# A Reinforced Man-made Steep and High Slope with Vegetal Cover

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ABSTRACT: High and steep cutting should be executed for the construction of highways, quarry pits, residential areas, etc., in mountain region or hill district. Man-made high and steep slope should satisfy not only the stability conditions but also environmental and scenic conditions. In order to fulfill these conditions at the said slope which is mainly constituted of rocks, a certain volume of soil mass which can foster trees and grasses should cover the slope surface at stable state. In general, man-made steep slopes should be protected by various devices such as anchors, slide prevention piles, etc., from the object of stability insurance. In addition to these devices, the author must insist on the preparation of soil mass of a certain volume on the above-stated slope, in order to secure vegetal cover, especially tree planting which is very important task for responding to the fundamental conditions.

## 1. FUNDAMENTAL CONCEPT OF THE MENTIONED SLOPE

Fig.1 shows an overall cross section of a comparatively steep mountain slope picked up by the author. This slope is constituted of granodiorite, propylite and colluvial deposit. Multimedia groundwater flows exist in different geologic zones of this slope, i.e. groundwater flow in weathered granodiorite, groundwater flow in granodiorite, and groundwater flow in colluvial deposit. A very steep and high cut slope was planned at this slope as shown in the figure. The stability and environmental scenery of this planned slope should be strictly taken into consideration. In order to respond to such requirements, careful and thoughtful investigations and considerations are necessary.

### 1.1 Preceding Investigations and Researches

Fundamental investigations and researches as indicated below should be pursued in advance of designing the said slope: (a)Geologic configuration of the slope ground and also free surfaces or pressure head surfaces of multimedia groundwater flows in the same original slope should be clarified by means of bore hole drilling and other appropriate means such as CSAMT (Controlled Sources for Audio-frequency Magneto-telluric) Sounding, etc.
(b)Physical and engineering properties of soil and rock sould be clarified by means of appropriate testing apparatuses
(c)Free surfaces or pressure head surfaces of multimedia groundwater after excavation should be carefully presumed.
(d)During excavation the stability of cut slope should be maintained under the following means; rock bolt or anchor works, step-cutting, groundwater lowering works, etc. Cutting operation must proceed from the top towards the lower portion of the slope, while preparing slope stability measures such as slide prevention and dewatering devices.

### 1.2 Necessary Procedures before and after the Excavation Work

In advance of the excavation work, the stability of the rear slope ground of the planned cut surface must be analyzed by using the data obtained by the said investigations. In case when the above-mentioned stability cannot be certainly obtained,dewatering work, slide prevention devices should be executed in order to

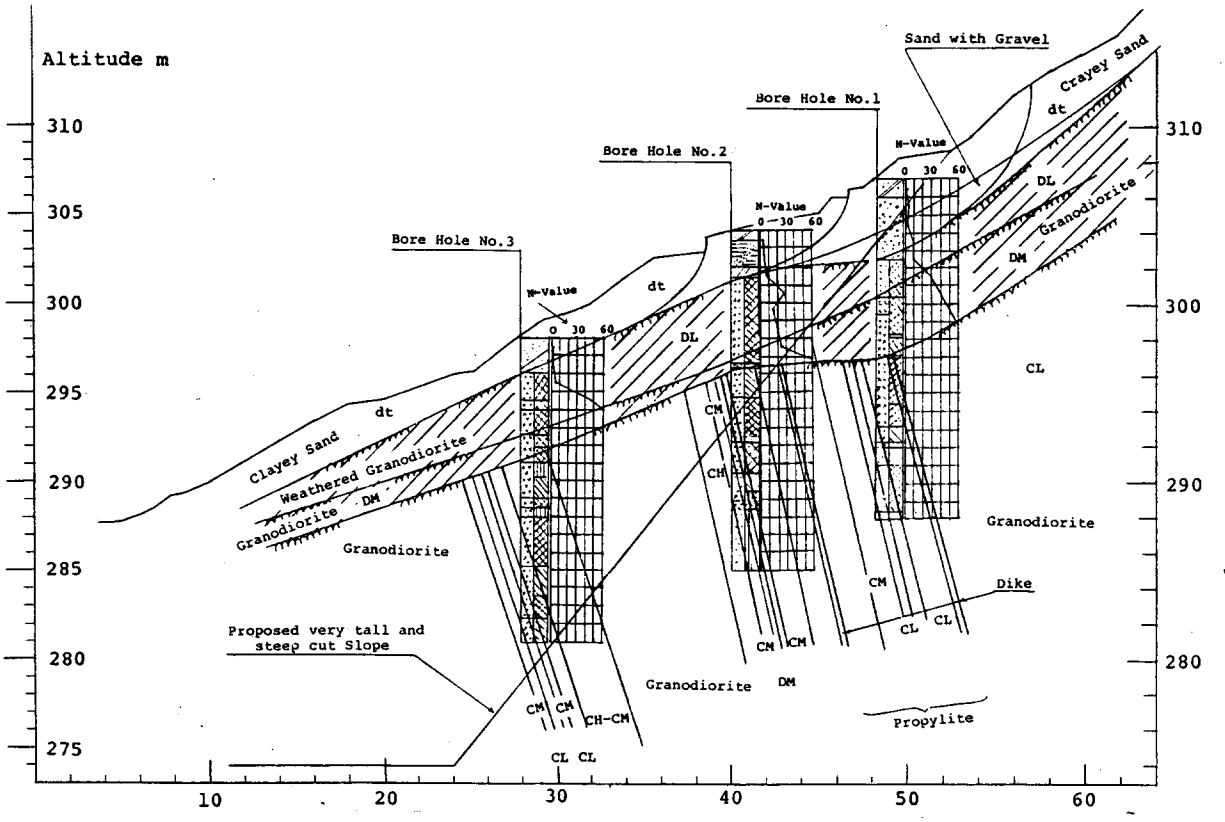


Fig.1 A Cross Section of A Steep Slope constituted of Igneous Rocks which are devided into Stratified Zones with Different Characteristics

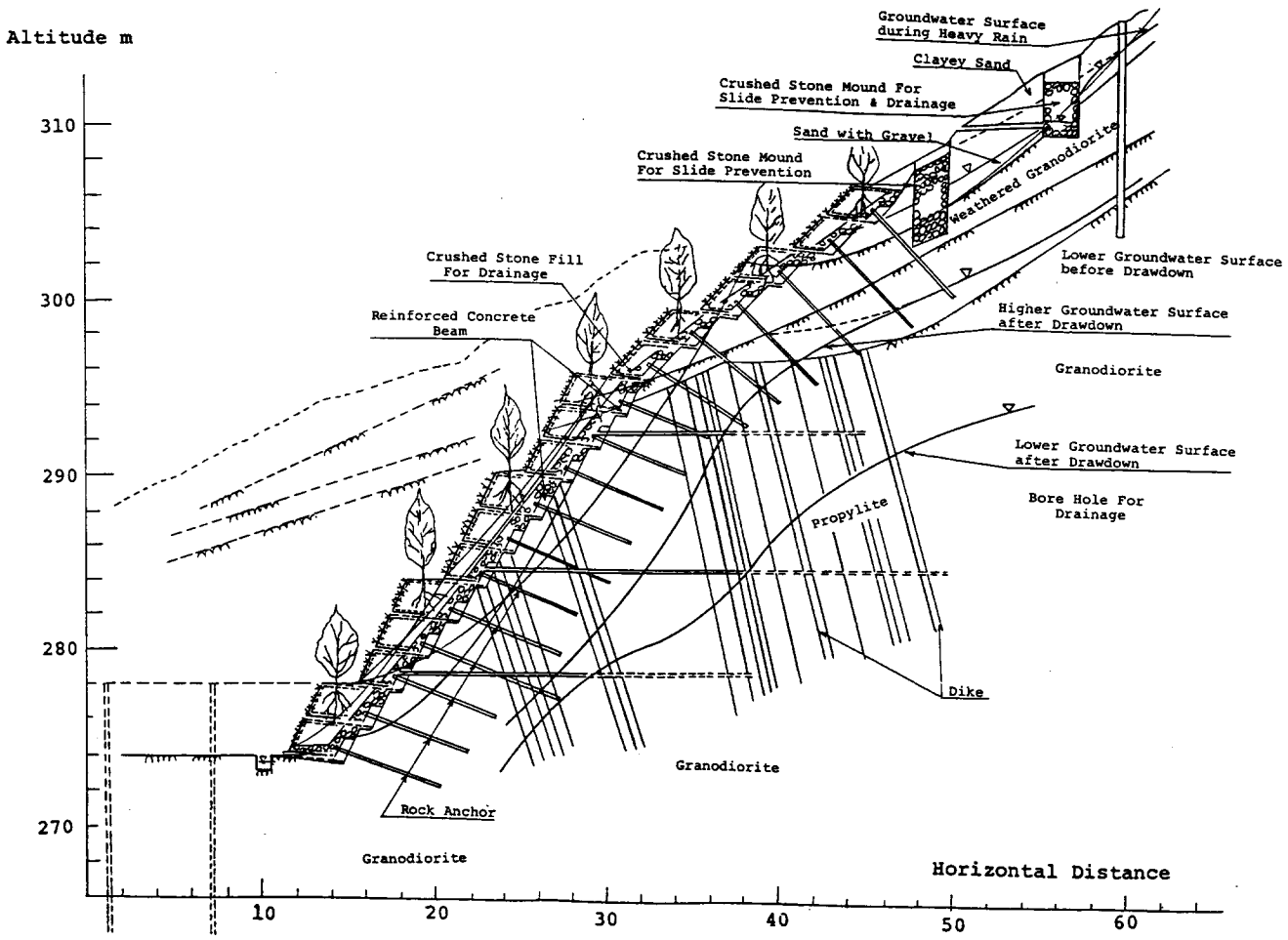


Fig.2 A Cross Section of an Overall View of a Reinforced Man-made Steep and High Fill Slope which is constituted of Granodiorite and Others

satisfy the stabilty as shown in Fig.2.
After the completion of cutting work, soil fill work must start from the foot towards the crest of the cut stepped slope. In this work, reinforcement devices should be applied by the use of geogrid, geotextile net, geomembrane, fixing devices of soil to the rear ground, etc., as shown in the figure which represents the cross section of a man-made reinforced steep and high stepped slope on the said cut slope.

## 2. ELEMENT STRUCTURES AND THEIR ROLES

Fig.3 shows a part of detailed cross section of the said reinforced high and steep slope fill work. In this example each 2.0m thick soil layer is reinforced by the following elements; (1)Geogrid which is set under the steel bar grid retaining structure and furthermore is prolonged and fixed into a thick steel bar bundled into a reinfored concrete beam, (2)Steel bar grid retaining structure which is set on the geogrid for the purpose of keeping the slope at a fixed inclination and also of resisting earth pressure acting on the back of itself, (3)Soil holding geotextile net which is set on the inner surface of the retaining structure and also on the geogrid, (4)Rock anchor and soil anchor which are to be executed in order to secure the said geogrid, by connecting it to the responding reinforced concrete beam to which it is firmly fixed, (5)Crushed stone fill which is set between the rear side of filled soil and the

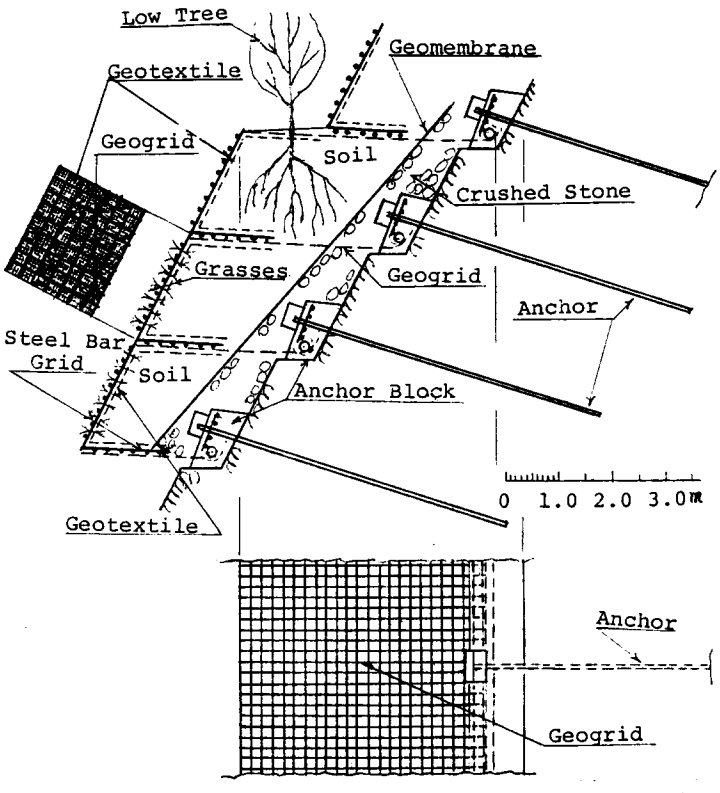


Fig.3 A detailed Cross Section of a Reinforced Steep and High Fill Slope

cut ground including the beam, (6)Suitable geomembrane which is to be inserted for the sake of separation at the interface between filled soil and crushed stone. By the way, the purpose of using geotextile net is due to the fact that it can prevent the outcoming of inner soil through the grid openings, and also it can facilitate for germinated grasses inside to grow up through net openings. As regards the stability of the filled soil and the rear ground, many sliding surfaces through grids and filled soil can be assumed and also some slip planes and surfaces may be assumed in the cut rock or deposit. Safety factors for such sliding along these surfaces or planes can satisfy each determined allowable value of both ordinary and extraordinary cases. Resisting forces for sliding can be considerably increased, by the aid of geogrids having sufficient shearing and tensile strength, and furthermore, by rock bolts or anchors and soil anchors having satisfactory strength.
In the case of heavy rain, infiltrated depth of filled soil from the surface is estimated to increase soil moisture content and also to drain into crushed stone fill, and furthermore, the rest of rainfall flows down on the filled soil surface as surface runoff. As the surface of steep slope is covered with dense grasses and also the surface is not continuous but is interupted by intermittent flat berms, so steep slope erosion cannot occur.
As for the growth of grasses and trees, grasses can grow outwards by extending their stalks and leaves through net openings, and planted young trees can extend their roots into thick soil layer and grasp firmly soil particles as trees grow up. Low trees of 3.0-4.0m are preferable. The volume of filled soil is considered to be kept in suitable condition to foster the said vegetation. The reason is considered as follows; Excess moisture filled in soil is not held in the soil even during heavy rain owing to the effectiveness of good drainage, and even during dry season the soil layer having ample thickness and depth can afford to keep the moisture at a moderate degree against evaporation and transpiration.
Fig.4 represents an example of measured outflow discharge from drain pipe outlet of crushed stone fill at a reinforced high and steep slope executed at Takarazuka City near Kobe in 1988. The discharge was measured by means of triangular notch and automatically recording gauge of water level in gauging water tank. The outflow discharge hydrograph responds sharply to rainfall hyetograph and time lag of discharge peak to hyetograph one is estimated about 10 hours. Thus, crushed stone fill plays efficient drainage role to infiltrated rain from soil surface and to groundwater in rear ground. In addition, when heavy rain hits this slope, there may be hardly any possibility

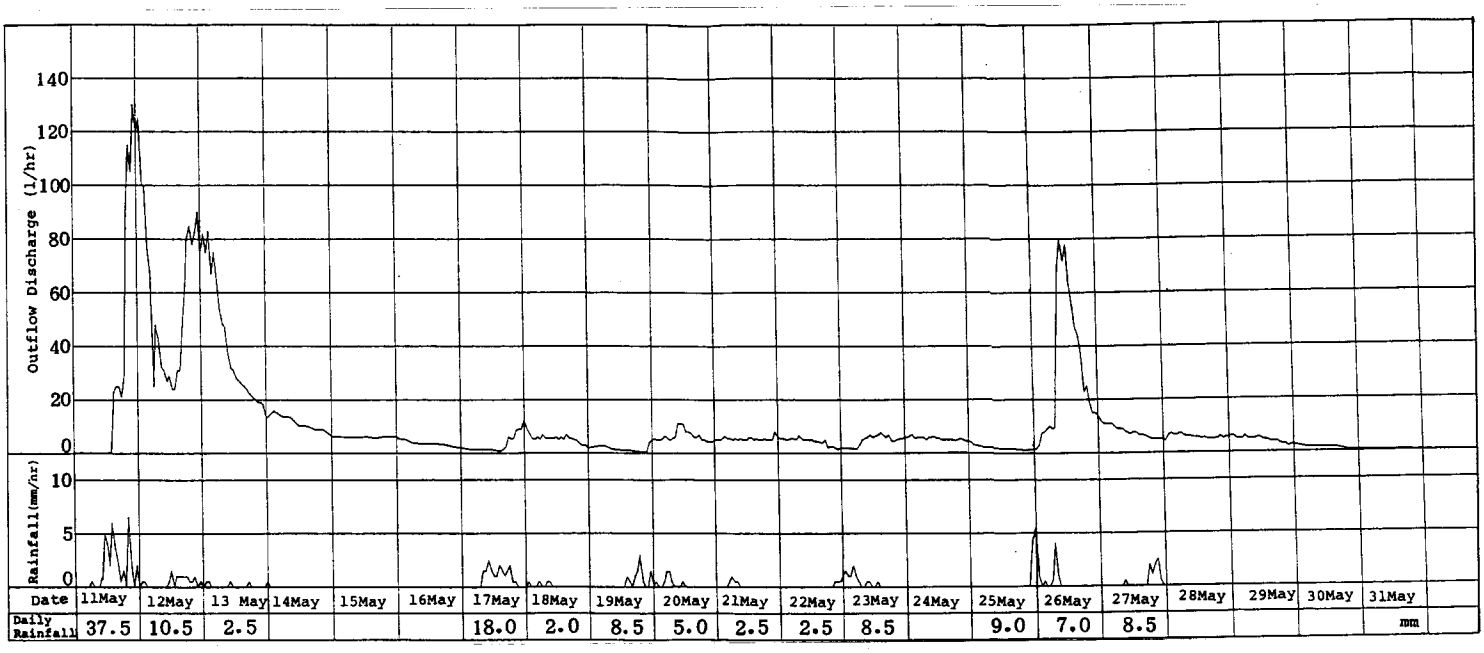


Fig.4 An Exmple of Measured Outflow Discharge from Drain Pipe Outlet of Crushed Stone Fill for The Period of 11 May–31 May, 1989 at A Real Man-made Reinforced Slope

of appearance of groundwater table in the filled soil. Therefore, it is no need to take into account pore water pressure acting on any assumed slip surface in filled soil, caused by free surface of seeping water. Here, the author must emphasize that in considering disaster prevention of the said slope not only the stability of the said filled soil slope but also the entire slope including the rear slope ground, should be taken into consideration and suitable countermeasures should be taken in advance of the execution of works.

## 3. OTHER PROJECTS PROPOSED BY THE AUTHOR

The author completed other projects which can respond to more severe requirements, such as 60m high and 100m high man-made steep slopes. These projects can be completed by the use of geogrid, geotextile, geomembrane, etc. strength and durability of which are more improved. Detailed report will be made public in the near future.

## 4. CONCLUSION

Method of reinforcement of high and steep fill on a steep cut rock slope has used mainly geogrid, geotextile, geomembrane, etc. Characteristics of these materials have been improved to meet with the requirements of the users. The importance of environmental considerations has been strongly stressed in many countries on world-wide basis in recent years. Rock cut slope, concrete dam, high masonry retaining wall, etc. have been designed and constructed on the basis of stability requirement only. But, nowadays concrete surface appearance in mountain forest is considered to be out of keeping with surrounding scenery. Under such circumstances, the said slope structure should respond not only stability condition but also environmental requirement, by applying the stated method in this report.

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