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ABSTRACT

In construction of roads or large residential complexes, the formation of large scale cut slopes is inevitable due to the large proportion of mountains in Korea. The problems involving the slope stability has emerged as a major concern. Inaccurate subsurface exploration can result in slope failure during or after the construction, thereby increasing the construction cost and delaying the construction duration.

This study reviews problems involving the cut slope survey methods, design criteria, and examining the collapse mechanisms through various case studies. This study suggests the optimum survey methods and design criteria based on the possible failure mechanisms.

INTRODUCTION

As effective developments of national land are required due to population growth and industrial development, our country with many mountainous terrains has a tendency of increasing a formation of large scale cut slope to open roads and develop districts by cutting mountainous district(Chung etc, 1996 ; Lee, 1988).

For the factors of giving influences to stabilize cut slopes, there are internal factors such as rock types, weathering, geological structure, etc. and external factors such as rainfall, melting, earthquake, blasting, etc. Among these factors, the internal factors are important elements to have greater effects on the stability of cut slope, so that it is very significant to grasp geological classification and geotechnical characteristics for internal factors of the ground. In other words, it is judged that the stability of slope can be improved by analyzing degradation characteristics in accordance with ground types and geological structure and reflecting these into investigation and design(Hoek etc, 1981).

This study proposes the investigation method and design standard to advance the stability of slope by grasping problems of degradation characteristics of cut slope with case studies of investigation method and design standard for cut slope applied currently in the field and by considering improvement of seized problems and degradation characteristics.

CASE STUDY 1

Slope conditions

The subject area of case study is an area in OO city of Kyeongki-do, where has a large cut-slope in a length of 400M, a inclined direction of N70W/64SW and maximum height of 310M.

Site investigation

For the soil investigation at execution design, face mapping, drilling investigation 1 boring, elastic wave exploration, point load test, indoor soil and indoor rock test has been performed. Constituent rock is biotite and the direction of major joint is N24-60E/34-64SE. It presents that the unconfined compressive strength of rock is 418~1149 kg/cm^2, TCR is 79~90%, RQD is about 10~90%, and it comes under III-IV class in the result of Rock mass classification system by RMR.

Design conditions

The result of executing stereographic projection method based on the face mapping result indicates that the slope is stable, as there is no joint to generate a definite plane failure.

Therefore, in application of standard inclination, it has been designed that earth and sand are 1:1.2~1.5, ripping rock is 1:1 and blasting rock is 1:0.5. Installation of berm has been performed installing berm of 3m width at 20 m point from the bottom of slope and berm of 1m width for every 5m of the rest section. The section of slope is as Fig. 1(You, 1997).

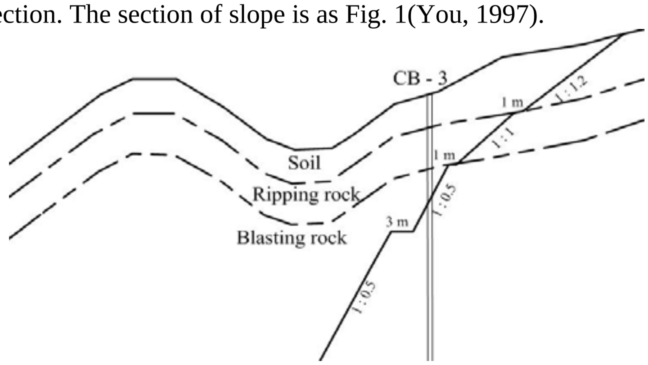

Fig. 1. Slope cross section

Slope collapse conditions

In construction by the design, the toppling failure and wedge failure is generated on 4 places due to the development of a fracture zone paralleled with slope on lower part of the slope and by the fracture zone or combination of fragmental zone of fault and joint.

Problems and alternatives

For the cause of slope failure, it is investigated that the slope failure has been generated from development of fracture zone, unexpected at design, on lower part of the slope.

Though this result has cost problems and limitations of site investigation in design, it is judged that it has been generated from some of the following causes.

First, at planning soil investigation, it could not consider the topographical characteristic (fault topography) indicating that strike-slip fault growing parallel with route has been developed.
Second, while the investigation has been executed down to 1.0m of design height of slope to cut, the depth of boring investigation could not meet the requirements of investigating position and toppling failure.

Finally, since topographical characteristic could not be considered, the position of boring investigation and horizontal direction of elastic wave exploration are inappropriate.

Therefore, the way of resolving these problems is to set the position of boring investigation and the horizontal direction of geophysical exploration at planning soil investigation fully reflecting the result of preliminary investigation and to increase the depth of drilling investigation properly to satisfy the geological condition of toppling failure (Fig. 2). The inclined boring is also a recommendable method.

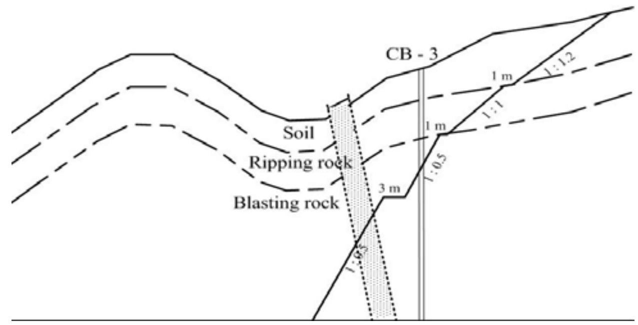

Fig. 2. Relationship between survey location and depth

CASE STUDY 2

Slope conditions

The location of the subject slope is an area in OO city of Kyeongsangbuk-do, where has a large cut-slope in a length of 250M, inclined direction of N42E/64SE and maximum cutting height of 35M(You etc, 1991).

Site investigation

For the soil investigation at execution design, face mapping, drilling investigation 1 boring, point load test, indoor soil and indoor rock test has been performed.

Constituent rock is sedimentary rock, the direction of discontinuous bedding is N30-40E/18-28SE, and the 2 groups of vertical joint have been developed. It has been estimated that the unconfined compressive strength of rock is 380~725 ㎏/㎠, TCR is 80~100%, RQD is about 35~90%, and it comes under III-IV class in the result of Rock mass classification system by RMR.

Design conditions

From the result of executing stereographic projection method based on the face mapping result, the plane failure by bedding, a characteristic of sedimentary rock, is predictable. The result of limit equilibrium analysis for activities of block field is reviewed as being stable more than allowable safety factor.

Therefore, in application of standard inclination, it has been designed that earth and sand is 1:1.2, ripping rock is 1:1 and blasting rock is 1:0.5. Installation of berm has been performed installing berm of 3m width at 20 m point from the bottom of slope and berm of 1m width for every 5m of the rest section. The representative section of slope is as Fig. 3.

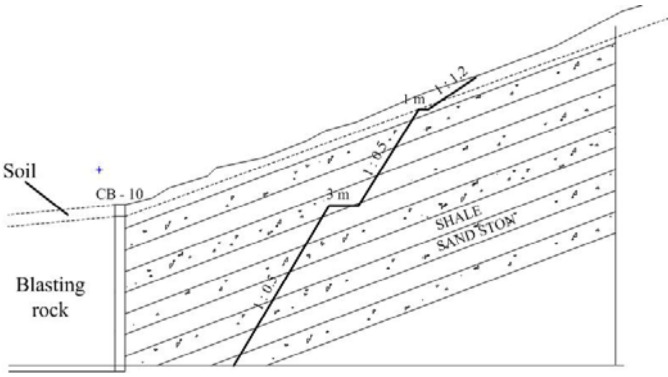

Fig. 3. Slope cross section

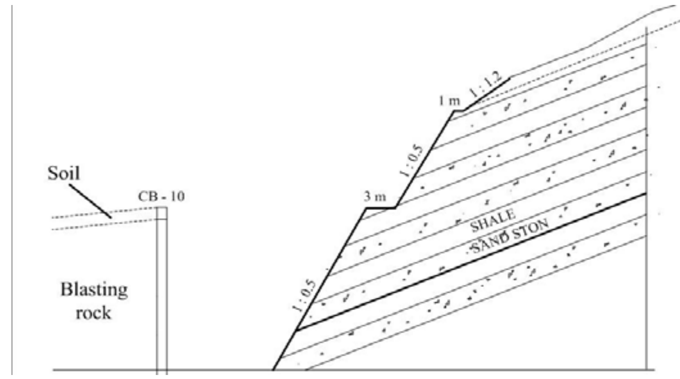

Fig. 4. Relationship between survey location and depth

Slope collapse conditions

As a bedding plane with narrow uncemented clay layer between sand stone layer and shale layer in the lower part of the slope has been developed during the construction, a large scale plane failure has been generated along with vertical joint performing a role of tension cracking.

Problems and alternatives

For the cause of this slope failure, it is shown that the slope failure has been generated from development of uncemented clay layer, unpredicted at design, in narrow existed bedding plane, and from increase of sliding force and decline of shear strength of ground by rainfall.

Though this result has cost problems and limitations of site investigation in design, it is judged that it has been generated from some causes as follows.

First, at planning soil investigation, it could not consider the characteristic of bedding (stratification) that is a feature of sedimentary rock developing paralleled with route.

Second, the depth of boring investigation has been performed to 1.0m down of design height of slope to cut, regardless of satisfying the position of investigation and geological condition of plane failure.

Therefore, the way of improving these problems is to select the position of boring investigation with fully reflecting the result of preliminary investigation at planning soil investigation and increase the depth of drilling investigation properly to satisfy the geological condition of plane failure (Fig. 4).

CASE STUDY 3

Slope conditions

As the subject area of case study is an area in OO gun of Jeollanam-do, where has a slope in a length of 220M and inclined direction of N55E/64SE. It is a large excavated slope with maximum height of 40m.(You etc, 1991)

Site investigation

For the soil investigation at execution design, face mapping, drilling investigation 1 boring, 1 location of test pit investigation, indoor soil and rock test are executed.

Constituent rocks are black mica and granite; the earth and sand (weathered- residual soil) are distributed in a layer of 5.5m from the ground, 4.0m of the ripping rock distributed in its below and 9.5m of blasting rock in the lower part (Fig. 5). N value of earth and sand is 18 times/30 ㎝ ~ 50 times/13 ㎝ that indicates a relative density from middle to high dense, and unified classification is resulted to classify as SM. It has been estimated that the unconfined compressive strength of rock is 765~1210 ㎏/㎠, TCR is 73~95%, RQD is about 35~90%, and it comes under III-IV class in the result of Rock mass classification system by RMR.

Design conditions

From the result of face mapping, the safety of slope could not be evaluated by stereographic projection method, as the discontinuity could not be investigated due to absence of outcrop development and fine growth of vegetation.

Therefore, in application of standard inclination, it has been designed that earth and sand is 1:1.5, ripping rock is 1:1 and blasting rock is 1:0.5. Installation of berm has been performed installing berm of 3m width at 20 m point from the bottom of slope and berm of 1m width for every 5m of the rest section.

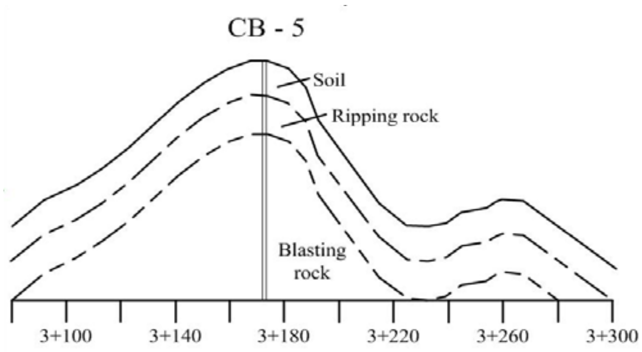

Fig. 5. Layers conditions(design)

Slope collapse conditions

As the following Fig. 6, the collucial deposit is distributed with 8.5m thickness in valley part, a circular failure has been generated during construction (slope inclination 1:1.5).

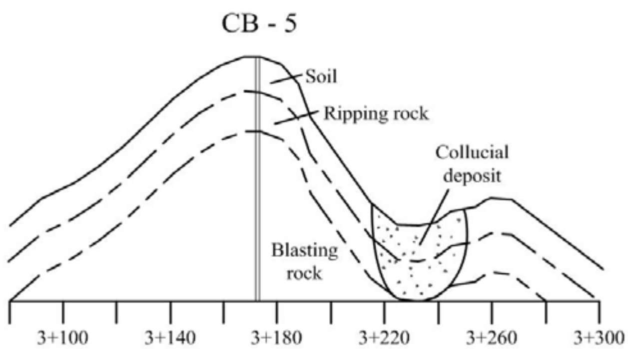

Fig. 6. Layers conditions(construction)

Problems and alternatives

For the cause of slope failure, it is reviewed that the slope failure has been generated from development of collucial deposit, unpredicted at design, on valley part, and pore water pressure and increase of sliding force by rainfall.

Though this result has cost problems and limitations of site investigation in design, it is judged that it has been generated from some of the following causes.

First, the face mapping has not been performed properly as, at planning soil investigation, it could not consider the geological characteristic (gentle slope) showing that collucial deposit was growing.

Second, the item and position of soil investigation have not been appropriate. In other words, the test pit investigation has been performed only at maximum cutting section and a hand auger boring has not been performed at valley part of cutting block.
Finally, design standard of cut slope is insufficient. In other words, in case of the slope of earth and sand, the inclination of cut-slope is determined in accordance with stratigraphic type, relative density, grain-size distribution and excavation height, but the constituent factor of the layer(residual soil and collucial soil), i.e. a significant influence factor, has not been considered.
Therefore, the way of resolving these problems is that directional set, terms and position of soil investigation should be determined by fully reflecting the result of preliminary investigation at planning soil investigation. In other words, the investigation of face mapping should be executed as; examining the distribution of collucial deposit; in accordance with the result of the examination, performing test pit investigation, hand auger boring, or etc. even in valley part; and seizing the distribution characteristic of collucial deposit.

The design standard of cut-slope should set an adequate standard inclination (over 1:2.0) by adding constituent items of the layer that is a primary factor affecting the safety of slope.

CONCLUSIONS

The failure characteristics of cut slope are, for the slope of earth and sand, mostly circular failures by rainfall and plane failures by scour or erosion; for the rock slope, it shows various failure characteristics according to various factors, such as type of rocks, discontinuity, rainfall, weathering, etc.

The modification and supplementation on the standard of investigation and design of cut-slope are as follows.
1. The face mapping should include an investigation of the geological characteristic (fault zone and collucial deposit) that has an important effect on the safety of slope.
2. It is reasonable that the line direction of geophysical exploration is set as the horizontal direction of road.
3. The position of investigation should be selected by judging all results of preliminary desk study (desk study, ground investigation, face mapping, physical survey, etc.) at planning soil investigation.
4. The depth of drilling investigation should be modified to be adjustable in accordance with the position of investigation to satisfy the geological condition of plane failure or toppling failure.
5. The inclination in cutting area of slope should be improved to apply the inclination in cutting area (over 1:2.0 in collucial deposit) that classifies residual soil and sedimentary layer with different creation of layer.

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