Remodeling characteristics of slope rock and soil and BIM-based refined management of engineering cost

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Abstract
The construction industry is a labor-intensive industry in China. Due to the unsaturation of pore gas, the unsaturation of soil mechanical properties is more complicated than saturation. Changes in water and gas will cause changes in soil attractiveness, which will further affect the mechanical properties and permeability of the soil, and even threaten the stability of the slope. Therefore, in order to study such engineering problems, it is necessary to comprehensively and correctly understand the changes of unsaturated soils during the drying and wetting cycles, and to investigate the reasons for the changes in order to scientifically analyze the stress state of unsaturated soils. Because of the continuous advancement of technology, people’s comfort requirements for the function, appearance, and structure of buildings are also constantly improving. Especially in some modern large-scale construction projects, due to the large number of contractors, the amount of information that needs to be analyzed in the construction process is compared. The requirements for large and project engineering management are getting higher and higher, which makes the difficulty of the project greatly increased. Relying on traditional information communication and management methods, project cost management becomes difficult. Project cost management is one of the core contents of project management, and its management effect directly affects the final value of the project. On the basis of the continuous improvement of management ideas and theories in manufacturing management activities, project cost management introduces BIM technology currently active in the construction industry. Based on the characteristics of BIM core technology and BIM model software, it carries out in-depth research, explores the connection between BIM Technology and project cost management, and constructs the fine management mode of project cost.

Keywords  Slope rock and soil · Remodeling characteristics · BIM project cost · Refined management

Introduction
Due to the existence of some slopes in nature and the side slopes caused by engineering construction, the shallow underground soil and air are in contact with each other and are directly affected by weather changes in nature. Therefore, for the problems of engineering construction, scientific and reasonable methods are used to carry out research, so as to give targeted improvement countermeasures. The project cost management is the focus of project management. Whether its management is effective or not directly determines the benefits of the project. As one of the pillar industries of China’s national economy, the engineering construction industry, while achieving rapid development, is also facing a situation of huge investment, low returns, and rapid rise in production costs. In this article, directly guided by the refined management of engineering cost management, construct an information model Grigoratos and Martini (2015). This technology is based on 3D modeling technology, which increases the construction period and cost factors, thereby deriving 4-dimensional, 5-dimensional, and even N-dimensional models. As a result, the engineering data of the entire process and even the life cycle of the entire project can be managed (Gunawardana...
et al. 2012) (Hakanson 1980). Its 3D vision, parameterized geometric data and information integration, make full use of the advantages of work functions, and for the problems and defects of cost management in various stages, it can reconstruct the refined management model based on BIM to promote technical engineering cost and cost management informatization is further standardized and rationalized, thereby accelerating the transformation of project cost management from experience management to scientific management (Huang et al. 2014).

Definition and content of “refined management” of project cost

The so-called refined project cost management, strengthened phased cost management as the premise, and “correct, meticulous, and strict” as the management goal, so as to achieve the purpose of cost control. The detailed content of management includes the project from the initial design to the final completion acceptance. The main content of refined project cost management is the key to cost “reasonable judgment and effective management” (Karim et al. 2014). For the design budget management in the management process, it needs to be more scientific and reasonable. The main point of the management of the project quotation is the transmission and processing of information communication between the contractor and the construction department. At the same time, the management of the final settlement of the project needs to consider the management of each stage of the project, because stage management directly determines the final project revenue (Kováčik et al. 2016) (Fig. 1).

The application value of BIM technology in the refined management of project cost

Building Information Modeling, or BIM, is a revolution after CAD technology in the construction field. It is the technical support for the deployment of nodes, processes, and information such as “construction management,” “engineering design,” and “business management.” Through the timely and efficient circulation of the entire information, it provides strong support and guarantee for the improvement of project cost management.

The application value of BIM information expression and sharing

BIM has the characteristics of visibility and parameterization. In order to achieve the entire process of spatial high-precision visual design and virtual engineering construction, it can be achieved through the construction of BIM. Therefore, it is possible to find the “missing and unreasonable management” problem of the BIM model in time, improve the components, directly delete the unreasonable components, make the cost assessment more intuitive, and greatly reduce the cost caused by the duplication or irrationality of engineering components (Kurt-Karakus 2012).

For the BIM model is linked by parameterized attributes, which can promote project changes and avoid the lack and duplication of project costs, thereby avoiding the “not timely or incomplete” related content caused by project changes to the greatest extent. In addition, if the project design plan is changed, BIM software can be used to change the plan to reduce the cost of 2D drawings. Using the shared platform
of the BIM model, all design units can be adjusted remotely to reduce the cost of repeated changes, and at the same time can avoid the risk of changes after design errors occur. Before the start of the project, complete information sharing will lay a good foundation for evaluating the implementation status and reduce the risk of project cost management (Li et al. 2017).

The application value of BIM information calculation and transmission

The calculation function of BIM is a comprehensive integration of information collection, information storage, and information calculation and analysis. Each component of the BIM model includes “component types and specifications, material prices” and many other information (Liu et al. 2019). In the initial stage of project decision-making, project evaluation must be combined with the actual situation of the corresponding project at the current stage, which requires the correct processing of a large amount of information and complex content (Marcotte et al. 2017) Men et al. (2018). The BIM model saves all the information from the “decision-making stage” to the “complete acceptance,” as well as the price of each component at each stage. Through price adjustments in the construction stage, it helps all personnel involved in project development (Men et al. 2020).

Research design

Research on the experiment of remolding the soil-water characteristic curve of unsaturated loess

Experimental protocol

The soil samples used in this experiment were collected from the soil in the suburban hills. The soil is yellowish brown, which is a typical collapsible loess. According to the relevant regulations of the civil engineering test method standard (GBBT 50123-1999), the particle density, liquid plastic limit and recompression tests were carried out, and the basic physical and mechanical indexes were determined (Müller 1969). The results are shown in Table 1.

In order to show that the characteristics of the soil stabilized after 3 dry and wet cycles, this paper tested soil-water characteristic curves after 0 dry and wet cycle, 1 dry and wet cycle, 2 dry and wet cycles, and 5 wet and dry cycles. A total of 4 reshaped unsaturated soil samples were tested. Considering that the tightness of the slope is generally not high, the tightness of the comparative sample is 0.9. The test plan is shown in Table 2. In order to facilitate subsequent announcements, it is divided into 8 groups according to various dehumidification and moisture absorption paths.

Sample preparation

Preparation of compacted samples The soil samples were prepared by a fastening method with a height of 100mm and a diameter of 50mm. After sieving the test soil, it is 2mm, add water to make the moisture content reach the best moisture content. At this moisture content, samples were prepared, and the required soil mass was measured according to the specified degree of compression. The soil was divided into 5 layers of pretreatment samples, each layer is 20mm, and the layer is fastened. The quality of the soil material is equal to each layer. The height of the soil material is determined by the fastening technology. Each layer is fastened as required. The second layer of soil material is added after the surface is shaded. Add the sample preparation device to the last layer.

Preparation of dry and wet cycle samples In this paper, a three-axis outdoor environment simulation was carried out on the dry and wet cycle of soil samples in the natural environment. The specific operation method is to put the saturated sample in the oven, set the oven temperature to 40°C, turn on the air, and simulate the evaporation process of the sample under the conditions of sunlight and air drying (Pan et al. 2017). The sample taken out after a certain period of time is called quality, and the moisture content of the dried sample is controlled at 20% of the initial saturated moisture content. After meeting the requirements, take out the sample and put it in the vacuum cylinder to continuously pump into the saturated state (Phil-Eze 2010). This works as a wet and dry cycle. If a dry and wet cycle is performed, the real-time saturation of the sample can be calculated in the next process. Suppose the mass of the sample made with a specific moisture content is \( m \), and the volume of the sample is \( V \). In this case, the quality of the dry soil in the sample is as follows:

\[
m_s = \frac{m}{1 + \omega}
\]

Table 1  Basic physical and mechanical indexes of loess

| Proportion (Gs) | Liquid limit (wL)/% | Plastic limit (wp)/% | Plasticity index (Ip)/% | Optimal moisture content (wope)/% | Maximum dry density (\( \rho_{\text{max}} \))(g cm\(^{-3}\)) |
|----------------|--------------------|---------------------|------------------------|-------------------------------|----------------------------------|
| 2.66           | 28.49              | 15.32               | 13.17                  | 14.8                          | 1.86                             |
The volume of dry soil is:
\[ V_s = \frac{m_s}{\rho_s} = \frac{m}{G_s} \rho \]

Quality of pore water:
\[ m_w = m - m_s \]

The pore volume is:
\[ V_v = V - V_s \]

Suppose that the quality of the wet and dry cycle changes at a certain moment. The saturation at this time can be expressed as follows:
\[ S_r = \frac{\Delta m + m_w}{\rho_w V_v} \]

Experimental procedure

Preparation of airless water Open the water supply valve, close the air valve and output valve, and start the vacuum pump. Due to the pressure difference, tap water is injected into the water tank from the water injection port of the water tank. Please note that the water level does not exceed the suction tube port. Next, close the upper water valve, continue the pump until there are no large bubbles in the water, and open the back pressure of the air valve.

Saturated clay board The clay slab was in a saturated state, and the computer applied a sealing pressure of 600kPa. The residual gas in the clay board is dissolved by the action of water pressure. The water pressure under the clay slab, as time goes on, is equal to the limit pressure, which can be read by the gap water pressure sensor. Then, open one of the two external valves, release the dissolved gas until the bubbles disappear, and close the valve again.

Sample loading and exhaust pipe Open the supply hole of the counter pressure supply, and stop water injection when the supply hole overflows. The blocking pressure loader is a computer-controlled airless water intake, and the piston position is controlled near the minimum stroke. Connect all the pipes and clean under the clay plate until air bubbles are discharged from the gap water pressure outlet.

The soil sample is saturated After drying and wetting cycles, the dried soil sample was put into the triaxial chamber to achieve back pressure saturation. After sampling, first add a sealing pressure of about 5kPa to make the rubber membrane adhere to the soil sample, and then gradually increase the sealing pressure and back pressure. The steps in the pressure process are consistent.

SWCC experiment After the saturation is completed, the back pressure will not change, and the surrounding pressure and pore pressure will gradually adapt. During the 5kPa→10kPa→20kPa→Matrix Attraction (IAU W) will increase, and the moisture absorption process will be reversed (Safiuur Rahman et al. 2019).

Study on the stability of unsaturated loess slopes under rainfall-evaporation conditions

Calculation of slope seepage

A complete thermal model requires four parameters: permeability coefficient function, soil-water characteristic curve, thermal conductivity function and specific heat capacity (Škrbić et al. 2018). For analysis and calculation, various curves of various wetting and drying cycles are selected. The thermal conductivity K reflects the thermal conductivity of the soil block. This is defined as the heat of soil mass per unit thickness and unit area per unit time per unit temperature gradient, and the unit is usually J/(SEC m °C). The volumetric heat capacity is the amount of heat required for a unit temperature rise per unit volume of an object, usually J/(m³ °C). As shown in Fig. 2, the calculation is performed using the function obtained in the literature, ignoring the influence of the dry-wet cycle on the thermal conductivity and volumetric heat.

Taking into account the climatic difference between the rainfall period and the evaporation period, in order to better achieve a clear dry-wet cycle effect, as shown in Table 3, different climatic conditions are set according to the two working conditions, and the temperature of the slope is set to 20 °C.

Table 4 is the rainfall intensity classification standard issued by the National Meteorological Administration. According to this rule, the rainfall intensity is determined under the appropriate rainfall level.

Before calculating the transition permeability, the initial state of the model and the distribution of the interstitial water pressure of the slope soil must be defined. In other words, steady state calculations need to be performed. Here, the

| Table 2 Test plan |
|-------------------|
| Serial number | Description |
| RC-1 | Dehumidification process without dry-wet cycle |
| RC-2 | Moisture absorption process without wet-dry cycle |
| RDW1-1 | Dehumidification process under 1 dry-wet cycle |
| RDW1-2 | Moisture absorption process under 1 dry-wet cycle |
| RDW2-1 | Dehumidification process under 2 wet and dry cycles |
| RDW2-2 | Moisture absorption process under 2 wet and dry cycles |
| RDW5-1 | Dehumidification process under 5 wet and dry cycles |
| RDW5-2 | Moisture absorption process under 5 wet and dry cycles |
distribution of initial pore water pressure is determined by the initial groundwater level (US EPA 1989). Assuming that the groundwater level is \( y = 3 \text{M} \), the distribution of the initial gap water pressure of the model is shown in Fig. 3 after steady-state calculation.

In the process of unstable evaporation of slopes caused by rainfall intensity, the scouring force and the amount of infiltration affect the size of the slope, so do not ignore the impact of rainfall. It is necessary to study the characteristics of the non-intensity and non-sloping seepage field at different rainfall intensity levels (US EPA 1996). Under the conditions of total rainfall, long-term moderate rainfall and short-term gradient seepage field distribution (Wang et al. 2011).

The rainfall setting is shown in Fig. 4. In other words, in the case of moderate rainfall, set the rainfall intensity to 20mm/d, calculate 1 day as one step, and divide it into 84 time steps. Both of the evaporation cycles are set to 7 days and executed alternately. In other words, the dry cycle and the wet cycle are all implemented 6 times. During the storm, the rainfall intensity was 70mm/d, each rain for 2 days, the interval between the two rains was 7 days, and a total of 6 drying cycles were performed.

**Slope stability calculation**

Introduction to SLOPE/W The calculation principle of the SLOPE/W module is mainly the classic limit equilibrium method, and its embedded limit equilibrium method mainly includes Morgan, GLE, etc. This article selects Mohr-Colomb standard for analysis. The M-P method needs to balance the stress and moment of each piece of soil, and balance the overall strength. This is a strict and widely used method.

Safety factor of torque balance:

\[
F_m = \frac{\sum c' \beta R + (N - \mu \beta) R \tan \varphi'}{\sum W x - \sum N f + \sum D d} \tag{5}
\]

Safety factor of horizontal force balance:

\[
F_f = \frac{\sum c' \beta \cos \alpha + (N - \mu \beta) R \tan \varphi' \cos \alpha}{\sum N \sin \alpha - \sum D \sin \omega} \tag{6}
\]

Here \( c' \) is the effective cohesive force of the soil. \( \varphi' \) is the effective friction angle. \( \beta, R, D, X, F, \) and \( \Omega \) are geometric parameters. \( N \) is the normal force between the soil strips. \( D \) is the line load. \( W \) is the total weight of the soil strip.

\[
X = E \lambda f(x) \tag{7}
\]

Among them, \( f(x) \) is a function of the ratio of the normal force \( E \) according to the change of the sliding surface and the shear force between the horizontal bars. \( \lambda \) is the proportional constant, \( E \) is the normal force between the bars, and \( x \) is the shear force between the bars.

### Table 3 Value table of climatic conditions

| Working condition | Maximum temperature | Lowest temperature | Maximum humidity | Minimum humidity | Wind speed |
|-------------------|---------------------|--------------------|------------------|------------------|-----------|
| Rainfall          | 20°C                | 10°C               | 90%              | 60%              | 0.5m/s    |
| Evaporation       | 35°C                | 20°C               | 50%              | 30%              | 0.5m/s    |
Model parameter values The calculation results of the infiltration model are used as the basis of the slope stability analysis model, and other model parameters remain unchanged. Next, the distribution of the interstitial water pressure of the inclined plane is the interstitial water pressure calculated based on infiltration. In the wet-dry cycle, assuming that the weight of the soil does not change, as shown in Table 5, the strength parameters of the soil during 1 to 5 wet-dry cycles are determined according to the abovementioned test and predicted values. The soil shear strength parameter is constant in the same dry and wet cycle (Wei et al. 2015).

Research results

Reshape the soil-water characteristic curve of unsaturated loess

Soil-water characteristic curves under different numbers of dry and wet cycles

Figure 5 shows the unsaturated humidification and dehumidification curves reshaped in different dry and wet cycles. With different dry and wet cycles, the soil-water characteristic curve of unsaturated loess generally shows the same tendency, and the water content gradually decreases with the increase of matrix attraction. In the case of the same number of wet and dry cycles, the matrix attraction of the same moisture content on the dehumidification curve is larger than the moisture absorption curve under the same conditions. Since the drainage and water inflow caused by the capillary phenomenon of different channels are controlled by different hole sizes, the abovementioned hysteresis phenomenon occurs.

Fitting of soil-water characteristic curve

The Ghana model, Van Genting model, and Fred Singer model described in this paper are selected to meet the experimental results of this paper. The parameters of the FX model are changed from the residual water content \( \theta_r \) of the Ghana model and the VG model to the corresponding matrix attraction. The minimum value of the parameter is as shown in the parameter in the table (Yang et al. 2016).

It can be seen from Table 6 that the test results of the three models of the unsaturated loess soil-water characteristic curve are very good, and the correlation coefficients are all very large. Therefore, the fitting results of the VG model are used to illustrate the influence of the number of wet and dry cycles on the basic parameters of the soil-water characteristic curve.
Prediction model of soil-water characteristic curve considering different numbers of dry and wet cycles

Based on the above test results and the VG model, this article will discuss the variation rules of each parameter of the number of drying cycles. Through calculation, the prediction of the soil-water characteristic curve of the unsaturated loess reshaped in different dry and wet cycles is obtained, and the results are shown in Fig. 6.

In order to track the gradient calculation of multiple wet and dry cycles, the SWCC prediction curve is also calculated in this way in the 3 and 4 wet and dry cycles (please refer to Fig. 7).

In any wet and dry cycle, the relationship between unsaturated permeability coefficient and moisture content and matrix attraction will change exponentially, as shown in Table 7.

Analysis of slope seepage results

Figure 8 is the distribution diagram of the volumetric water content of the slope under the action of moderate rainfall evaporation. Choose the conditions of \( t=1 \) day, 7 days, 11 days, and 14 days for analysis.

As shown in the figure, at the end of the first day of rainfall, the depth of rainwater penetration is very shallow, and the maximum water content of the side slope is 0.18. At present, there is no stagnant water on the platform under the slope, and the equipotential line density at different depths is basically the same. The rainfall exceeds the infiltration capacity, and the water flows out on the slope, and the water is concentrated on the platform under the slope. When the rain stopped for 4 days, the depth of the affected area continued to increase. When the rain stopped for 7 days compared with 4 days, the infiltration depth remained basically unchanged, the water content of the surface soil continued to decrease with evaporation, and the water content of the upper part of the slope decreased to 0.1.

Figure 9 is an equipotential diagram of the volumetric water content of the slope in the first dry-wet cycle period in the case of a short-term storm. Use the results of time \( t=1 \) day, 2 days, 6 days, and 9 days for analysis.

As shown in the picture, due to the high rainfall intensity, the soil moisture will further increase and the penetration depth will increase. The penetration depth of the upper part of the slope surface is basically the same as that of the bottom part at about 1.5m below the surface. Moreover, the hydraulic gradient at the top and the foot of the slope is basically the same. After the rain stopped for 4 days, the water content of the slope surface gradually decreased, and the water content above decreased to 0.2. Rainwater further penetrated under the slope, and the penetration depth of the upper platform was 2.1m. The permeability of the foot of the slope is 1.8m, and there is still water at the

Table 5: Values of slope soil strength parameters

| Wet and dry cycle times/n | 0 | 1 | 2 | 3 | 4 | 5 |
|---------------------------|---|---|---|---|---|---|
| \( c' \)                  | 25.07 | 19.68 | 18.60 | 16.84 | 16.29 | 15.83 |
| \( \phi' \)               | 25.76 | 22.68 | 21.58 | 21.06 | 20.87 | 20.78 |
| \( \phi_b \)             | 13.50 | 10.76 | 10.04 | 9.27 | 9.01 | 8.81 |
foot of the slope. The maximum water content at the foot of the slope reaches 0.26, which is saturated. After 7 days of rain stopped, the surface water content at the top of the slope continued to drop to 0.14, and the penetration depth of the platform at the top of the slope remained basically unchanged. When the affected depth reaches below 3m from the slope surface, water still exists, and the maximum water content is found at the foot of the slope.

Seepage field under the influence of different slope ratios

Figure 10 shows the time-varying relationship of the water content distribution curve along the depth of the slope when the slope ratio is different. The results of 4 gradient ratios (1:0.5, 1:1, 1:1.5, 1:2) are listed for analysis. During the rainfall phase, rainwater gradually penetrates, and the volumetric water content gradually increases from top to bottom. In the evaporation stage, due to the continuous infiltration of rainwater, the deep soil moisture further increases, but the surface moisture content decreases from top to bottom with evaporation. The steeper the slope, the smaller the impact of evaporation on the deep soil moisture content. During the rainfall phase, the water content on the top surface of the slope is the largest, and during the evaporation phase, the water content is the largest at 0.5m down from the top of the slope. According to this phenomenon, 0.5m down from the top of the slope can be used as a boundary point for evaporation and infiltration.

It can be seen from the picture that this is the same as the situation on the top of the slope. However, due to the relationship between the elevation of the foot of the slope and the groundwater level, the distribution curve has an inverse curve, and the moisture content of the underlying soil becomes higher. The depth of influence of rainwater infiltration and evaporation is different under different gradient ratios. At the end of the first rainfall, the ratio of depth to tilt influence is 1:0.5, 1:1, 1:1.5, and 1:2, which are 2.5m, 2.8m, 3.2m, and 3.2m, respectively. In other words, the slower the tilt, the deeper the rainfall infiltration. The water content increases at different speeds at different depths (Fig. 11).

Figure 12 shows the different depths of the water content versus time curve at the top of the slope under the four slope ratios. It can be seen from this figure that the difference of the slope has no substantial influence on the water content change rule caused by the difference in the depth of the upper part of the slope, and the change rule is the same. However, the steeper the slope, the faster the water content in various places over time. In other words, the steeper the slope, the deeper the impact of rainfall. According to the moisture content of the non-stop depth

| Model | Sample no. | $\theta r/\psi r$ | $\theta s$ | $a$ | $b$ | $c$ | $R^2$ |
|-------|------------|-----------------|--------|----|----|----|------|
| Garder | RC-1 | 0.0990 | 0.2577 | 55.1505 | 1.5526 | - | 0.9994 |
| | RC-2 | 0.0998 | 0.2349 | 36.0120 | 1.4651 | - | 0.9978 |
| | RDW1-1 | 0.0936 | 0.2281 | 42.8096 | 1.2958 | - | 0.9979 |
| | RDW1-2 | 0.0954 | 0.2147 | 31.1831 | 1.4987 | - | 0.9978 |
| | RDW2-1 | 0.0899 | 0.2098 | 27.9919 | 1.5165 | - | 0.9981 |
| | RDW2-2 | 0.0902 | 0.2023 | 23.8407 | 1.5223 | - | 0.9967 |
| | RDW5-1 | 0.0850 | 0.2013 | 23.0146 | 1.5584 | - | 0.9935 |
| | RDW5-2 | 0.0851 | 0.1992 | 21.9052 | 1.5584 | - | 0.9934 |
| VG | RC-1 | 0.0947 | 0.2554 | 37.3702 | 1.8536 | 0.5911 | 0.996 |
| | RC-2 | 0.0953 | 0.2309 | 31.9115 | 1.9334 | 0.5052 | 0.9979 |
| | RDW1-1 | 0.0884 | 0.2191 | 25.9873 | 2.0392 | 0.4083 | 0.9993 |
| | RDW1-2 | 0.0873 | 0.2132 | 22.1296 | 2.3620 | 0.3799 | 0.9973 |
| | RDW2-1 | 0.0842 | 0.2015 | 17.4779 | 1.2560 | 0.2632 | 0.9995 |
| | RDW2-2 | 0.0835 | 0.1925 | 15.6663 | 3.1145 | 0.2332 | 0.9983 |
| | RDW5-1 | 0.0783 | 0.1882 | 10.3796 | 5.6420 | 0.1307 | 0.9996 |
| | RDW5-2 | 0.0788 | 0.1862 | 9.9207 | 7.9074 | 0.0958 | 0.9996 |
| FX | RC-1 | 5.8339 | 0.2677 | 81.7305 | 0.3658 | 0.2209 | 0.9978 |
| | RC-2 | 0.9767 | 0.2622 | 39.5214 | 7.2378 | 0.1224 | 0.9950 |
| | RDW1-1 | 2.0061 | 0.2442 | 19.091 | 2.9214 | 0.1915 | 0.9908 |
| | RDW1-2 | 2.2524 | 0.223 | 18.1691 | 26.2239 | 0.0811 | 0.9880 |
| | RDW2-1 | 3.0234 | 0.216 | 19.1913 | 130.7056 | 0.0657 | 0.9938 |
| | RDW2-2 | 0.7875 | 0.2231 | 19.0078 | 215.1874 | 0.0525 | 0.9883 |
| | RDW5-1 | 0.1373 | 0.3521 | 18.9701 | 215.8244 | 0.0572 | 0.9956 |
| | RDW5-2 | 0.1773 | 0.1866 | 11.8202 | 4.5318 | 0.2829 | 0.9995 |
at the end of the sixth dry wetting cycle, the steeper the slope, the wider the moisture content distribution along the depth, and the smaller the slope, the greater the moisture content.

Figure 13 shows the time-varying curves of the interstitial water pressure at various depths under different gradient ratios. It can be seen from this picture that the changing tendency of soil interstitial water pressure at the same depth is consistent with different gradient ratios. Before the rain starts, the further away from the groundwater surface, the greater the negative gap water pressure. When the first rain falls, the interstitial water pressure at each depth increases to different degrees, and the fluctuation range gradually decreases with the increase in the number of dry and wet cycles. The depth values eventually reach the same value and the change is stable.

Analysis of slope stability calculation results

Changes in the safety factor of slope stability over time

After calculation, Fig. 14 shows the time-varying curve of the slope stability safety rate under two rainfall intensities with different slopes. It can be seen from the figure that the slope...
safety rate with different slope ratios alternates with rainfall evaporation. The two cycles gradually decreased and showed a big change. As the number of humidity cycles increases, the range of changes also slows down. In other words, the influence of the dry and wet cycle will gradually decrease.

**The influence of the number of dry and wet cycles on slope stability**

In order to show more clearly the influence of the number of dry and wet cycles on the safety rate of slopes, Table 8 shows the safety rate values at the end of each evaporation stage when the two rains are intensified.

It can be seen from Fig. 15:

1. As the dry-wet cycle increases, the safety rate of the gradient decreases, and the amplitude decreases, especially in the first two stages of the next process. Rainfall, evaporation, and a lot of safety factors reduce the slope ratio of 1:0. For example, in the case of moderate rainfall during the second and subsequent drying cycles, the original safety rate of 2.186 to 1.531 was reduced by 30%. The safety rate after the sixth drying cycle was 1.272, which was 16.9% lower than the second cycle.

2. When the number of wet and dry cycles is small, the difference between the safety rates of the two rainfall intensities is small. However, the difference is large when the number of cycles is large, the case where the slope is relatively severely inclined has a large impact on the safety rate of the short-term storm, and the case where

| Number of wet and dry cycles | Dehumidification process | Moisture absorption process |
|-----------------------------|--------------------------|-----------------------------|
|                             | $a$          | $b$          | $a$          | $b$          |
| 0                           | 2.00E-12     | 42.62        | 1.06E-12     | 50.14        |
| 1                           | 3.22E-12     | 49.24        | 2.11E-12     | 53.85        |
| 2                           | 4.97E-12     | 52.04        | 4.44E-12     | 54.94        |
| 5                           | 7.81E-12     | 53.24        | 9.31E-12     | 55.75        |

Fig. 8 The contour plot of the volumetric water content of the slope during the first dry-wet cycle under long-term moderate rain conditions
Fig. 9  The contour map of the volumetric water content of the slope for the dry-wet cycle under short-term rainstorm conditions

Fig. 10  Variation curve of the spatial distribution of volumetric water content at the top of the slope with different slope ratios over time
Fig. 11  Variation curve of the spatial distribution of volumetric water content at the toe of different slope ratios over time.

Fig. 12  Variation curve of water content at different depths of slope top with time.
the slope is relatively slow has a large impact. In other words, in areas prone to rain for a long time, the stability of a smooth slope is worth noting.

The influence of slope on slope stability

As shown in Fig. 16:

(1) In the unstable initial state of the slope, the safety rate of the slope is higher. With the increase of the slope, the safety rate gradually decreases, and with the increase of the slope, the reduction range decreases.

(2) When the dry and wet cycle period is short, the rainfall intensity has almost no effect on the safety rate. The period is more than 4 times. Compared with the increase of short-term concentrated rainstorm, with the increase of slope under long-term moderate rainfall conditions, the decrease of slope stability and safety rate will be reduced. In other words, when heavy rain for a short period of time requires more attention to the slope, the slope should not be too steep.
Discussion and analysis

BIM technology related software

In order to build a BIM model with various functions, professional modeling tools are needed. In this section, as shown in Fig. 17, the commonly used BIM modeling software is classified.

The core of Fig. 17 is the BIM core modeling software that provides structured information based on the project-based BIM model. The main BIM modeling software is shown in Table 9.

| Slope safety factor table before and after dry-wet cycle |
|---------------------------------------------------------|
| Rainfall intensity | Cycles | Slope |
|                  |       | 1:0.5 | 1:1 | 1:1.5 | 1:2 | 1:3 |
|                  |       | (55.2°) | (45°) | (33.4°) | (26.5°) | (18.4°) |
| Prolonged moderate rain (q=20mm) |       | 0 | 2.186 | 2.278 | 2.499 | 2.756 | 3.242 |
|                      | 1 | 1.958 | 2.128 | 2.401 | 2.672 | 3.156 |
|                      | 2 | 1.531 | 1.709 | 1.964 | 2.217 | 2.637 |
|                      | 3 | 1.439 | 1.522 | 1.779 | 2.033 | 2.43 |
|                      | 4 | 1.352 | 1.48 | 1.649 | 1.903 | 2.383 |
|                      | 5 | 1.308 | 1.417 | 1.584 | 1.804 | 2.06 |
|                      | 6 | 1.272 | 1.392 | 1.452 | 1.704 | 2.025 |
| Short-term heavy rain (q=70mm) |       | 1 | 1.961 | 2.13 | 2.396 | 2.6 | 3.17 |
|                      | 2 | 1.543 | 1.724 | 1.95 | 2.109 | 2.637 |
|                      | 3 | 1.408 | 1.557 | 1.783 | 2.07 | 2.407 |
|                      | 4 | 1.261 | 1.442 | 1.675 | 1.874 | 2.245 |
|                      | 5 | 1.184 | 1.292 | 1.562 | 1.819 | 2.193 |
|                      | 6 | 0.971 | 1.168 | 1.598 | 1.806 | 2.167 |

The specific application of BIM in project cost management

Design phase

First of all, in the design stage, all relevant personnel of the project can implement BIM collision simulation inspection by introducing professional inspection software to visually reflect various large-scale conflicts such as structure, water supply and drainage, electricity and fire protection in the three-dimensional space. In this way, the efficiency of the previous drawing inspection can be improved, and various work cooperation can be realized. Secondly, the engineering cost-related staff can directly access the structure, and the mechanical and electrical work will be imported into the BIM cost model. From an economic point of view, the value engineering method is adopted to optimize the implementation of the design as the goal. Finally, according to the establishment, preservation, analysis of information and data and the interoperability with BIM technology, cost and design can be combined organically. This is very convenient for optimizing the design and can completely control the cost of the project in advance. Through BIM technology, all relevant personnel in the design stage can assist, provide effective information accurately and quickly, and achieve the goal of cost management.

Bidding stage

First, the tenderer uses BIM technology to quickly and accurately prepare the bidding control price, quickly establish a BIM project quantity model, and complete the project bidding production in a short time. After completing the data collection, use the BIM database to confirm the validity of the quantity list. Secondly, the bidder also uses the BIM model provided by the bidder to confirm the quantity of the list, speed up the preparation process including the bid quotation, and allow sufficient time for quotation analysis to conduct detailed quotation and strategy analysis, thereby enhancing its own competitiveness. Then, the bid quotation produced by the bidder using the BIM model is also an important part of the bid document. The person who evaluates this can directly confirm the economic bid part and determine the winning bidder based on the valuation information contained in the model. Finally, bidders can use the BIM model to quickly design quantity tables and bid management prices. In addition, bidders can also use the BIM model added to the bid documents to quickly confirm the quantity table and make a reasonable estimate.

Construction phase

First of all, the engineering quantity and price should be calculated. On the basis of correctly determining the number of completed projects, obtain the existing price information in the BIM database, and directly summarize the progress price
of the corresponding stage project. This mode reduces the time cost of engineering cost personnel wasted in basic work, so that the construction phase of cost management will be more efficient. Secondly, cost information data needs to be tracked in real time. Focusing on the 3D visualization and parameterization technology of the BIM model, all relevant...
personnel involved in the project can record monthly or visually accurate cost-related information, and can record relevant cost information dynamically and in real time, thereby avoiding a lot of work. The accumulation of load and the loss of data and information during the construction process. Then, the dynamic monitoring of the project cost in the construction phase, the estimated cost of completing the planned project. Then, the visa is changed. The abovementioned information will be stored in a structured manner, and it will be easy to record the information of all relevant personnel related to the project, and visa changes will not be lost. On the other hand, cost managers can modify the original BIM model to calculate the number of items related to the change, quickly and accurately verify the cost changes caused by the change plan, provide an economic basis for the selection of design change plans, and control the cost of changes in advance. Finally, the construction stage of cost management based on the BIM technology that is different from the previous management model, according to the design of the BIM model, combined with the construction stage of the dynamic change of the project deadline, the price, visa change request and other information are combined with BIM technology, digital and
other functions. The combination of parameterized BIM modern dynamic construction, rapid acquisition of accurate data, cost deviation analysis, visa change fee calculation, etc. effectively realizes dynamic cost management. Figure 18 shows the workflow based on BIM cost management in the construction phase.

Completion stage

First of all, BIM technology provides a reasonable technology platform, based on the BIM three-dimensional model, saves limited time, price, contract, and visa change information in the BIM central database, which can be used and shared by project participants. Secondly, based on the 3D Boolean calculation function of BIM, you can directly use the 3D model of the project in the bidding process to modify the modified part of the original design drawing during the settlement process. Then, the BIM model is combined with the Internet, and the latest policies and restrictions on charges issued by government departments can be directly obtained through the Internet. According to the engineering characteristics of the model, the BIM model can extract the corresponding cost standards by itself according to the corresponding strategies and rules to ensure the accuracy of completing the settlement cost audit. Finally, at the completion stage of the settlement stage, the BIM database constructed using BIM technology only needs to obtain the relevant completion settlement information from the BIM model, complete the settlement BIM model according to the contract and agreement combination, and use BIM to automatically calculate the cost.

The refined management process of engineering cost based on BIM technology

At each stage, you can see BIM-based project cost management. Through cost management, you can see the BIM model as an information carrier. In the design phase, you can increase the project schedule cost, and establish the standard of the BIM model as a prototype. In the relevant information, establish the bidding stage, the construction stage, the completion stage, and the corresponding cost model, extract the correct data required for each stage of cost management, and carry out relevant analysis and decision-making.

The relevant data information generated by the entire project can also be input into the BIM database to form all types of practical and reliable indicators that can be used as reference data for future investment decisions of the project. Each link is based on the cost management of the BIM model, which maximizes the use of the accumulated quantity, price and other information models in the final stage, greatly avoids repeated inefficient measurement and evaluation work, and improves the fineness of cost management.

| Serial number | Use                  | Modeling software                  |
|---------------|----------------------|-----------------------------------|
| 1             | BIM structure analysis | ETABS, STAAD, Robot, PKPM         |
| 2             | Visualization         | 3DS Max, Lightscape, Artlantis     |
| 3             | BIM cost management   | Innovaya, Solibri, Luban, Guanglianda |
| 4             | BIM operations management | Archibus, Navisworks               |
In all stages of cost management, the new work process established on the BIM model platform can effectively and accurately send information and improve the accuracy of communication and coordination. The detailed management process of the project cost based on the BIM model is shown in Fig. 19. Therefore, the various links of cost management are closely connected, which helps to improve cost management and truly realize the effective management of project costs.

**Conclusion**

Geotechnical parameters are one of the important indexes that affect the accuracy and reliability of slope stability analysis results. There are many ways to determine many factors and parameters that affect parameters. Among them, one comprehensive method for determining the optimal application of foundation engineering parameters is determined based on quantitative and qualitative comprehensive analysis, so that more accurate parameter values can be obtained to the greatest extent. As a representative tool of the second technological leap after CAD technology, BIM technology has received widespread attention and is currently mainly used in engineering construction and management. Facing the problem of engineering cost management in my country’s construction industry, when BIM technology has not been popularized in my country, it is recommended to use BIM cost software to grasp the overall situation, so as to achieve refined management of project costs.

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**Declarations**

**Conflict of interest** The authors declare that they have no competing interests.

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