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THE ANISOTROPIC UNLOADING NONLINEAR ROCK MASS MECHANICS IN OPEN CUT MINING SLOPE

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ABSTRACT Unloading nonlinear rock mass mechanics, one new concept in geotechnics, is put forward by the author in this paper, and whose mainly researching contents are discussed in the paper The results identify that there are differences between unloading nonlinear rock mass mechanics and loading rock mass mechanics

Different kind of rock engineering has different rock mass mechanical condition The foundation engineering of loading mechanical condition is suitable for applying loading rock mass mechanics For rock mining slope engineering of unloading condition, unloading nonlinear rock mass mechanics should be used

The above mentioned anisotropic unloading nonlinear rock mass mechanics has been initially testified by the rock mining slope engineering

1 INTRODUCTION-ROCK MECHANICS AND ROCK MASS MECHANICS

Rock block stability and rock mass deformation are two essential problems m the rock engineering The rock block stability is described in a very clear concept | "safety factor Concerning the rock mass deformation, it is related to the mechanical properties of rock block, geological structure and rock mass engineering mechanical dynamics The rock mass deformation can hardly be expressed in safety factor When considering the rock mass engineering, the first thing is to properly calculate the deformation, and then the rock mass stress status can be identified

The study on rock block stability is the task of rock mechanics and essential condition of the rock mass engineering stability The study on rock mass deformation is the task of rock mass mechanics and is the sufficient condition of the rock mass engineering stability In the rock mining slope engineering, the rock mass deformation is a most difficult and important problem Study on rock block stability and rock mass deformation of rock engineering are showed in Table I

2 ROCK MASS MECHANICAL CONDITION OF EACH KIND OF ROCK ENGINEERING

The surface rock project can be classified into foundation engineering and slope engineering After the completion of the project, rock foundation engineering has loading mechanical condition, for example, the foundation of a dam

Slope engineering after rock excavation the rock mass mechanical condition is mainly the unloading with enough ground stress releasing

The stress status of the underground engineering are more complicated, which has both mechanic condition loading and unloading condition m same one project

So, different kind of rock engineering has different rock mass mechanical condition (Table 2)

The studying object of the rock mass engineering is a very complicated and anisotropy geological mass, which mechanical characteristic has intrinsic difference in loading and unloading condition Ordinary rock mass mechanics are only suitable for applying loading mechanic condition

The mechanic test method and applicable for rock mass parameters and numerical analysis models are bagged on the loading mechanic condition, which is not suitable for applying unloading mechanic condition of rock mass mining slope engineering (fable 3)

The deformation analysis results of slope engineering are quite different from the actual monitonng data, which can reach several ten times These differences come from the discordance between the applied loading mechanic model and the unloading physical model of slope engineering

fable I Study on Rock Blast Stability and Rock Mass Deformation of Rock Engineering

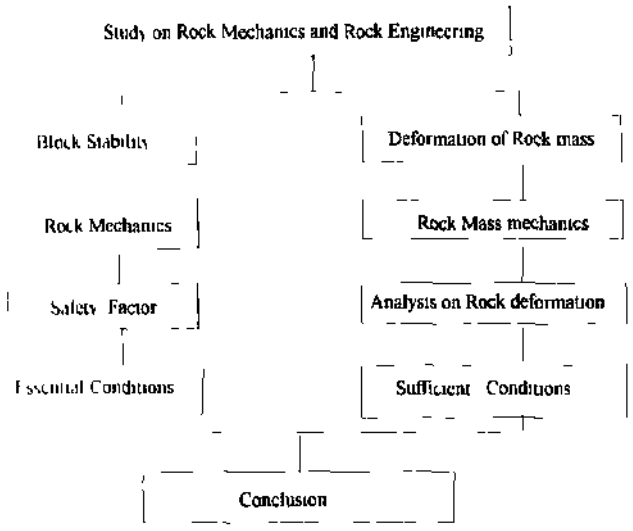
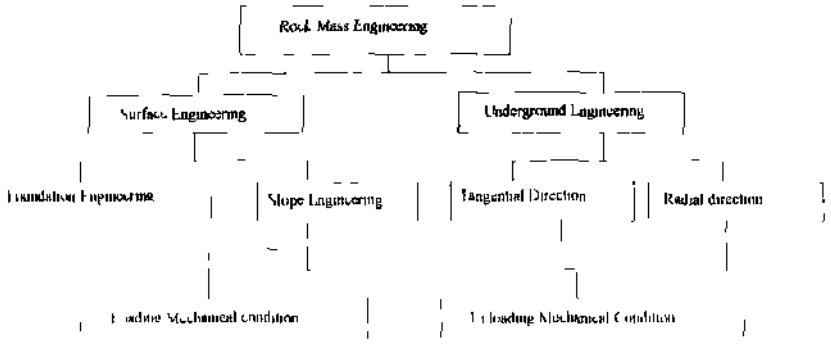


Table 2 Different rock *mass* mechanical conditions of different kinds of rock projects



I able i llıc d|i|İK.dl)le condition for each mechanical models

Classification ol thcpiojea	Loading rock mechanics	Unloading nonlinear rock mass mechanics
Foundation project	Applicable	Inapplicable
Undetground projet (	Applicable	Inapplicable
Slope pruieU	Inapplicable	Applicable

3 THE MAIN CONTENTS OF THE UNLOADING NONLINEAR ROCK MASS MECHANICS IN THE ROCK MINING SLOPE ENGINEERING

3 1 Consideration in Scale Effect

The rock mining slope engineering has bigger size than underground engineering The scale effect will be very important influence in the rock mass mechanic parameters in the rock mining slope So the scale effect should be considered

3 2 Geological investigation

It is necessary to investigate all the geological structures which are unfavorable to the rock mechanical condition in the slope project with consideration on the amsotropy mechanical feature of the geological condition The steep dip angle of inclination joints and the other geological structures of poor quality are very much unfavorable to the slope engineering The rock mass deformation module(Ey) along the unloading direction is smaller than that along the vertical direction (Ez) (Ey<Ez)

3 3 Study on unloading rock mass macro-mechanic parameters

Considering the rock mass damages after all previous geological tectonic movement, the slope excavation unloading, and the deformation module (["y) al each stress level, which is relatively low, it is noticed that at the low stress level, especially after the appearance of the tensile stress, the rock mass deformation module tends to be very low (L'y'<Fy) which is very much unfavorable to the slope deformation The unloading rock mass macro-mechanic parameters (E'y.Rt) can be obtained through simulation testing, geo-physical investigation, numerical analysis and empirical methods

3 4 Establishment of Anisotropic Unloading N-Qikisar. Rock Mass Mechanical Analysis. Calculation Model

According to the Stress status of the slope project after its unloading excavation and unloading rock mass parameters, the amsotropy unloading nonhneai rock mass mechanical analysis calculation model can be established to calculate the slope deformation A={A a }/{E'y} and to carry out the sensibility analysis based on the different tensile strength(Rt)

The amsotropy unloading nonlinear rock mass mechanical mode' established on the above mentioned conditions can basically meet the physical modeling conditions of mining slope rock excavation (Table 4)

Table 4 Unloading Nonlineas Rock Mass Mechanics

I Unloading Nonlinear Rock Mass Mechamcs m the Slope Engineering

Consideration on scale effect

Geological investigation with consideration of the anisotropic mechanical features of the geological condition

Study on unloading inacto parameter oi rock mass mechanics

Establishment of anisotiopic unloading nonlinear rock mass mechanics cacul.ition model

Support design and construction ol the in.is[1]. umjmetfnny

Monitoring survey in-situ and back ıuılysıs

4 THE DISTINCTION BETWEEN THE UNLOADING NONLINEAR ROCK MASS MECHANICS AND THE LOADING ROCK MASS MECHANICS

Owing to the different conditions of rock engineering under loading or unloading, the mechanical properties of rock masses are of essential distinction (Table 5)

The foundation and underground engineering are of loading mechanical condition and are suitable for applying loading rock mass mechanics The slope project is of unloading mechanical status and unloading nonlinear rock mass mechanics should be used

Al present the rock mechanics study is mainly focused on the loading rock mechanics The rock mechanical conditions of the foundation and underground projects basically meet that of the loading rock mechanics Rock mechanics testing condition and the mechanics analysis calculation model are all basically as same as the engineering mechanical conditions

The rock excavation in slope engineering is under unloading condition which is different from the underground and foundation project However, at present, in the study on the rock mechanics for slope project, the conventional test results and calculation method are still used The writer thinks that the conventional method can only be applied to the loading mechanical conditions but not suitable for the large area unloading mechanical condition dunng the slope excavation because of the opposite conditions it posses Owing to the above mentioned reasons, the analysis results of the slope project are quite different from the actual monitoring data It is the consequence of the difference between the mechanical model and the project physical model At present, it is seldom seen the reports on the study of unloading nonlinear rock mass mechanics

Table 5 Anisotropy Unloading Nonlinear, Rock MassMechamcs vs Conventional Rock Mechanics Theory

	Item	Anisotropic Unloading Nonlinear Rock Mass Mechanics	Conventional Rock Mechanics Theory (loading rock mass mechanics)
I	Scale effect	Important influence in rock mass parameter full consideration should be paid	no consideration
2	Geological investigation	Emphasizing high inclined angle structural plane Ey^Ez	Ey=Ez
3	Mechanics parameters	Unloading nonlinear stress-strain relationship E'y<Ey	E'y=Ey=Fz
4	Tensile strength	Form sensibility analysis Rt vanes from big to zero	Rt=constant
5	CalculaUon mechanics	Anisotropic nonlinear mechamcs(Ey)	Constant ngidify
6	Testing results	The testing results tally with the surveyed data	The testing results does not tally with the surveyed data
	Conclusion	The mechanical model corresponds with the physical model	The mechanical model does not correspond with the physical model

5 A MINING Si OPE (ARTIMCIAL SLOPF) PR0J1 CT

Jinchuan open mine was put into operation m 1966 In 1969 when the excavation reached in the depth of 100m d «.erimiş slope déformation occurred Therefore simulation of the defoimalion and failure features of the open slope in HEM was made by some relative research institutes based on loading rock ITMSS mechanical parameters and loading FF M analytical software which show that the maximum deformation of open slope was 20 centimeteis or so In fact the aUual deformation of slope was bigger than 800 cm

We have done some studies recently for the same slope based on unloading nonlinear rock mas«, mechanics theory and in correspondent FLM calculating program, which testify that the maximum deformation of the slope is over 775 cm I he conclusion is quite tally with that in situ

Obviously according to cases analysis V S results in anisotropic unloading nonlinear rock mass mechanics are quite consistent with that in-situ, while there are at least grades differences or inconsistent tendency of deformations of the natural slope and the artificial slope between calculating results and monitoring data in-situ in conventional mechanics parameters and analytical model (i.e. in loading rock mass mechanics) (Table 6)

Table 6 The research results on difference analysis theory

	Calculating Theory	Max deformation	Compare with monitoring data
1	Ordinary rock mass mechanics (loading rock mass mechanics)	«20	1/40
2	Unloading nonlinear rock mass mechanics	»775	»1/1

6 CONCLUSION

i. The rock mechanics is used to study the rock block stability which is described by use of the concept of safety factor. The rock stability is the essential condition of the rock mass stability

The rock mass mechanics is used to study the rock mass deformation which is beyond the description of safety factor. Only with the precise deformation can the rock mass mechanical status be identified. This is the sufficient condition of rock mass stability

ii. The foundation and underground projects are mainly under the loading mechanical status and the slope project is mainly under the unloading status. The mechanical conditions of the two kinds of project are of essential difference.

lii At present, when using the conventional rock mechanical theory to study the unloading rock mass deformation in slope project, the results from that are far away from the monitored data in-situ.

iv. The anisotropic unloading nonlinear rock mass mechanics should be applied to the unloading deformation study for rock slope excavation. The anisotropic unloading nonlinear rock mass mechanics is established based on the anisotropic geological feature with the application of the unloading rock mass macro-mechanics parameters ar^-»fit to mechanical conditions of the rock slopes.

v. The above mentioned anisotropic unloading nonlinear rock mass mechanics has been initially testified by the mining rock slope project.