Application Analysis of Foundation Pit Monitoring Technology in Geotechnical Engineering

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Abstract. In the process of foundation pit excavation, due to the comprehensive influence of many complex factors and the fact that the theoretical predicted value cannot accurately, comprehensively and fully reflect the various changes of the project, it is particularly important to monitor the foundation pit in real time. During the construction of pile foundation and soil reinforcement, due to the damage of soil stress balance, it will have a certain adverse impact on the surrounding buildings (structures), roads and pipelines. In order to ensure the normal construction and use of the project, the surrounding buildings (structures), roads and underground pipelines should be monitored periodically, and the construction scheme should be timely adjusted according to the monitoring results.

1. Introduction
The demand for land space in urban economic development is increasing day by day, and the aboveground space can no longer meet the demand for land use, so underground engineering is more and more favored[1]. As a part of underground engineering, foundation pit engineering cannot be ignored in civil engineering or other engineering fields. During the excavation of the foundation pit, due to the influence of many factors, it will cause damage to the underground foundation and surrounding roads and underground pipelines. Through the processing and analysis of monitoring data, the trend of foundation pit changes can be predicted in time, and the hidden dangers in the excavation of the foundation pit can be fully understood, the problems can be solved in a targeted manner, and advice and suggestions can be provided for the organization of construction.

2. Project overviews
The project foundation pit project is located in Hunnan District of Shenyang City. The foundation pit is approximately triangular. The northwest side is Greenland square, the east side is next to South Tiantan Street, and the south side is next to Jinka Road. The minimum distance between the side line of the foundation pit on the east side and the curbstone of South Tiantan Street is about 6m, and the width of South Tiantan Street is about 20m; the curbstone of Jinka Road on the south side of the foundation pit is about 4m, and the width of Jinka Road is about 20m. There are many underground pipelines around the East and south sides of the foundation pit, and the deformation requirements are strict[2].

3. Foundation pit monitoring schemes

3.1 Monitoring frequency and period
The monitoring period of this project starts from the construction of enclosure (pile foundation) to the end of ± 0.00 of underground structure.

According to the design requirements of Party A, the design depth of the foundation pit is 12.2m-14.0m, the excavation and support construction period is 31 days, the pile foundation construction period is 65 days, and the structure positive and negative zero construction period is 65 days. The total monitoring period is 161 days.

| Serial number | Image progress                                      | Duration (days) | Standard frequency (point / time / day) | Estimated times (point · time) |
|---------------|-----------------------------------------------------|-----------------|----------------------------------------|-------------------------------|
| 1             | Support to within 5m under natural ground           | 6               | 1/2                                    | 3                             |
| 2             | Support to 5-10m below natural ground               | 12              | 1                                      | 12                            |
| 3             | Support to more than 10 meters under the natural ground | 12              | 2                                      | 24                            |
| 4             | Completion of pile foundation construction          | 65              | 1/2                                    | 32                            |
| 5             | Completion structure plus or minus zero             | 65              | 1/5                                    | 13                            |
|               | Total                                               |                 |                                        | 84                            |

Explain: The average monitoring times of each monitoring point is 84 points per time.

In the implementation process, the measurement frequency of each project can be adjusted according to the construction progress, measurement results, owner's requirements and supervision instructions.[3]

### 3.2 Foundation pit monitoring and early warning mechanism

| Serial number | Monitoring items                                      | Alarm value | Control value |
|---------------|------------------------------------------------------|-------------|---------------|
| 1             | Horizontal displacement of support structure top     | 40mm        | 50mm          |
| 2             | Top of support structure and ground settlement       | 40mm        | 55mm          |
| 3             | Settlement of surrounding roads                      | 15mm        | 20mm          |
| 4             | Internal force of bolt                               | Below 0.4nk or above 1.2nk | |

### 3.3 Layout and protection of datum points and monitoring points

#### 3.3.1 The horizontal displacement of the top of the foundation pit supporting structure has the following characteristics: The deformation measurement mainly focuses on the coordinate change value of the measuring point, and the precision of the coordinate change amount is very high, but the absolute coordinate value of the measuring point is not high; The directivity is mainly directed to the free side; the site has poor visibility conditions and is greatly affected by the construction; it is difficult to have a suitable measurement reference point in the site[4]. According to the characteristics of the horizontal displacement of the foundation pit, a two-level measurement system is selected for this project. During the monitoring process, the benchmark network should be regularly tested and calibrated to ensure the stability of the benchmark. The observation technical requirements are in Table 3.
### Table 3. Accuracy index

| Grade       | Weakest edge length (mm) | Mean square error of angle measurement (") | Weakest edge relative error |
|-------------|--------------------------|------------------------------------------|-----------------------------|
| Secondary   | +3                       | 300                                      | 1:100000                    |

#### 3.3.2 Settlement observation of top and surrounding roads of foundation pit support structure

In this project, the second-class geometric leveling method is used for settlement observation. Three shallow benchmarks Bm1, BM2 and BM3 are buried on the stable building far away from the foundation pit to be measured as the datum points for settlement observation. The technical requirements of leveling observation shall be in accordance with the technical requirements of secondary deformation observation (national first-class leveling). The observation requirements are shown in the Table 4 and the Table 5...

### Table 4. Line of sight length, front and rear sight distance difference and line of sight height

| Category                  | Line of sight length | Parallax difference between front and back | Accumulated difference of front and rear sight distance | Line of sight height |
|---------------------------|----------------------|-------------------------------------------|--------------------------------------------------------|----------------------|
| Control network           | Less than 25         | Less than 1                               | Less than 2                                            | More than 0.3        |
| Settlement point          | Less than 30         | Less than 2                               | Less than 3                                            | More than 0.2        |

### Table 5. Tolerance of leveling observation (mm)

| Category                  | Kiev Division Reading difference | Kiev Branch Office Difference of elevation difference | Poor return and attachment Or loop closure error | One way two station measurement Poor height difference |
|---------------------------|----------------------------------|------------------------------------------------------|-------------------------------------------------|------------------------------------------------------|
| Control network           | 0.3                              | 0.5                                                  | $0.3\sqrt{n}$                                    | $0.2\sqrt{n}$                                        |
| Settlement point          | 0.5                              | 0.7                                                  | $1.0\sqrt{n}$                                    | $0.7\sqrt{n}$                                        |

#### 3.3.3 Layout of reference points and monitoring points

Figure 1. Distribution of monitoring points
4. Monitoring data analysis
In order to intuitively analyze the deformation of each building measuring point in the surrounding environment, we draw the following settlement curve chart of buildings in the construction process.

4.1. Table and curve of cumulative change of horizontal displacement of foundation pit support

| Order number | Cumulative value (m) | Order number | Cumulative value (m) | Order number | Cumulative value (m) | Order number | Cumulative value (m) |
|--------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|----------------------|
| V1           | 0.023                | V7           | 0.0202               | V13          | 0.0235               | V19          | 0.0228               |
| V2           | 0.0251               | V8           | 0.0209               | V14          | 0.0236               |             |                      |
| V3           | 0.03                 | V9           | 0.0212               | V15          | 0.0231               |             |                      |
| V4           | 0.0267               | V10          | 0.0236               | V16          | 0.0227               |             |                      |
| V5           | 0.0266               | V11          | 0.0229               | V17          | 0.0221               |             |                      |
| V6           | 0.0251               | V12          | 0.0232               | V18          | 0.0233               |             |                      |

Figure 2. Cumulative value curve of horizontal displacement monitoring points

It can be seen from the above list and curve chart of accumulated horizontal displacement of foundation pit support that the foundation pit is always in a safe state during the foundation construction of the project. The cumulative maximum value of V3 monitoring point is 0.03m, and the cumulative value of all monitoring points does not exceed the warning value range.

4.2. List and curve of cumulative change of vertical displacement of foundation pit

| Order number | Cumulative value (m) | Order number | Cumulative value (m) | Order number | Cumulative value (m) | Order number | Cumulative value (m) |
|--------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|----------------------|
| V1           | 0.0119               | V6           | 0.01                 | V11          | 0.0105               | V16          | 0.0109               |
| V2           | 0.0122               | V7           | 0.0097               | V12          | 0.0111               | V17          | 0.0108               |
| V3           | 0.0129               | V8           | 0.011                | V13          | 0.0098               | V18          | 0.0102               |
| V4           | 0.0146               | V9           | 0.0092               | V14          | 0.0131               | V19          | 0.0069               |
| V5           | 0.0126               | V10          | 0.0097               | V15          | 0.011                |             |                      |

The cumulative value curve of 19 monitoring points of foundation pit support in the whole monitoring period is in the Figure3:
Figure 3. Cumulative value curve of vertical displacement monitoring points

The above data "+" indicates sinking and "-" indicates rising. From the cumulative change trend and curve of vertical displacement of the settlement monitoring points in the surrounding areas, it can be seen that the cumulative change of the maximum value V4 monitoring point is + 0.0146m. In the excavation stage of foundation pit, the change curve is relatively uniform and gentle.

Table 8. Accumulated values of road settlement monitoring points

| Order number | Cumulative value (m) | Order number | Cumulative value (m) | Order number | Cumulative value (m) | Order number | Cumulative value (m) |
|--------------|----------------------|--------------|----------------------|--------------|----------------------|--------------|----------------------|
| L1           | 0.0021               | L6           | 0.0028               | L11          | 0.0025               | L16          | 0.0032               | L21          | 0.0026               |
| L2           | 0.0024               | L7           | 0.003                | L12          | 0.0017               | L17          | 0.003                |
| L3           | 0.0022               | L8           | 0.0031               | L13          | 0.0025               | L18          | 0.003                |
| L4           | 0.0035               | L9           | 0.0022               | L14          | 0.0035               | L19          | 0.003                |
| L5           | 0.0032               | L10          | 0.0033               | L15          | 0.0024               | L20          | 0.0029               |

The cumulative value curve of 21 settlement monitoring points around the foundation pit in the whole monitoring period is in the Figure 4:

Figure 4. Cumulative vertical displacement curve of surrounding road monitoring points

The above data "+" indicates sinking and "-" indicates rising. From the above vertical displacement curve, it can be seen that in the excavation stage of the foundation pit, due to the pressure of the
underground soil, the surrounding roads are forced to change under the external force, and the accumulated maximum value of monitoring point L11 in the whole monitoring cycle is 0.0041m.

5. Conclusion
During the excavation construction of the foundation pit of the project, the earth pressure and water pressure outside the pit move horizontally to the foundation pit due to the excavation of the soil in the foundation pit and the construction factors such as the precipitation in the pit, which drives the surrounding soil to sink, resulting in large deformation of the surrounding environment[5]. Although the change of individual monitoring points exceeds the alarm value, the overall monitoring data is relatively normal, the enclosure structure is relatively stable, there is no surrounding road rupture, and there is no major danger. It is suggested to speed up the construction and reduce the impact on the surrounding environment in the future construction process. The deficiency of the monitoring work is that some monitoring points cannot be observed in the later stage of monitoring due to the complex site environment, narrow site in the base and other external factors, resulting in the discontinuity of some monitoring content data.

Reference
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