

Research on Safety Factor of Important Slope of Extra Height Dam

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Abstract: The slope stability allowed reliable index is 4.2 in specification of rockfill dam for 200 m height, critical slope safety factor of stability is 1.3, but there is not a fitted safety standard for rockfill dam of more than 200 m height and critical slope of this project. Summarizes the failure probability, safety standards and puts forward an acceptable risk criteria of slope (failure probability), ratio safety margin is a method to verify the rationality of risk standards and risk control level of safety factor of slope stability. Allowed reliable index for the slope of rockfill dam with extra height is 4.2 and 3.95, and the corresponding safety factor of the slope stability is 1.35 and 1.4, according to the practical engineering to verify reasonability of safety factor and allowed reliable index of rockfill dam with extra height. The safety control standard of the slope of rockfill dam with extra height should to be improved.

1 Introductions

With the development of construction technology of embankment dams, a group of more than 200m height embankment dam has been built, such as Nuozhadu, Shuangjiangkou, Shuibuya and so on. The exist design specification of embankment dam only be used for the embankment dam whose height below 200m, The design of high embankment dam are based on previous experience or design specification of embankment dam only be used for the embankment dam whose slopes stability analysis does not have a uniform safety standard. However, a safety factor for high embankment dam slopes according to design specification of embankment dam with below 200m height at high risk which is not appropriated and need to be solved, so a safety factor of slopes stability of embankment dam with extra height should be urgent need.

Embankment dam with extra height slope stability safety evaluation is a critical technical issues when the design and construction of embankment dams, the design specifications (SL274-2001) stipulates clearly that the nonlinear strength index be used to stability analysis, an average of small value of shear strength index be used to calculate slopes stability safety factor of grade □ embankment dam, the result is greater than 1.5 under normal conditions; conservancy and hydropower project standard for reliability design (GB50199—94) provisions that reliable indicator is 4.2 when the Grade□dam occurred the Grade□damage, corresponding to the probability of failure is 1.33×10^{-5} . So the probability of failure of embankment dam with extra height should be less than the embankment dam with below 200m height, another words, allowed reliable indicator of slope stability for embankment dam with extra height should not be less than 4.2.

For more than 200 m high earthfill dams now does not have a widely recognized allowed reliability index, but the failure probability of earthfill dams should not higher than the current 200 m class the failure probability of earth dam, IWHR put forwards slope stability failure probability 10^{-8} and slope stability allowed reliability index is 4.7 for more than 250 m height earth dam,

The height between 200 m to 250 m earth dam, slope failure probability 5×10^{-8} , and allowed reliable index is 4.45. According to this reliable indicators of water resources and hydropower engineering, this paper study on safety standard of the high earthfill dams, and to validate the rationality of the proposed standard.

2 Risk Control Standard of Slope

The extra height dams are constructing, the problem of security and stability of high slope is coming with it. The slope specification of Water conservancy and hydropower stipulated safety level of slope according to the level of the hydraulic structures to determinate, but a first-class engineering safety standard is unlimited, so slope safety standards of high dam which influence the safe of the engineering follow the first-class engineering standard to design safety slope is not reasonable. Another, the current slope design specification of the earth dam is not a widely accepted allowed reliable indicator. In this paper, from the viewpoint of statistics and engineering safety, on the slope failure probability are discussed.

In the field of engineering risk analysis and risk management, allowed risk standard usually is described as a probability that the life of person will be destroyed in every single year. This is an easy operation description of risk index. In China there is no clear slope risk standard, the overseas related research started early, more mature. Risk figure related materials of other countries and regions slope are collected, on the basis of this information to research slope risk control standard of China.

According to the ministry of land and resources issued in 2004 ~ 2013 national geological disasters, according to the landslide disaster of geological disasters by the proportion of the total number of casualties calculated landslide casualties every year in our country, the significant individual landslide disasters have the detailed record need separate statistics. Roughly counted casualties in this decade caused by landslide disaster, statistical data as shown in table 1.

Table 1 China's annual landslide disaster casualties' statistical table

year	casualties	risk (10^{-5})
2004	735	0.2
2005	486	0.6
2006	970	1.0
2007	635	0.3
2008	757	0.2
2009	394	0.6
2010	647	0.6
2011	302	0.8
2012	380	0.8
2013	476	0.6

From table 1 can be seen, nearly 10 years in China, the landslide disaster caused casualties every year is about 400 ~ 1000, through a risk figure access to the risk of slope in 10^{-5} ~ 10^{-6} . International risk analysis of slope expert professor Fell, through analysis of the risk of various industries, for passive risk-drivers, allowed risk should be less than 10^{-6} in annual terms, no larger than 10^{-5} . For the slope engineering, Fell on the detailed review and analysis of the risk of slope in theory and practice experience, put forward as shown in table 2 control standards.

Table 2 Professor Fell advises slope risk analysis control standards

situation	allowed risk in annual
Established slope	10^{-4} , the nearby people
	10^{-6} , the general population
New slope	10^{-5} , The nearby people
	10^{-6} , the general population

Risk criteria and location of slope region also has a certain relationship with the level of economic development, through the statistics, in general, different countries and regions have the probability of death all around 10^{-6} caused by disasters, as shown in table 3.

Table 3 Recent years, the average number of deaths and the annual probability of countries

country	annual death	toll population	landslide in personnel death probability
Japan	150	1.5×10^8	$1/1 \times 10^{-6}$
South Korea	56	0.7×10^8	$1/1 \times 10^{-6}$
The United States	25~50	2.5×10^8	$1/1 \sim 2 \times 10^{-6}$
Australia	<1	1.7×10^7	$1/17 \times 10^{-6}$
Canada	5	0.3×10^7	$1/6 \times 10^{-6}$
Hong Kong (1984 ~ 1984)	1	5.8×10^6	$1/6 \times 10^{-6}$

According to the analysis of slope of countries and regions, reference to risk standard of some foreign countries and China's economic development level, for the natural slope and slope of China water resources and hydropower engineering, put forward the acceptable risk of slope in China should be set as the failure probability in annual between $10^{-5} \sim 10^{-6}$. For the slope of the importance, the bigger, and the influence after the destruction, set the level of the failure probability of slope in annual terms as 10^{-6} can be widely accepted.

Chen zuyu suggested that the risk calculated by one year as P_y and risk calculated by many years as P have the following relations.

$$P_y = \frac{P}{T} \times \frac{N_d}{T} \quad (1)$$

The T for the life, N_d to design a base year.

Calculation follow as (1), often difficult to determine the life of a slope, as a conservative approach, assumes that $T = N_d$, the type can be expressed as:

$$P_y = \frac{P}{N_d} \quad (2)$$

In water resources and hydropower engineering, the design base year for 100 of first-class, the slope failure probability can be calculated for 10^{-4} by type (2), looking up the failure probability and reliability index table, the level of the slope reliability index is 3.7.

3 Safety Standard Calculation of Slope

China Institute of Water Conservancy and Hydropower institute proposed ratio safety margin method which is a measure between the safety standards and the design requirements of the building standard. Defined safety factor method of ratio safety margin η_R and traditional methods ratio safety margin η_F are calculated as follows:

$$\eta_R = (\beta - \beta_a) \sigma_F + 1 \quad (3)$$

$$\eta_F = \frac{F}{F_a} \quad (4)$$

Under the provision of the reasonable safety factor F_a premise, reliability Methods of the ratio safety margin η_R has a better ability to insinuate η_F . under any condition, can get $\eta_R \approx \eta_F$. So, it should be known that F and β at same risk control level which can be used as important theoretical references for preparation of specification working.

Factor safety standard of slope stability with extra height, which be determined by fitting coefficient of ratio safety margin. Calculate ratio safety margin of songta, nuotheadu and jingping hydropower station dam spillway slope with reliability index 3.95 and 4.2, respectively different section forms to calculate the ratio safety margin with safety factor method and reliability method, and linear regression, if fitting slope approximation is 1, safety factor and reliability index at the same level of risk control.

3.1 The Height between 200 m to 250 m Earth Dam. Using the ratio safety margin theory, in the case of allowed reliable indicator is 3.95, calculation ratio safety margin of reliability method, using different safety coefficient standard 1.35, 1.4, and 1.45 to calculation ratio safety margin of

safety factor method, and carries on the linear regression. Results are shown in figure1.

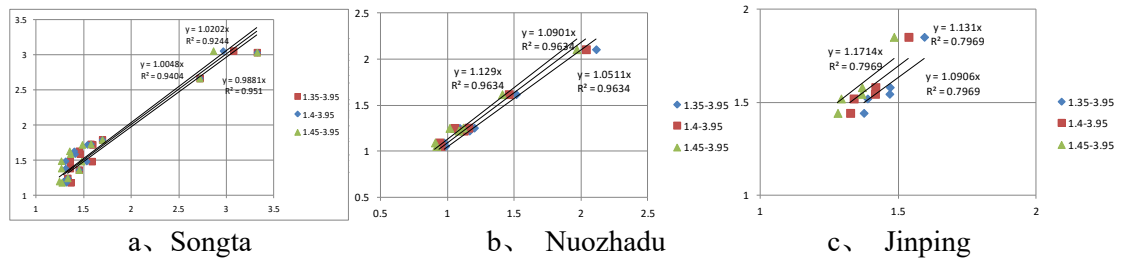


Fig. 1 hydropower station slope η_R - η_F correlation diagram

Fitting slope ratio of safety coefficient standard 1.35 and the slope reliability index 3.95 is closing to 1, the highest correlation coefficient, the results are shown that safety coefficient standard 1.35 and reliability index 3.95 of slope engineering instance have the same safety margin. Slope stability safety coefficient 1.35 and reliability index 3.95 belong to the same level of risk control.

3.2 More than 250 m Height Earth Dam. Do as section 2.1, using the ratio safety margin theory, in the case of allowed reliable indicator is 4.2, calculation ratio safety margin of reliability method, using different safety coefficient standard 1.4, 1.5, and 1.6 to calculation ratio safety margin of safety factor method, and carries on the linear regression.

Fitting line ratio of Slope stability safety coefficient standard 1.4 and the slope reliability index 4.2 is closing to 1, the highest correlation coefficient; the results are shown that safety coefficient standard 1.4 and reliability index 4.2 of slope engineering instance have the same safety margin. Slope stability safety coefficient 1.4 and reliability index 4.2 belong to the same level of risk control.

4 Conclusion

Based on the method of ratio safety margin, considering the influence of parameters variability, computing the ratio safety margin of safety factor method and reliability method, the results shown that when the safety factor is 1.3, the traditional method of the ratio safety margin, and allowed reliability index is 3.7, the reliability method of the ratio safety margin, the results shown ratio of slope of linear regression fitting is 1, both at the same level of security.

The height between 200 m to 250 m earth dam, the acceptable failure probability is 5×10^{-7} , allowed reliable indicator 3.95 for important high slope at the same risk control level; The acceptable failure probability is 10^{-7} , allowed reliable indicator 4.2 for important high slope of more than 250 m height earth dam at the same risk control level.

By the calculation of ratio safety margin of three different engineering slopes of the height between 200 m to 250 m earth dam and more than 250 m height earth dam, the corresponding safety coefficient are 1.35 and 1.4. Failure probability, allowed reliable indicator and minimum safety coefficient at the same risk control level.

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