Application of Premixed Solidified Soil in Backfilling of Foundation Trench

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Abstract: Taking integrated pipe gallery of Tongzhou City Sub-center in Beijing as studied project, the research on the formulation of solidified soil and its preparation process were carried out for the silty clay and sandy soil samples on the site. The parameters were analyzed by finite element software simulation, which in results show that the ready-mixed fluidized solidified soil is characterized by high strength, self-compacting performance, impermeability, water stability, construction performance, and economic performance. It is in advanced compared with the traditional backfill materials. The application of solidified soil technology needs to be developed to adapt special equipment. After 7 days of placing the concrete structure, in view of factors of construction quality and construction period, the concrete structure is selected to be demolished for backfilling of the pre-mixed fluidized solidified soil, with single backfilling 0.5 meters and 1 meter respectively. The impermeability and water stability of the ready-mixed fluidized solidified soil are qualified. but the resistance to freezing and thawing is unacceptable. The mixed fluidized solidified soil should be backfilled in the area below the frozen soil layer.

1. Introduction

The administrative office of Beijing City Sub-Central is near the Sixth Ring Road. The comprehensive pipe corridor project in the administrative office start-up area includes a total of 9 roads. The pipe gallery project is with high standards, strict requirements, large scale, complete functions, wide construction range, and multiple crossover operations, and there are many backfill projects for comprehensive pit manure trenches [1 ~ 2], as follows:

1) The working surface is narrow: the fertilizer tank is 3.5m and 1m wide, with depth 19m, and there is a special section. There are many horizontal braces and scaffolds that have not been dismantled. Enormous equipment is unavailable for compaction fill, so the traditional compaction process is given up.

2) Small allowable post-construction settlement: The comprehensive pipe corridor is used for road construction after backfilling completed, so the post-construction settlement requirements are controlled strictly.

Therefore, to study new-type foundation trench filling technology for small spaces with open cut method and short construction period is needed now.

The foundation trench filling material [3] needs to have a certain strength and impermeability. Soil solidification technology is available because it meets the requirements of building a conservation-oriented society in China.

Since the 1950s, extensive researches on soil solidification technology has been found in foreign countries, especially in the past 20 years. Soil solidification technology has developed rapidly. China
began to introduce foreign soil solidification technology in the 1980s, and developed a series of soil solidification technology [5].

Fluidized solidified soil is of a guide for the backfilling of foundation trenches in the future. Mixing different types of curing agents, which is better than the traditional ways, is a correct research direction.

2. Study on Preparation Technology of Solidified Soil
According to the design of “composite mineral+ chemical excitation”, the project gained the formula of composite mineral curing agent, through experimental research. By the formulation experiment, the mix ratio of ready-mixed fluidized solidified soil suitable for the base trench backfill of this project was found.

2.1 Preparation of key control parameters
During the preparation of the solidified soil, controlling the fluidity (slump) of the slurry in construction process is significant, to avoid accidents caused by insufficient slump control which leads to weak strength of the final solidified soil. Controlling the slump can not only ensure the quality of the construction, but also takes advantages of the “fluid” of the ready-mixed fluidized solidified soil [6].

Fig1 Effect of the amount of cementing material on the strength
From Figures 1 and 2, increasing the slump will weakens the strength of the solidified soil, but increasing the amount of cementitious material will enhance its strength. Therefore, the slump of the solidified soil required for engineering construction should be determined first. The content of other materials is determined according to the strength of the backfill material required for the project, and the slump should be controlled between 150mm and 200mm.

2.2 Related supporting equipment
In construction of the integrated pipe gallery of the Tongzhou City Sub-center in Beijing, supporting equipment systems for the production of ready-mixed fluidized solidified soil, including storage equipment, slurry mixing equipment, solidified soil mixing equipment, and metering and conveying equipment, were developed. The special mixer for solidified soil is the core of the whole system. To stir the slurry evenly, the tank body of the mixer adopts tandem double-cylinder tangency arrangement, and the horizontal stirring rods on the vertical main stirring shaft are staggered. The two main shafts can do the same or divided rotation. Through this combined structure and working method, the filled materials is mixed well to produce fluidized solidified soil.

3. Research on Backfilling Process of Solidified Soil
3.1 Construction process
The backfilled trough of the solidified soil is centrally mixed by a mixing station, and transported to the site by vehicle for pouring. The construction process is as follows:
Inspection of soil quality → test of solidified soil ratio, determination of formula of curing agent →
inspection of solidifying agent → determination of ratio of solidified soil → stirring of solidifying agent
slurry → transportation → stirring of solidified soil → cleaning of tank bottom → layered pouring →
vibration Pounding → Maintenance → Construction completed.

3.2 Research on Backfilling Key Control Parameters

The pouring time and single pouring height of the ready-mixed fluidized solidified soil are the key to
control parameters to ensure the safety of construction and the quality of backfill of the foundation
trench. Therefore, based on the Midas GTS finite element simulation software, the analysis and research
have determined the key control parameters.

3.2.1 Study on Backfill time

In order to study the optimal backfilling time for fluidized solidified soil,
the backfilling time was selected as 3d, 7d and 14d after the concrete was poured, and the backfilling
thickness was selected as 0.5m.

Numerical simulation was carried out by Midas GTS NX software. The stratum parameters are
shown in Table 1.

The numerical simulation model, of the backfilling time of the solidified soil, is shown in Figure 3.
Through numerical simulation, the displacement of the concrete structure of the pipe gallery is analyzed
to compare the effects of backfilling at different times.

| Material | Test weight /kN/m³ | Cohesion /kPa | Internal friction angle /° | Elastic Modulus /Mpa | Poisson's ratio |
|----------|-------------------|--------------|--------------------------|---------------------|----------------|
| Silty clay | 19.8              | 50           | 21                        | 7.1                 | 0.24           |
| sand     | 19.5              | 50           | 19                        | 5.2                 | 0.26           |

The displacement clouds at different backfill times are shown in Figure 4. The maximum
displacements of the backfill side wall structures after 3d, 7d, and 14d of concrete pouring were 16.2mm,
2.65mm, and 2.48mm, respectively. The results show that when the pipe gallery structure is backfilled
with solidified soil after 3 days of pouring, the side wall displacement will be large due to the weak
concrete strength, which may cause cracks. It is not conducive to the later structure waterproofing and
durability. Therefore, in the case of ensuring the quality of the structure, the demoulding is performed
after the concrete structure is poured for 7 days to backfill the premixed liquid solidified soil.
3.2.2 Study on Single Backfill Thickness

There is a balance point in the setting of the single backfill thickness. Too small a setting value will delay the construction period, while too large will affect the structure. In the case of combining the specific capacity of the mixing station, the single backfill thickness is selected as 0.1m, 0.5m, 1.0m, and 1.5m in order. When 7 days since constructing the concrete, the horizontal and side displacement of the backfill soil with different thicknesses are analyzed. The internal force of the side wall, in which the word is backfilled with a thickness of 1 meter, is shown in Figure 5, and the analysis results are shown in Figures 6 and Figures 7.

The results of calculation and analysis shows:

One-time backfill of 0.1 m, 0.5 m, 1 m, and 1.5 m, the pipe gallery structure is in a safe state under the action of solidified soil; on the side wall displacement of the pipe gallery structure, the shallower
one-time backfill depth is, the smaller the structure displacement will be. With earth pressure of backfilling solidified soil, the bending moment is the largest and the smallest when on-time backfilling is 1.5 meters and 0.1 meters, respectively.

To complete the project requirements on schedule, reduce the impact of backfill on the existing structure of the pipe gallery and ensure the safety of the structure, one-time backfill of 0.5 meters and 1 meter were selected for construction.

4. Application effect test
The quality of backfilling, as a significant process in construction, directly affects the performance of the entire foundation pit project. Therefore, much attention should be paid to adopt scientific and reasonable technical measures to strictly control the quality of backfill.

The testing of the filling effect of ready-mixed fluidized solidified soil mainly includes two aspects: irrigability testing and strength testing.

With the experience of construction of the comprehensive pipe gallery of the Tongzhou Sub-center in Beijing, a systematic and complete ready-mixed solidified soil production and construction process in the ready-mixed fluidized solid soil filling project was founded. The corresponding enterprise standard called "Technical Standards for Filling Engineering of Ready-Mixed Fluidized Soil" has been made.

After maintenance of the Tongzhou comprehensive pipe gallery foundation trench backfill project, the core samples were sent to the National Construction Engineering Quality Supervision and Inspection Center for testing. The intensity data in feedback was satisfied and, the effect of the backfilling of the ready-mixed fluidized solidified soil met the engineering requirements, approved by supervisors. The effect of site backfill is shown in Figure 8.

This project also conducted indoor durability tests, including impermeability test, water stability test and freeze-thaw test. The results show that the anti-seepage performance and water stability of the ready-mixed fluidized soil performed better, but the freeze-thaw resistance was poor.

5. Conclusions
Based on the comprehensive pipe gallery of Tongzhou Urban Sub-center in Beijing, this paper conducted research on the preparation process of solidified soil, and used finite element software simulation for key construction parameters of the backfill time and height of the backfill. The following conclusions were obtained:

1) The ready-mixed fluidized solidified soil is characterized by strength, self-compacting performance, anti-leakage performance, water stability performance, construction performance, economic performance, which are better than traditional backfill materials.

2) To make the backfilling process, of the base tank with ready-mixed fluidized solidified soil, more convenient, it is necessary to develop special equipment supporting the technology of solidified soil, to form a streamline for the production and transportation of solidified soil.

3) A numerical simulation study was made on the pouring time and the height of a single pouring of solidified soil. Considering the factors of construction quality and period, the mold was dismantled and backfilling of premix the fluidized solidified soil was started after 7 days of concrete structure, with 0.5m and 1m backfilling for single construction.

4) By Tongzhou field application and indoor test, it was observed that the strength, impermeability and water stability of the ready-mixed fluidized solidified soil are good. A water-proof curtain is formed around the underground structure to better the waterproofing of the underground structure. However, the freeze-thaw resistance is poor, and the mixed solidified soil should be backfilled in the area below the frozen soil layer.

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