Discussion on Consolidation Effect of Dynamic Compaction Replacement on Special Soil

Chengliang Wang[1,a,*], Shasha Zhang[1] and Youlong Zhang[1]

[1]*China Aviation International Construction And Investment CO.,LTD., Beijing 100120, China*
a. wcl19831983@163.com
**Chengliang Wang*

Keywords: Dynamic compaction replacement, construction parameters, static cone penetration.

Abstract: Dynamic compaction replacement is an economical, simple and effective method for foundation reinforcement. Before construction, it is usually necessary to select typical test areas for experimental construction to determine its applicability and reinforcement effect, so as to guide large-area engineering construction. Especially, airport engineering has high requirements for roadbed settlement and uneven settlement, which meets the engineering quality. Under the premise of time limit and economy, it is particularly important to deal with soft soil foundation effectively. This discussion is based on the example of foundation reinforcement of Yanji Town in Ezhou, Hubei Province. Through the dynamic compaction replacement test in typical test area, the construction parameters are determined, and the rationality of dynamic compaction replacement method used in this kind of filling foundation is verified. At the same time, the special reinforcement effect caused by dynamic compaction replacement on the surface soil is studied.

1. Introduction

Dynamic compaction replacement is a method used to reinforce saturated soft clay foundation. The consolidation mechanism of dynamic compaction replacement method is different from that of dynamic compaction method. It uses the strong impact caused by the high drop of the heavy hammer to force the materials with better properties such as gravel, slate and slag into the foundation, forming one granular pier in the foundation, and the soil between the piers to form composite foundation, so as to improve the bearing capacity of the foundation and reduce the settlement. Dynamic compaction replacement method has the advantages of obvious reinforcement effect, short construction period and low construction cost so it has been used in engineering such as depot, highways, airports, housing construction and oil tank, especially, the airfield pavement for road base settlement and uneven settlement has high requirements. On the premise of satisfying project quality, time limit and economy, it is particularly important to deal with soft soil foundation effectively. In construction, we often need to use the static detection in the evaluation of dynamic consolidation effect of foundation treatment. In this construction, the reinforcement of soil surface soil is tested and studied based on the replacement method of high level dynamic compaction and we also discussed the special effect caused by construction of strengthening surface layer of soil and laid the foundation for the ZouMa lake project.

2. Project Summary

Zouma lake system comprehensive management project (airport supporting project) is located in Yanji town, Ezhou of Hubei province (including Zouma lake, Huangtian lake, Luosijing lake and other areas), and it is a basic project to guarantee the flood control safety of aviation metropolitan area and Ezhou airport in the future. The main project content of this period is to deal with the soft soil in the area of the lake area and carry out earthwork filling. This test section is a regional test before the formal construction of soft soil foundation treatment in the lake area. This regional test of dynamic consolidation replacement is divided into four dynamic consolidation replacement test areas, using the control variable method, as shown in the Table 1 below.

Table 1: Dynamic compaction replacement test area.

Process	Dredging Situation	Heap Load	Dynamic Compaction Energy Level	Cushion Layer	Partition Number
Dynamic Compaction Replacement	no dredging	/	2000N•m	√	Q1
	no dredging	√	3000N•m	√	Q2
	dredging	√	3000N•m	/	Q3
	no dredging	/	4000N•m	√	Q4

In the experimental area Q1 of dynamic compaction replacement, construction cushion is adopted for non-dredging. The single click compaction energy is 2000kN·m, and the estimated bottom depth is considered as the deepest 3.0m.

In the experimental area Q2 of dynamic compaction replacement, construction cushion is adopted for non-dredging. The single click compaction energy is 3000kN·m, and the estimated bottom depth is considered as the deepest 5.0m.

In the experimental area Q3 of dynamic compaction replacement, construction cushion is adopted for dredging. The single click compaction energy is 3000kN·m, and the estimated bottom depth is considered as the deepest 5.0m.

In the experimental area Q4 of dynamic compaction replacement, construction cushion is adopted for non-dredging. The single click compaction energy is 4000kN·m, and the estimated bottom depth is considered as the deepest 6.0m.

After the replacement of dynamic compaction in Q2 and Q3 test areas, the 1:2 discharge slope is filled to 20m elevation. Before the earth and rock filling, the whole area of 2-GZ-QH-6 should be replaced by dynamic compaction.

The number of single point ramming is determined through field trial ramming to reach the designed pier length (If it cannot be reached, the average ramming amount of the last two strikes should be less than 50mm).

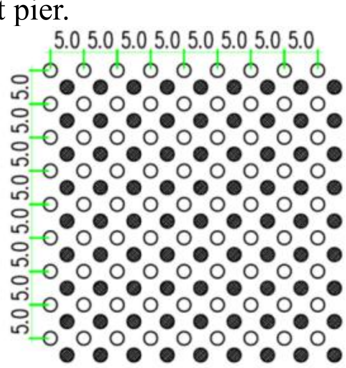
In the data obtained through control variables, the test results of Q4 area were finally taken as typical and analyzed.

3. Field Test of Dynamic Compaction Replacement Area

3.1.Plane Layout of Dynamic Compaction Displacement Test Area

The topsoil of this foundation treatment is soft so that the mechanical walking is difficult. The same material filler in the area is used to lay the construction cushion, and the thickness of the cushion is as thin as possible under the condition that the mechanical walking can be satisfied. The laying thickness of the construction cushion is determined through the test section.

According to the construction principle of "from inside to outside, alternate lines of ramming", all ramming points are completed according to the construction principle of soft foundation treatment with dynamic compaction replacement method. Figure 1 is for the plane layout of dynamic consolidation displacement pier.



○—the First time point compaction ●—the Second time point compaction

Figure 1: Plane layout of displacement pier of dynamic compaction.

3.2.Determination of Experimental Construction Parameters

The replacement of dynamic compaction is mainly to use the high impact caused by the high drop of the heavy hammer to force the materials with better performance into the foundation, which can form one granular pier in the foundation a composite foundation between the pier and the pier, so as to improve the bearing capacity of the foundation and reduce the settlement.

Technical parameters of dynamic compaction replacement composite foundation treatment in this project:

(1) The replacement of dynamic compaction adopts the column hammer to impact holes and the layered filler to expand and squeeze, so as to achieve the purpose of squeezing silt and draining water to accelerate consolidation. The replacement of dynamic compaction adopts the column hammer with a diameter of 1.2m and a weight of about 15t. The diameter of ramming and expanding piers is 2.0m. When the thickness of soft soil is 2~3m, 2000kN•m dynamic compaction is used for replacement. When the thickness of weak soil is 3~5m, 3000kN•m dynamic compaction is used for replacement. When the soft soil is larger than 5m, 4000kN•m dynamic compaction is used for replacement. The energy level of 1000kN•m should be increased in the local area containing hard shell layer or hard soil inter layer. The dynamic compaction should be replaced by 2 times point compaction.

(2) The replacement filler of dynamic compaction should be made of well-graded hard and coarse particle materials such as block stone and gravel. The particle size should be 10-30cm. The particle size larger than 30cm should not exceed 30%, and the particle size smaller than 10cm should not exceed 20%.

(3) Prior to the replacement of dynamic compaction, gravel layer should be laid according to the actual site conditions to facilitate the construction of compaction machine. Construction from all sides at the same time, not from one side to the other side of the construction sequence. After the completion of construction, bulldoze the site and use the single click ramming energy of 1000kN•m for full ramming. The hammer seal lap joint shall be no less than 1/4.

4. Test

4.1.Pore Water Pressure Monitoring

In order to determine the interval between the first and second compaction, we monitored the pore water pressure growth and dissipation, as Figure 2, Figure 3, Figure 4 show.

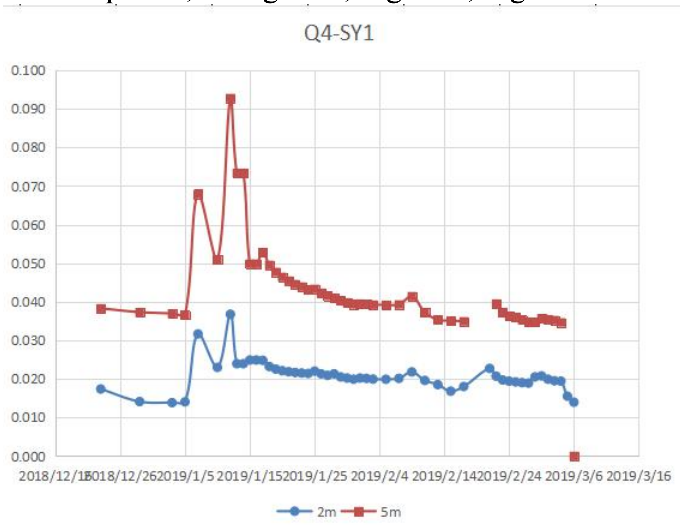


Figure 2: The pore water pressure growth and dissipation of Q4-SY1.

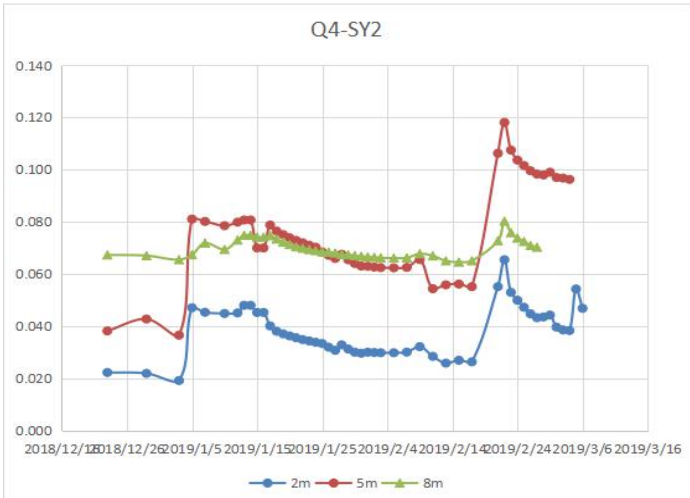


Figure 3: The pore water pressure growth and dissipation of Q4-SY2.

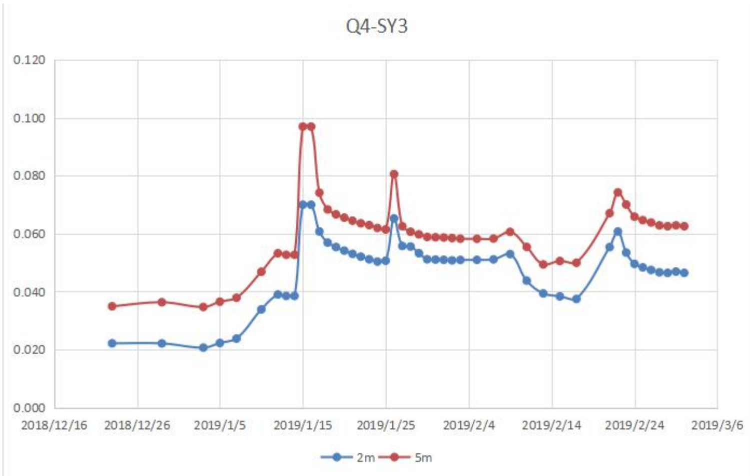


Figure 4: The pore water pressure growth and dissipation of Q4-SY3.

By analyzing the observation data of three observation points at depths of 2 meters, 5 meters and 8 meters, in addition to rainy days, the linear change of pore water pressure in a period of about 7 days is flat or decaying. It can be judged that the dissipation period of pore water pressure is about 7 days, so the interval time between the first and second compaction is about 7 days.

4.2.Static Penetration Test

Static penetration test was carried out before and after the construction of the dynamic compaction, one test was conducted before the replacement of the dynamic compaction, and another test was conducted on 3, 10, 15 and 28 days after the replacement of the dynamic compaction so that we could determine the compression modulus of soil in the depth of effective consolidation before and after compaction, as well as the compression modulus of the underlying soft soil after dynamic compaction. Figure 5-8 are the curves obtained from the experimental results.(X-axis is static penetration value(MPa) and Y-axis is the depth(m).)

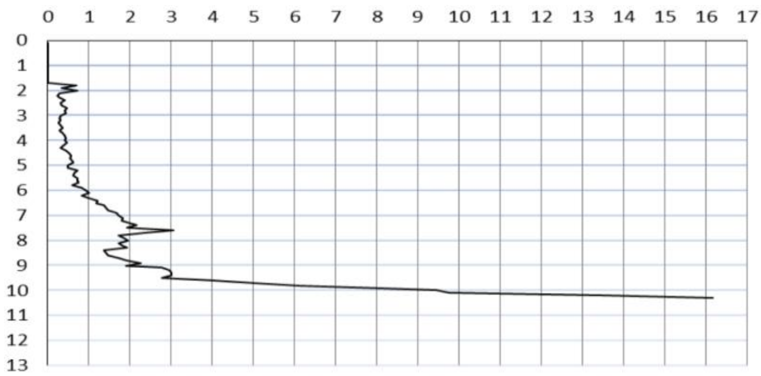


Figure 5: Static penetration curve of no. 1 pile before dynamic compaction replacement.

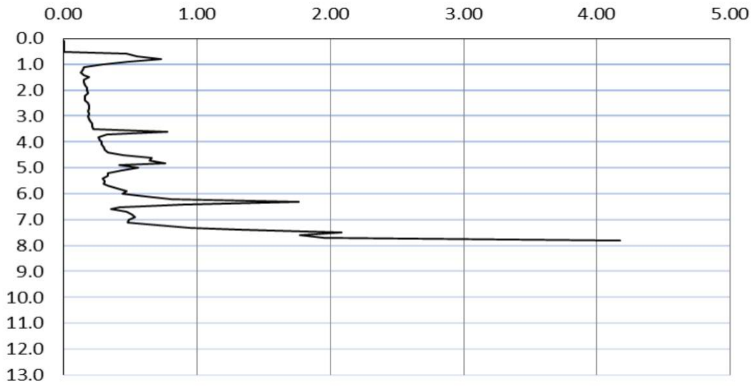


Figure 6: Static penetration curve of no. 1 pile after dynamic compaction replacement.

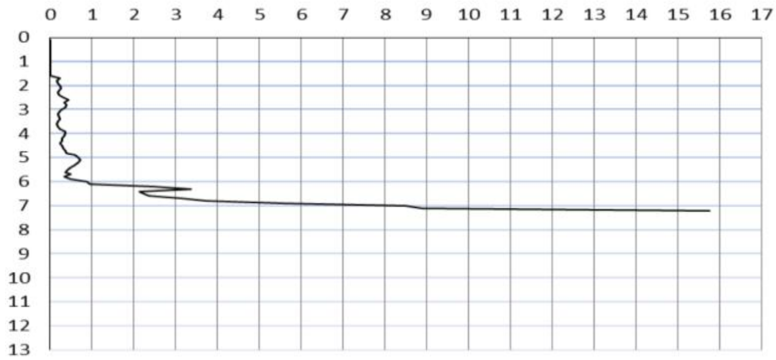


Figure 7: Static penetration curve of no. 2 pile before dynamic compaction replacement.

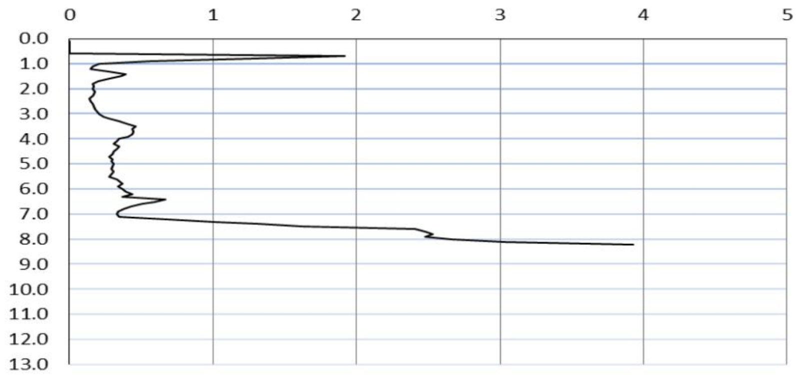


Figure 8: Static penetration curve of no. 2 pile after dynamic compaction replacement.

	Check point number and coordinates	Sampling depth/m	The basic physical properties of natural state							Liquid limit	Plastic limit	plasticity index	Liquidity index	Named according to plasticity index and particle composition
			specific gravity	water content	wet density	dry density	void ratio	poro-sity	satura-bility					
			Gs	ω %	ρ g/cm^3	ρd g/cm^3	e	n %	Sr %	W_{L10} %	W_P %	I_P	I_L	I_{P10}
1#-1	P174+2.55/H110+11.38	1.0-1.2	2.75	44.3	1.90	1.32	1.089	52	100	46.8	28.6	18.2	0.86	Clay
1#-2		5.0-5.2	2.72	27.0	2.01	1.58	0.719	42	100	30.5	19.3	11.2	0.69	Silty clay
1#-3		6.0-6.2	2.70	24.6	2.05	1.65	0.641	39	100	28.5	20.4	8.1	0.52	Silt
1#-4		7.0-7.2	2.72	19.9	2.02	1.68	0.614	38	88	32.0	18.5	13.5	0.10	Silty clay
1#-5		9.0-9.2	2.72	23.4	1.96	1.59	0.712	42	89	31.8	17.5	14.3	0.41	Silty clay
2#-1	P174+10.05/H109+18.88	0.6-0.8	2.63	66.6	1.68	1.01	1.608	62	100	58.8	32.5	26.3	1.30	Sludge
2#-2		3.0-3.2	2.64	58.4	1.63	1.03	1.565	61	98	55.8	30.6	25.2	1.10	Sludge
2#-3		6.3-6.4												Fine sand
2#-4		8.2-8.4	2.70	18.8	2.00	1.68	0.604	38	84	23.7	14.8	8.9	0.45	Silt

Figure 9: Soil sample report.

According to static penetration data and static penetration curve, before the replacement of dynamic compaction, the resistance of filling the surface layer of soil foundation is very small. The static penetration value of pile 1 and pile 2 before 1.6m depth is almost 0, but it can reach about 0.73MPa at depth of 0.8m after construction, and then it declines rapidly. After construction, the penetration value of no. 2 pile at 0.7m can reach 1.92MPa, and then it declines rapidly, too. According to the soil sample report obtained from the soil test as Figure 9 shows, it can be judged that the hardness performance of silt layer after compaction is better than that of other soil layers, and the consolidation effect is more obvious. Except silt soil, the resistance of other soil layers increases exponentially with depth.

4.3.Standard Penetration Test

Standard penetration tests were carried out in the test area before and after the test to detect the effect of dynamic compaction in the depth. The test results with the test depth of 4.2m show that the number of hammer strikes in the displacement test section of 4000kN• m dynamic compaction is 18-20, with obvious reinforcement effect.

4.4.Static Load Test

In the field test, the slow maintenance load method was adopted to load the oil pump step by step, which was divided into 12 stages. The first stage load was 1/6 of the estimated graded load, and then it was added to the estimated ultimate bearing capacity. The settlement of pile top shall be measured and read every 5, 15, 30, 45 and 60 minutes after each stage of loading. After that, the settlement of pile top shall be measured and read every 30 minutes. The stability standard is that the settlement of the pile top is less than 0.1mm per hour for two consecutive times under the action of each grade of load (calculated from three consecutive observations within 1.5h). Pile q4-1-33 was loaded to 1440kN, which took 210 minutes, and the settlement totaled 40.06mm, reaching the final loading condition. Therefore, 1320kN of the first class is taken as the ultimate load, and its bearing capacity characteristic value is 660kN, which is shown in Figure 10.

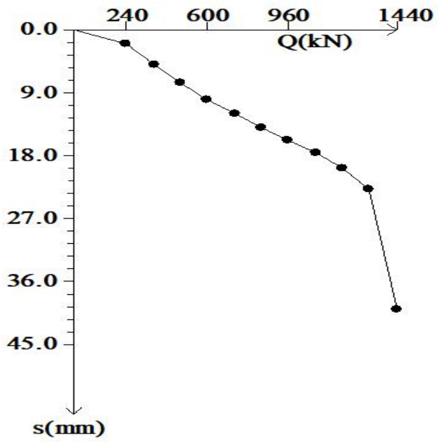


Figure 10: static load test curve.

4.5.Pier Detection(Super Heavy Power Dynamic Penetration Test)

Stake number	41#	Point coordinate	P109+11.249/H173+14.375/Z=14.80	Test date	2019.01.07
Depth (m)	Blow counts	Depth (m)	Blow counts	Depth (m)	Blow counts
0.1	5	1.6	2	3.1	4
0.2	3	1.7	2	3.2	4
0.3	3	1.8	3	3.3	4
0.4	3	1.9	3	3.4	5
0.5	4	2.0	2	3.5	5
0.6	3	2.1	1	3.6	5
0.7	3	2.2	3	3.7	4
0.8	2	2.3	3	3.8	3
0.9	3	2.4	2	3.9	2
1.0	3	2.5	3	4.0	1
1.1	2	2.6	3	4.1	1
1.2	3	2.7	4	4.2	1
1.3	2	2.8	3	Stop	Blank
1.4	2	2.9	4	/	/
1.5	2	3.0	2	/	/

Note: The hammer weighs 120 kg.

Figure 11: Results of super heavy dynamic penetration test.

The density, length, bottom contact, bearing capacity and density of the pier are measured by heavy-duty dynamic sounding. The load test of displacement pier is mainly to determine the characteristic value of compressive bearing capacity and deformation modulus of the displacement pier.

According to the comprehensive analysis of dynamic sounding data, as Figure 11 shows, the compactibility of soil mass roughly determined by super-heavy dynamic sounding data is consistent with the distribution of actual soil layer, which is of comparative significance with coring test. After tamping, the depth of reinforcement passes through the filled soil, silt and fine sand layer and enters the bearing layer. Under the depth of 4m, the reinforcement is slow to sinking, which indicates that the reinforcement of the dynamic compaction crushed stone pier has a good reinforcement effect on the soil between piles within the construction limit.

5. Conclusions

According to the study of typical test areas under the control variable method, the replacement and reinforcement scheme of dynamic compaction is feasible and the reinforcement effect meets the design requirements.

After reinforcement, the characteristic value of bearing capacity reached 660kN, the number of dynamic penetration in the range of filling was significantly increased, and the average number of standard penetration penetration was up to 18-20 so the reinforcement effect is obvious.

In the field construction inspection, static load test is used to determine the bearing capacity of the foundation, and it can be judged that the silt layer has a better hardness performance than other soil layers and the reinforcement effect is more obvious after the compaction effect superposition.

The dynamic consolidation replacement project has laid a foundation and provided a guarantee for the basic project of flood control safety in the aviation region and Ezhou airport in the future.

References

[1] GUO Wendong. Experimental research on dynamic compaction replacement for reinforcing filling foundation[J]. Industrial Architecture, 2006, 36, pp. 680-682.

[2] DU Jing. Research on dynamic compaction replacement technology for saturated soft soil roadbed of Yingkou Airport[J]. North Traffic, 2019, (6), pp. 62-65.

[3] LIU Binbin, Liu Kun. Application and study on dynamic compaction and replacement of macadam pier in the Coastal Petrochemical Railway Engineering[A]. Railway Construction Technology 2015 (4), pp. 89-93.

[4] LUO Qitian. Study of vibration attenuation laws when reinforcing soft foundation by high energy level dynamic replacement.[B] HIGHWAY, 2018, 5, pp. 60-62.