact on coefficient of collapsibility at the beginning .But the impact is more and more obvious with the increase of pressure.

This time makes a good deal of in-situ soil tests for Tong Huang highway at the area of Yanchi. All of the test site's data on the basis of different tests results is shown in Table 2, according to 《Collapsible loess building codes》(GB50025-2004)

Table 2 The statistical table of collapse type and collapsible level

Region	Depth of start-stop (m)	Thickness of collapsible loess (m)	Thickness of dead-weight collapsible loess(m)	Total content of collapsibility of loess(cm)	Collapse type	Collapsible level
Yanchi	1.5~9.3	7.8	5.3	41.2	own gravity	II (medium)
Wangjiahe	1.5~5.2	3.9	4.1	52.2	own gravity	II (medium)

Dynamic consolidation applied at the section between Yanchi and Wangjiahe, and then field test and indoor test carried out on the treated foundation, we can get the variation of ultimate bearing, collapsibility, compressibility parameters, shear strength index.

Experimental observations.

(1) The foundation ultimate bearing capacity test.

The main test method of ultimate bearing capacity of foundation is field loading test. We test the ultimate bearing capacity of foundation Respectively before flooded and after flooded the ultimate bearing capacity of foundation soil test results are shown in Table 3 . The flooded foundation soil bearing test results are shown in Table 4

Table 3 Ultimate bearing capacity of foundation soil test results

Region		Yancchi (kPa)	Wangjiahe (kPa)
Original Loess		130	125
After Dynamic Compaction	600kJ	280	302
	1000kJ	370	421
	1600kJ	472	452

Table 4 Flooded foundation soil bearing test results

Region		Yanchi (kPa)	Wangjiahe (kPa)
Original		95	90
After dynamic compaction	600kJ	240	223
	1000kJ	315	341
	1600kJ	385	378

After dynamic compaction ultimate bearing of foundation can reach at 280-480KPa,increased about 2.33-3.69 times.

Field loading test results show that the original loess bearing is at about 120-130KPa, 90-100KPa when flooded. The ultimate bearing decreased at 16.7-23.1%. When flooded, the dynamic compacted foundation ultimate bearing is 240-390KPa;decrease 14.3%-18.75%.

From those above we get that dynamic consolidation can meet the requirements of subgrade bearing capacity when the height of embankment is under 10m.

(2) Testing of basic physics properties index of foundation soil.

Estimated value of modulus of compression and coefficient of compressibility of loess (before and after dynamic compaction) is shown in Table 5.

Table 5 The foundation compresibility index value

Region	Disposition	Modulus of compression (MPa)	Coefficient of compressibility (MPa^{-1})
Yanchi	Before	17.85	1.35
	After	22.6	0.85
Wangjiahe	Before	12.7	0.73
	After	15.8	0.36

(3)Testing of shear strength index

Value of shear strength index before and after dynamic compaction is shown in Table 6

Table 6 Shear strength index of foundation

Region	Disposition	Cohesive force (kPa)	Internal friction angle ( )
Yanchi	Before	45	25
	After	82	30
Wangjiahe	Before	30	28
	After	52	35

(4)The foundation soil collapsibility coefficient detection

Collapsibility results of foundation before and after dynamic compaction are shown in Table 7.

Table 7 The foundation soil collapsibility coefficient

Treatment depth（m）		0.3	0.5	0.8	1.0	1.5	2.0
Yanchi	Before	0.125	0.135	0.132	0.087	0.089	0.091
	600kJ	0.006	0.007	0.003	0.012	0.009	0.009
	1000kJ	0.001	0.001	0.001	0.003	0.003	0.006
Wangjiahe	After	0.061	0.062	0.075	0.047	0.049	0.050
	600kJ	0.003	0.004	0.024	0.022	0.018	0.021
	1000kJ	0.002	0.002	0.003	0.004	0.003	0.004

Conclusions

(1)From the field foundation bearing test, after dynamic consolidation, the bearing of loess foundation is largely increase to 3.0-5.0 times of before. The bearing of loess foundation exceed 260kPa after dynamic compaction. The effected depth reaches 4.0-5.0m.

(2)According to the shear strength index of the test, the strength of foundation soil after dynamic compaction process is greatly increased. From the results, the coefficient of compressibility decreased largely.

(3)Collapsibility decreased largely after dynamic compaction, and the collapsibility of foundation deeper than 2m can be completely eliminated through larger level of dynamic compaction.

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