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Stability analysis of high slope embankment design principles

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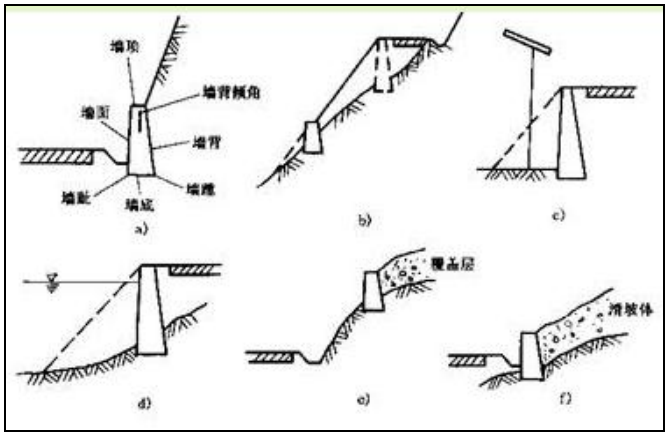
Abstract
Transportation construction in the western region, the construction and development of mountain highway very rapidly, due to the complex geological environment mountain, high fill roadbed therefore appear more and more. High stability Embankment largely determines the quality of the road. In practical engineering, construction accident caused by slope instability due uncommon. Therefore, an important part of the project is to study the stability of the slope. By using Lizheng geotechnical software and finite element software and other methods for some road high fill slope stability analysis. Finite difference method, limit equilibrium method and finite element method is the primary method for slope stability analysis of high fill path analysis. Therefore, this article also compares these methods, and draw their own advantages and disadvantages of these methods, and these methods were evaluated. Slope stability analysis is to find a safe and reliable form of slope and slope stability values.

Keywords: High Slope; Stability; Analysis; Design Principles

1. Introduction
With the rapid development and urbanization of our economy and society, the road construction is also accelerated. Road slope is an important part of road design. And because of this particular form of high slope to the embankment slope stability of road have special requirements, so the slope design, it is necessary for the stability of the high slope analysis and evaluation.

For slope stability analysis and design methods there are many, in general, there is law and engineering geological mechanics test both types of algorithms. Geological method is mainly based on the previously accumulated a lot of experience on different soil or rock slope class to determine the value for slope stability. The mechanics test algorithm a sliding face assumed failure surface, through the use of mechanical equilibrium principle be calculated. For different sliding surface, we can test the mechanical method algorithm is divided into arcs, straight-line method and unbalanced thrust transfer method [2]. Under normal circumstances, the slope of the soil type, the usual practice is to carry out by checking the mechanical method, and then use the method to check the geological engineering. As for the type of rock slope, usually by geological methods for analysis and design.

2. Main forms of protection of integrated design principles slope protection and slope
2.1 Principles of slope protection integrated design-related
(1) Slope protection principles should be in accordance with the principles of design, construction and maintenance combine to carry out [21]. For this first principle needs according to the situation of the local slope of slope engineering geology and materials to carry out in-depth research, select the appropriate form of slope and slope values to ensure the stability of the slope.
(2) For slope protection measures, we can consider the slope by the local soil and lithological, hydrological situation to local conditions. In addition, we should combine road surface drainage conditions to be considered.
(3) For road slope slope method is considered the first plant protection approach to protection against road slope [1]. If the slope of the soil and other conditions are not suitable for the form of plant protection, before considering other ways to use engineering protection road slope protection.
(4) For using the engineering approach road slope protection, slope for such first thing to consider is the impact of terrain slope form, which should be considered for lithological slope of. To be selected according to the geological conditions in the end what kind of engineering approach to protection against road slope.



a) Cutting wall b) Embankment wall c) Shoulder wall
d) Revetment e) Hillside retaining wall f) Skid retaining wall

Fig 1: Retaining Wall

2.2 The main form of slope design and prevention measures
2.2.1 Protective grid
Grid protection method is a method using paste blocks and other materials form a skeleton of the road slope, so that we can effectively prevent the erosion to road side ditch whom formed. At the same time this approach can also improve the surface roughness of the slope of the road, and thus slow down

the speed of the water, so as to stabilize the slope [12, 13]. We setup the road slope, the method is generally used grid protection and plant protection combine slope protection.

2.2.2 Slope

Slope is the slope above the road with a stone, stone and other sheet materials paved road above the slope to prevent water runoff or erosion of the road slope, this method is called slope. We generally use mortar or a dry method to build a paved [8]. When the above we use the softest ground slope slope protection, it can be carried out with a dry slope puzzle pieces of stone or stone, which can reduce the deformation of foundation settlement arising from road slope.

Fig 2: Berm

2.2.3 Cover

Cover of the road slope methods are shotcrete, sprayed concrete, plaster and other means.

(1) For Plastering way of protection, this protection mode uses less than. If the slope of the road is low, it can be used to wipe the surface protective manner, while the incorporation of seeds, because it not only can play a protective effect, but also to bring the slope greening effect.

(2) For the protection shotcrete and shotcrete, this protection method is applicable to easily weathered road slope or slope uneven road rock slope [16]. This protection is the main way the cracks in the rock slope road closed to prevent further rock slope weathered road, while protecting the rock slope collapse does not occur. On road construction, sprayed concrete is a widely used form of protective cover, as this form of protection is the need to set up a metal mesh or geogrid polymers[18-19] in the concrete, consider setting is to prevent in the concrete cracks or peeling in the hardening and shrinking process occurs.

2.2.4 Plant Protection

Plant protection is a form of slope protection, since the effect of plant roots, plant roots and soil can be well consolidated [3]. Thus, the roots of plants can make soil stabilization, thereby strengthening the stability of the road slope. Because parts of the country and more rain, so a lot of rainy areas of the plant protection widely used approach to protect the slope of the road, so not only can protect the slope, but also beautify the environment [5].

Fig 3: Plant Protection

3. Factors affect the slope stability

When the slope of the road shape, the slope of the natural environment and man-made environment have an impact on the road, and thus affect the stability of the slope of the road, and even lead to the collapse of the road slope.

3.1 Potential factors

(1) Topography: due to natural or man-made factors, the current terrain, showing a variety of forms. Slope height, slope and aspect are the main forms of these terrain performance. These factors will determine the degree of slope of the road after the molding is affected by the environment. Among these factors, the most direct impact factor is the slope, if the slope is too large, it will have an impact on the growth of plants. In turn may cause slope instability.

(2) Geological material factors: the road slope from a variety of geologic materials composed of material will be because of the merits, thereby affecting the stability of the road slope [14]. For these geological materials, the main consideration is the type of these materials, cemented condition, and lithology, mechanical strength and weatherproof capability is its main external manifestations.

(3) Geological structure factors: the most important factors influencing slope stability are geological formations. When the presence of conditions such as rock slope level, joints, shear crack, etc., will be rock becomes discontinuous rock, but also improve affected by weathering, but also easy to make the structure of surface discontinuities become sliding surface[15]. So we will - slope stability based on the road from good to bad, is divided into skew slope, reverse slope and forward slope.

3.2 Inciting influence

(1) Environmental factors

Environmental impact slope, mainly rainfall, weathering, groundwater and earthquake will affect the slope of the road.

1. Rainfall: Road slope damage, water is the main factor. Because after the rain, the ground will soften the material, which reduces the strength, but also reduce the stability of the slope. In all the rain, the continuous heavy rain is the most adverse environmental factors, likely to cause the collapse of the slope, and the rain will make the rise in the water table, which affect the stability of the slope.

2. Groundwater: Groundwater also affect the slope of the road, mainly groundwater pressure will be applied on vertical crack, resulting in the force will push slope. Also have buoyancy, so that the contact area of the friction is also reduced. For sheet-like minerals, groundwater can produce lubrication effect, thereby reducing the ability of anti-sliding slope.
3. Weathering and erosion: After weathering slope will reduce the strength of the slope, thereby reducing the effect of slope, thereby increasing the amount of erosion, so exposing fresh rock, making the new rock erosion and weathering.
4. Earthquake: Acceleration due to earthquake on the surface, which will make the slope decline, thereby reducing the resistance, but also because of the lack of slope resistance to loads and damage occurs.

(2) Human factors

For example, these factors due to human activity caused by road slope instability blasting, mining or road excavation and other man-made factors.

1. Improper hillside development: The current destruction of natural terrain and vegetation important reason is improper [22] the use of hillside. In addition, deforestation of natural vegetation will lead to the loss of water and soil conservation function of slope, leading to the collapse of the slope occurs.
2. A lot of digging and filling side: For uneven subsidence and deformation, mostly due to improper loading at the top of the hill, thereby increasing the sliding force, exceeding the resistance itself can provide.
3. Improper slope protection: We need to develop in conformity with the slope specification of soil and water conservation, ecological protection to the slope, if the protection properly, it will affect the stability of the slope.

4. This section of high fill slope geological conditions

Since the address conditions of high slope of this section of road is more complex, from the top of the slope in the end portion of the soil there is a fill soil, strongly weathered sandy shale, sandy shale weathering constitution, and this section side slope height relatively poor, covering soil thickness on the uneven slope. This paragraph Geological both silty clay and sandy mudstone extensive road distribution, but also the impact of groundwater and natural high and steep slopes. In addition, the filler particles of the section of the road is uneven, and the filler has a strong permeability and other engineering properties. Thus, under the action of external predisposing factors, the segment of high fill slope is likely to lead to slope instability or deformation of engineering accidents. In addition, some similar to the lot of soil and soil, because it has a similar wet and expansive soil deformation characteristics. And rock of the slope of its expansion is relatively low, with some disintegration properties.

5. This section of high fill slope stability analysis

High fill slope belong to the High Fill coarse aggregate. The high slope is artificial pair made. Due to the terrain, fillers and other factors, the high road fill slope sliding surface potential may be located inside of the fill slope or a cut to fill the interface [9-10]. Factors can undermine its instability also includes internal and external factors. Internal factors are mainly mechanical properties and soil structure and other factors figure; the impact of external factors mainly affecting the groundwater and the topography and other factors.

6. This segment of high fill slope calculated by the software analysis

Because this section of road engineering geological special and therefore require a higher safety factor to ensure that this segment of high fill side slope stability. Therefore, high safety factor this section of road fill slope should not be less than the values in Table 1 are listed.

Table 1: High fill side slope safety factor (stability)

Slope Category	Conditions	Safety factor (stability)
High fill slope	Irregular situation I	1.1-1.2
	Irregular situation II	1.05-1.1
	normal circumstances	1.2-1.3

Wherein an irregular situation I mean this segment of high fill slope in a state of continuous rainfall, irregular situation II refers to the natural state of this segment under special high fill slope in earthquakes, but normally refers to paragraph high fill slope in the natural state [4].

We were under rainfall conditions, seismic conditions of the first and natural state, through the use of geotechnical software selection, he is the highest permanent slope slope, this segment of high fill sections Slope stability checking, checking that slope slope rate is 2.31-1.605 paragraph, paragraph checking the stability of high fill slope results follows Table 2.

Table 2: The coefficient of stability of high fill embankment slope

Slope rate	Conditions	Stability factor
1:2.31	Irregular situation I	1.426
	Irregular situation II	1.311
	normal circumstances	1.508
1:1.80	Irregular situation I	1.402
	Irregular situation II	1.285
	normal circumstances	1.390
1:1.75	Irregular situation I	1.321
	Irregular situation II	1.195
	normal circumstances	1.327
1:1.70	Irregular situation I	1.284
	Irregular situation II	1.183
	normal circumstances	1.315
1:1.65	Irregular situation I	1.281
	Irregular situation II	1.161
	normal circumstances	1.279
1:1.605	Irregular situation I	1.153
	Irregular situation II	1.038
	normal circumstances	1.189

From the results of the stability coefficients in Table 2, it can be seen that with the high rate of fill slope slope gradually slowing down, ask the stars corresponding coefficient will increase. If we fill for this high road slope of 1: 1.605 to grading, we cannot guarantee the safety requirements of this paragraph high slope stability under the corresponding geological conditions.

Therefore, been to analyze our results based on current research on high fill slope for the high slope of coarse aggregate type, slope is not less than the general rate of 1:

1.75, the stability of the high fill slope when there is such a weak interlayer geological conditions, which does not vary with the rate of increase of its slope increases; however, we combine empirical and theoretical research project, so that, for practical engineering degree of compaction, moisture content and other indicators parameters, since which is affected by many factors, so for high fill slope of the road, we have worked slope ratio is 1: 2.31. When this high fill slope is continuous rainfall conditions, due to the slope stability factor of this slope is relatively small, so the impact of the high water fill slope overall stability is relatively large. But even if we take into account the long rains in this particular weather conditions, the water content of the slope of the high fill slope saturation of this situation is more difficult, so in the natural state, as long as we do the high fill slope of a hill slope and drainage measures and take appropriate measures such as reinforcement at the toe of the fill slope paragraph high, then high fill slope of the road in rain conditions under still be guaranteed safe.

7. Finite element software for the simulation of high fill slope analysis

To test this we design is reasonable, but also to software and in being compared. Therefore, we chose a slope, according to this high fill slope survey and design, etc. as well as the actual situation, the use of general-purpose finite element software Geo-slope establish an analytical model[6], and the segment of high fill side slope stability calculations. Eventually, using the classic method to calculate the stability factor of 2.305, using Bishop Method to calculate the stability factor of 2.412, using Janbu calculated stability coefficient of 2.230, using Morgenstern method to calculate the stability factor 2.401, meet the requirements of table 1. Moreover, the maximum potential sliding surface location through software resulting in maximum potential sliding surface of the positive results of geotechnical software basically the same.

8. General analysis method for slope stability analysis and Disadvantages

The method of slope stability analysis is divided into a variety of these years, there are a lot of new slope stability analysis, slope stability analysis method but each has its own scope, and the corresponding limitations. Therefore, I feel the need for some typical road slope analysis method to make a comparison, in order to facilitate future engineering practice to select the appropriate slope stability analysis approach this geological engineering geological conditions under which the slope, thereby the road to reduce the possibility of slope failure.

8.1 Limit equilibrium analysis

Limit equilibrium analysis method can be divided into a plurality of categories, including Bishop method, Janbu, friction circle method. These methods are based on different factors and considerations different use conditions divided. Its slope stability factor expressed as:

$$F=S/\tau$$

Where in, S is the shear strength, τ is the shear stress.

But the limit equilibrium method has a drawback of this method is to ensure that the upper and lower limit theorems obtained answers is the upper limit or lower limit.

8.2 Finite Element Method

FEM is a very sophisticated numerical methods, this method can be used to solve high road fill slope, and a method for filling high side slope stability analysis is used more than the finite element method [7]. In addition, the finite element method can be used to solve plasticity, viscous elastoplastic problems, and therefore finite element method is a better method.

8.3 Discrete Element Method

Discrete element method (DEM), this method is suitable for solving the discrete analog media, and other related issues. This method is proposed in the 1970s, since this proposed method, discrete element method this method has been widely used in high fill slope road problems Fangzhong. An outstanding feature of this method is that you can calculate the stress and deformation distribution inside rock, of course, it also reflects the contact surface between the rock and the rock slippage, tipping and other large displacement.

8.4 Discontinuous Deformation Analysis

Discontinuous deformation analysis method is mainly for the discontinuous variation of this problem, it is a new method of calculating discrete. This approach combines some of the advantages of finite element and discrete element methods of these two methods. Object of study of this approach is that each block as a unit to carry out research, but also by contact between rock and rock mechanism to make the connection [20]. By analyzing the rock or rock dynamic equilibrium of the system to be solved by the force of rock and rock movement. This approach may reflect a specific part of the continuity and discontinuity of rock rock mass. Because this method takes into account the relevant factors of rock discontinuities, so that this method can solve the problem of static calculation, and calculation power can also solve the problem.

8.5 Inversion Analysis

This approach by assuming that the slope is the limit equilibrium state, while this method is based on the limit equilibrium theory. Therefore, at this time of slope stability factor K = 1, with the balance by stabilizing force slope sliding force and sliding force between the slope, and then calculate the shear index sliding surface rock mass, back analysis method general transfer coefficient method.

Block for many small landslide, this method is used to calculate one by one to the front of the slider body by the rear slide, until finally a small landslide, in addition to this approach is the assumption that the remaining landslide sliding force is close to zero or is equal to zero under the premise of[11]. The correct application of the method of inversion analysis, we must first select the section in the limit before sliding balance, and this time, the landslide stability coefficient is 1.

Inversion analysis commonly used formula is as follows:

$$c^{trial} = c / F^{trial}$$

$$c_j^{trial} = c / F^{trial}$$

$$\sigma_t^{trial} = \sigma_t / F^{trial}$$

$$\sigma_{jt}^{trial} = \sigma_{jt} / F^{trial}$$

$$\varphi^{trial} = aratan(\tan\varphi / F^{trial})$$

$$\varphi_j^{trial} = \arctan(\tan\varphi_j / F^{trial})$$

Slippage reflects slider obtained by this method is slippery Shear index by inverting the analysis obtained, although may be due to different back calculation formula or the calculation is due to select a different cross-section, resulting in anti-shear index vary. But as long as in the same cross-sectional forward to do stability analysis in this way, we are able to obtain similar results. Shear index obtained by inverting the analysis of the impact of the sliding body contains stability and many other factors [17]. For example, the difference between the ups and downs, slip inside force lateral restraint and other related factors. If the cross-sectional direction while sliding direction and analysis of calculation used does not match, it will also affect the results of inverse analysis method.

9. This segment of high fill slope conclusions and recommendations

The segment of high fill slope located on the hills, undulating terrain changed greatly, while the complex geological conditions of the lot. Through this study, the following conclusions and recommendations can be given:

(1) We were in rainfall conditions, under natural conditions, under earthquake conditions, by selecting the maximum cross-sectional permanent slope to passers typical section of high fill slope stability checking, paragraph high fill side slope slope rate of change 2.31-1.605. Slope higher than the section of the fill slope preparation is 1: 2.31.

(2) Due to a variety of analytical software uses different methods of calculation, resulting in this segment of high fill slope stability coefficient is different, but the results obtained by the finite element software and software obtained through Lizheng geotechnical slip surface the result is basically the same.

(3) All natural external factors of high fill slope generated by the landslide, the greatest external factor is the role of water. Therefore, in order to prevent a reduction of high fill slope rock mass strength, it is necessary to handle high fill slope slope drainage problems. Therefore, remediation of landslides Disease is an important part of the slope drainage.

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