Slope Stability and Support Lag-property Analysis of a Hydropower Station Intake Slope

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Abstract: In order to analyse the slope displacement and stress of a hydropower station during excavation and support, evaluate the support Lag-property and anchor cable effect, the MIDAS GTS software nonlinear calculation method are used to analyze the slope displacement and stress. The study adopts the lag three-step support and carries out the 11-step calculation and compares the results. The results show that graded excavation support is beneficial to control the slope deformation, which provides the basis for the design of the slope support.

1. Introduction
During the slope excavation, the excavating and support carried out simultaneously is adopted to ensure the stability and reduce the adverse impact on the slope. However, when the site conditions are not allowed, the feasibility of adopting hysteretic support measures is discussed.

Numerous researches has been done for the calculation of excavation support, but few attend to the slope lag-property analysis. Liu Jun et al [1] designed the support for the deep and thick overburden slope of the Dagangshan Hydropower, Wang Da-wei et al [2] evaluated the mechanism and effect of the high slope support of highway reconstruction and expansion project, Shao Yong et al [3] carried out numerical simulation of the prestressed anchor cable frame beam slope support, Li Yi et al [4] built a calculation mesh to analysis the combined slope and tunnel deformation for No.1 spillway tunnel outlet of Centianhe Project.

2. Slope stability analysis and excavation-support design
The lithology of the slope is microcrystalline limestone intercalated conglomerate, and a counter-inclined fault developed in the slope. The slope is in a stable status, and no unstable rock block is found. A plane simulation model was made to simulate normal pool level (NPL), NPL+ heavy rain, NPL+ earthquake and rapid drawdown calculation cases of the nature slope by means of FEM simulation. And the safety factor of NPL+ earthquake is low, then partially unstable engineering treatment is required. According to the survey situation and excavation scheme, the slope excavation is divided into 11 excavations from top to bottom. The height of each step is 20m while the platform is 20m, and the slope ratio is 1:0.7 or 1:0.3 in different section. The prestressed anchor cables are adopted to support, with 1000kN cable prestressed, length 30m and spacing 4m.

The safety factor of the excavation slope meets the specification requirements in all cases, which indicates the excavation slope is in a stable state. Limited by the construction condition, the control of
slope stability and deformation is concerned in the lag-property analysis.

3. Lag-property Analysis of support structure

3.1 Calculation model and analysis method
The calculation model is 546m long and 457m high. Strongly weathered rock mass, unloaded rock mass, weakly weathered rock mass and fresh rock mass are developed successively from the earth's surface. The rock mass and fault are all thin layer solid elements, and the Mohr-Coulomb elastoplastic model is used to calculate. And the calculation model, which is shown in figure 1, and the boundary is hinged. In order to obtain the actual displacement and stress of the slope in different excavation and support stages, the simulation calculation of the construction conditions is carried out by using the non-linear calculation method of Midas/GTS.

![Figure 1. Calculation model diagram](image)

3.2 physical and mechanical parameters
The parameters were selected in combination with laboratory tests and in-situ test results. The calculation parameters are shown in Table 1.

4. Support measures lag-property analysis
This paper mainly simulates the construction method of support while excavating during construction. The lag-property support calculation is performed according to the 3 step lag-property support. The displacement results of the lag-property analysis are shown in Table 2.

According to the calculation results (Figure 2 to Figure 5), through the analysis of three steps of lag-property, it can be seen that due to the excavation of the relatively severely weathered rock mass, the remaining rock mass has greater strength and less deformation, and the lag-property during construction is not obvious. And the displacement of one-time excavation support is 30% more than excavation immediate support. The lag-property support has a certain degree of influence, which can play the role of controlling the overall displacement of the slope.

| Rock-soil mass types          | Elastic modulus (GPa) | Poisson’s ratio | Unit weight (kN/m3) | Cohesion (kPa) | Friction angle (°) |
|------------------------------|----------------------|----------------|--------------------|---------------|-------------------|
| Strongly weathered rock mass | 4                    | 0.28           | 26.1               | 140           | 28.0              |
| Weak unloading rock mass     | 8                    | 0.28           | 26.2               | 400           | 35.0              |
| Slightly weathered rock mass | 13                   | 0.26           | 26.5               | 900           | 45.0              |
| Fresh rock mass              | 25                   | 0.25           | 27                 | 1100          | 50.2              |
| Fault                        | 0.2                  | 0.32           | 20                 | 20            | 23                |

Table 1. Physical and mechanics parameters
Table 2. Calculation results of slope lag-property displacement value (m)

| Calculation steps | maximum displacement | Calculation steps | maximum displacement | One-time excavation support maximum displacement |
|-------------------|----------------------|-------------------|----------------------|-------------------------------------------------|
| Excave and support grade 1-2 | 0.002 | Excave grade 1-3 slope | 0.004 | |
| Excave and support grade 3 | 0.003 | Excave grade 4 support grade 1 | 0.005 | |
| Excave and support grade 4 | 0.004 | Excave grade 5 support grade 2 | 0.006 | |
| Excave and support grade 5 | 0.005 | Excave grade 6 support grade 3 | 0.006 | |
| Excave and support grade 6 | 0.005 | Excave grade 7 support grade 4 | 0.006 | |
| Excave and support grade 7 | 0.005 | Excave grade 8 support grade 5 | 0.007 | |
| Excave and support grade 8 | 0.006 | Excave grade 9 support grade 6 | 0.007 | |
| Excave and support grade 9 | 0.006 | Excave grade 10 support grade 7 | 0.007 | |
| Excave and support grade 10 | 0.006 | Excave grade 11 support grade 8 | 0.007 | |
| Excave and support grade 11 | 0.007 | Complete excavation and support grade 9 | 0.040 | |
| Complete | 0.036 | Complete | 0.040 | |

Figure 2. Unsupported displacement cloud map of excavation grade 1–3 slope
5. Conclusions

- The natural slope is in a stable state under various working conditions, after the slope excavation and support, the safety factor is greatly improved. Therefore, the deformation control of the slope is important. The displacement of the one-time excavation support is more than 30% than
that of the graded excavation support, which indicates that the graded excavation support is beneficial to control the slope deformation.

- For the numerical analysis of slope, the deformation and stress value of each excavation stage can be clarified by using the finite element nonlinear method, and the calculation result is closer to the practical application.
- This research only considers the influence of excavation lag-property on slope stability and deformation. In the subsequent work, orthogonal test can be further designed to analyze the factors such as excavation height, track width, bolt inclination, length and spacing. The influence law of the safety factor of the slope makes the bolt support scheme more reasonable in terms of support effect and economy.

References

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