Filled ground site investigation and ground treatment testes of five ring circuit Fushi road in Beijing

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Abstract. The project is located at the interface point of Fifth Ring Road and Fushi Road in Beijing, China. The filled ground depth was 32.6m. There are Fushi Road multi-level crossing bridge, circular route bridge, rain water pipeline and main road foundation on the filled ground. According to the geotechnical investigation, the filling soil layer includes miscellaneous filling soils, domestic waste filling soils, pebbles filling soils, fine and medium sand filling soils and so on. The characteristics of backfilled soils consist of short consolidation time, the bad constitutive property, low bearing capacity, and high factor of porosity. In the period of site investigation, the ground water had not been met in the 50m depth drill hole. The thick location sector of backfilled soils in the site were chosen to carry on the experiment of heavy tamping (3000 kN.m), ram-compacted piles and the DDC piles composite foundation. And the composite foundation testes were carried out with load test, the compaction effects of ram-compacted piles and the DDC piles were determined with heavy dynamic penetration tests. The heavy tamping (3000kN.m, 4000kN.m and 6000kN.m), ram-compacted piles and the DDC piles composite foundation were carried out in site. After foundation treatment was completed, the load tests and heavy dynamic penetration tests were used to determine the bearing capacity and compaction effects of foundation. After foundation treatment was completed, it had been arranged 61 subsidence observation points in the ground processing location. According to the settlement observation result, the maximum settlement was 26.97mm, which was less than 200mm of post-construction settlement required by the design, and it proved that the effect of the foundation treatment was very good.

Key words: filling soil layer; heavy tamping; ram-compacted piles composite foundation; the DDC piles composite foundation; load test; dynamic penetration tests; subsidence observation.

1. Introduction
The project is located at the interface point of Fifth Ring Road and Fushi Road in Beijing, China. The north-south width of filling soil pit is 900m, and east-west length 950m, the great depth 32.6m. There are Fushi Road multi-level crossing bridge, circular route bridge, rain water pipeline equipotential line and main road foundation on the filled ground. the backfill time is short, filling ingredients are uneven and filling depth is very deep.

2. Geotechnical engineering condition
According to geotechnical engineering investigation report[1], filling soil layers and its characteristics are as follows, engineering geological profile in Fig 1.
Figure 1. Engineering geological profile

2.1. Artificial Filling Soil
a. Miscellaneous filling soils: ①: Mottled; slightly wet to wet; loose to slightly dense. It is composed of bricks, ashes, concrete blocks, gravels, pebbles, and clay soil. The thickness of layer is from 1.00m to 32.60m and the layer bottom elevation is from 34.39m to 65.24m.
b. Domestic waste filling soils:①: Mottled; slightly wet to wet; loose to slightly dense, containing a small amount of brick, ashes and clay. The layer thickness is from 0.70m to 6.90m.
c. Pebbles filling soils:①: Mottled; slightly wet to wet; loose to slightly dense. The general diameter of the object is from 2cm to 6cm, the maximum is greater than 10cm, filling in fine sand, clay, small amount of brick and ashes. The layer thickness is of 0.30m ~ 8.00m.
d. Silt clay filling soils:①: The color from tan to brown gray slightly wet ~ wet, plastic, slightly dense. With brick dust, ashes, pebbles, round boulders. The layer thickness is of 0.30m ~ 12.50m.
e. Clayey silt filling soils:①: The color from tan to brown gray slightly wet ~ wet, plastic, slightly dense. With brick dust, ashes, pebbles, round boulders. The layer thickness is of 0.50m ~ 5.40m.
f. medium- fine sand filling soils:①: Tan color, slightly wet ~ wet, slightly dense. The main filling ingredients are medium- fine sand and it also includes broken bricks, ashes, pebbles and round boulders. The layer thickness is of 0.30m ~ 4.90m.
2.2 General Quaternary Sedimentary Layers
Gravel: Mottled, wet, and medium dense. The general diameter of the object is from 2cm to 6cm, the maximum is greater than 10cm. It is composed of sandstone, limestone and 30% ~ 40% fine sand, filling in fine sand, high liquid-limit clay or sand lenses. The layer thickness is greater than 24.00m.

2.3 Groundwater
In the survey period, no underground water was found within the borehole depth of 50 m.

2.4 The nature of the geotechnical engineering filling Soils
The thickness of filling soils: According to the drilling, exploratory well expose, geophysical prospecting, geological surveys and comprehensive analysis of the existing data, the filling soil thickness is 3.00m to 32.60m.

The Analysis of the geotechnical engineering filling soils: To evaluate the type of backfill, density, compression modulus, bearing capacity and other parameters, we use in-situ testing, shear wave velocity, load test and other methods to evaluate and analyze them respectively.

In-situ Testing: Field tests were conducted using a continuous penetration of heavy dynamic penetration test to detect the density and uniformity of the filling. As its mainly filling is mixed filling (construction waste), the heavy dynamic penetration test hammering hit number range is from 1 to 180, with an average 11 attack, coefficient of variation 1.39 and index number 360.

The large scope of hammering hit changes shows the poor uniformity nature of the filling and the significant change.

Shear wave velocity: Shear wave(S wave) velocity inspection level test were carried out in 10 boreholes to detect the Vs of different layer. Testing from the surface to the end of hole, the soil filling scope is 120m / s to 380m / s, the Vs scope of pebble is 400 ~ 500m / s. The great variation of filling value of wave speed shows the uneven nature of the filling soil.

Load tests: In the survey scene, we made four load tests near the boring holes 19#, 22#, 37# and 49#. The test depth is under subsurface 0.40m, soil for the mixed filling, pressure plate area of 0.5m2, the standard value of the bearing capacity of 90 kPa ~ 110kPa, average 100kPa, the deformation modulus of 5.60 MPa ~ 7.00MPa.

According to survey and drilling exploration, filling ingredients mainly includes construction waste, clay plain fill, some garbage, etc. Due to the complex composition filling, the backfilling method, thickness, and time are random. It shows poor structural, non-uniform and low intensity. As without compaction, the soil becomes loose, porosity high, collapsibility after wet. It is proposed to eliminate the collapsibility of the filling and increase its carrying capacity.

3 Foundation Treatment Scheme

3.1 Practical Tests
According to the Foundation Treatment experience in Beijing, heavy-tamping, ram-compacted piles and the DDC piles composite foundation were carried out in site. According to the technical code for ground treatment of buildings(JGJ79-2002)[2], the three methods are often used for filling ground treatment, we choose the thick sections for the testing of the heavy-tamping (3000kN.m), ram-compacted piles and the DDC piles composite foundation[3]. Drilling and heavy dynamic penetration test were detected before the testing, with the heavy dynamic penetration test hole between of the DDC and plum-shaped rammed pedestal pile.

After the testing in the same region the heavy dynamic penetration test was carried out to compare the compaction effective and influence depth. According to the load tests and heavy dynamic penetration test, the results of various programs on the filling of foundation treatment effect are as follows[2]:

a. The ram-compacted piles, the DDC piles composite foundation and heavy-tamping foundation should meet the requirements of the design requirements 220kPa bearing capacity.
b. The influence depth of the rammed pedestal pile is 2 m ~ 4m under the pile. Under the pile length and depth impact, the compaction effects raised to 51.3% ~ 119%. DDC pile's influence is 4m under the pile. The compaction effects were 143%; tamping (3000kN.m) affects the depth of 6.0m.

3.2 Foundation Treatment
According to previous test results, we determine to use heavy-tamping (3000kN.m, 4000kN.m, 6000kN.m), ram-compacted piles and DDC piles composite foundation.

3.3 Construction of Foundation Treatment
On the status of lots of water in the Fushi gravel pit, we should extract water and dredge. The first layer we should fill grading gravel with thickness of 2.0 m ~ 3.0m, layered crushed; and the second layer of backfill 10.0m of the soil filling, using 6000kN.m tamping energy; the third layer to the sixth layer, layered backfill 5m after the filling of the main road 4000kN.m tamping energy, in areas outside the main road using 3000kN.m tamping. The main road 3 +220 ~ 3 +436,3 +600 ~ 3 +700 paragraph does not require stratification back filling, while rammed pile or pile foundation DDC treatment was carried. We deal with the 5 to 7 line of rainwater pipeline using rammed pile composite foundation.

4 Ground Treatment Effect Detection
Taking into account the complicated ingredients of sand and gravel pit backfilling, great depth and short time, the heavy dynamic penetration test and load test was used. The heavy dynamic penetration test is for the compaction effective of the soil filling and influence depth of the rammed pedestal pile and DDC compaction pile. The load test is for the value of bearing capacity of composite foundation or heavy tamping foundation.

4.1 Load Test
0.5 m² load plate is used between heavy tamping foundation and DDC compaction pile. Rammed pile composite use 0.81 m², 1.46 m², 2.40 m² load board. Load test was implemented according to The People's Republic of China national standard, "Code for design of building foundation" (GBJ7-89)[2] and the People's Republic of industry standard "Technical code for ground treatment of buildings" (JGJ79-91)[4].

4.2 Dynamic Penetration Testst
According to the code for investigation of geotechnical engineering(GB50021-2001)[5], Dynamic penetration test with hammer weight 63.5kg, recording the number of penetration 10cm hammer. The depth of the heavy tamping foundation's dynamic penetration test is related to the thickness of fill layer and depth affect, which is not thin than the heavy tamping layer.
Rammed pile testing depth: the main section of the holes depth is to the original pebbles, and other section's holes depth is 10.0 m to 12.0m.
DDC compaction pile testing depth: below 4.0m of the pile (the detection depth is 12.0m). Ram pile and DDC compaction piles carry out testing in the center of the plum-shaped pile.

4.3 Testing Results [5]
a. Test results based on load test, the standard value of bearing capacity of pile crossing the main sections of composite foundation is not less than 250kPa which can meet the design requirement. About other sections of composite foundation bearing capacity, the standard value is not less than 200kPa which can meet the design requirements. About the heavy tamping main section, the foundation bearing capacity is not less than 200kPa which can meet the design requirements. The standard value of bearing capacity of soil between DDC piles is not less than 200kPa which also can meet the design requirements.
b. The dynamic penetration test
The average number of hammer blow in the affected depth scope of heavy tamping test is not less than 15 blow. The average number of hammer blow in the affected depth scope of DDC compaction piles is not less than 15 blow. The average number of hammer blow in the affected depth scope of rammed pedestal piles is not less than 10 blow. All of them can meet the requirements of 8 blow by the design.

5 Subsidence Observations
After the foundation treatment, according to the design requirements, 61 observation points was layout in the venue to observe the foundation treatment results. The observation time is from June 2002 to June 2005. the settlement was meet the standards of 1mm/100d, the settlement observation effects were the largest settlement of 26.97mm, general settlement value of 14.0mm ~ 18.0 mm. The observed settlement value were less than 200mm of post-construction settlement required by the design,subsidence observation results show that the foundation treatment effects well.

6 Conclusions
According to surrounding environmental conditions, the heavy tamping, ram-compacted piles and the DDC piles were carried out in site. After the load test and heavy dynamic penetration tests, it shows that it can meet the design requirements. Settlement observation data in site proved that the effect of the foundation treatment settlement was the largest 26.97mm, less than 200mm of post-construction settlement required by the design.

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