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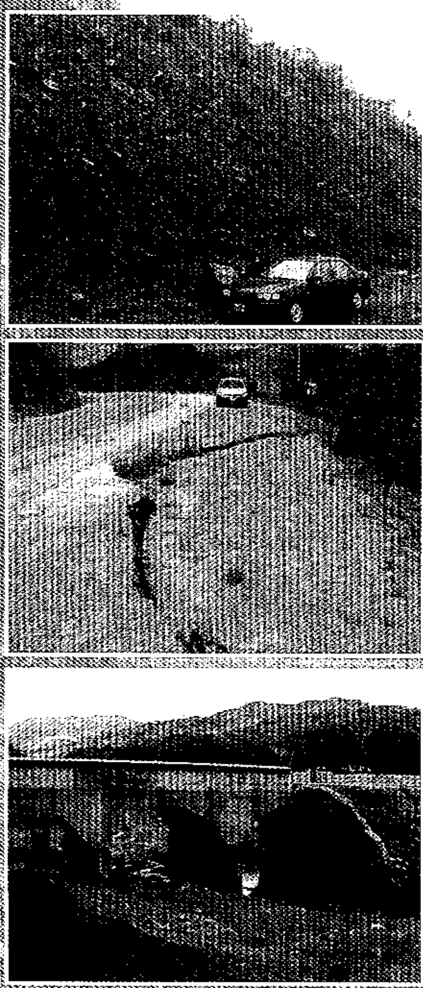
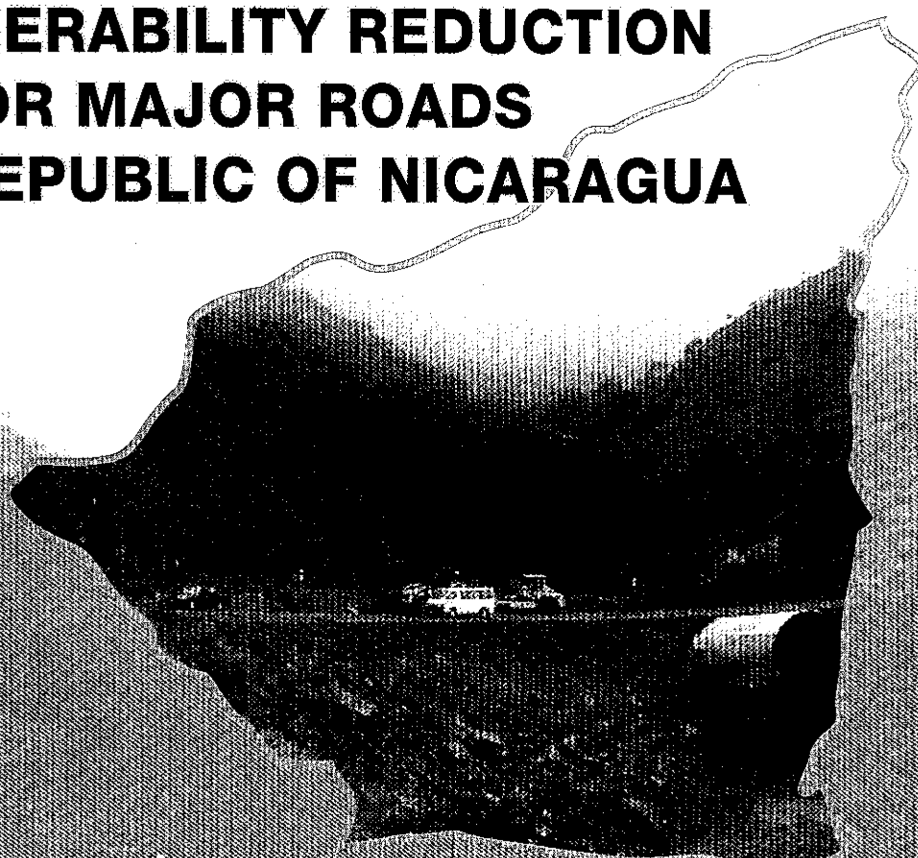
JAPAN INTERNATIONAL
COOPERATION AGENCY (JICA)

MINISTRY OF TRANSPORT AND
INFRASTRUCTURE
REPUBLIC OF NICARAGUA

THE STUDY ON VULNERABILITY REDUCTION FOR MAJOR ROADS IN THE REPUBLIC OF NICARAGUA





FINAL REPORT

Volume 5 of 5 (3/4)

DESIGN/EXECUTION WORKS MANUAL

January 2003

ORICONSUL
Oriental Consultants Company Limited

Japan Engineering Consultants Company Limited

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List of Abbreviations

(In alphabetical order)

AADT	:	Annual Average Daily Traffic
AASHTO	:	American Association of State Highway and Transportation Officials
AHP	:	Analytic Hierarchy Process
ASTM		American Society for Testing and Materials
B/C	:	Benefit to Cost ratio
BH		Boring Hole
BHN	:	Basic Human Needs
BIT		Central American Development Bank
DID		Densely Inhabitant District
EIA	:	Environmental Impact Assessment
GDP	:	Gross Domestic Product
GRN	:	The Government of Republic of Nicaragua
ID		Identification
IDF	:	Rainfall Intensity Duration Frequency
IEE	:	Initial Environmental Examination
INETER	:	Institution of National Territorial Study
IRR	:	Internal Rate of Return
JICA		Japan International Cooperation Agency
MARENA	:	The Ministry of Natural Resources and Environment
MTI	:	The Ministry of Transport and Infrastructure
OD	:	Origin and Destination
PRSP	:	Poverty Reduction Strategy paper
QV	:	Volume capacity
ROW	:	Right of Way
STRADA		System for Traffic Demand Analysis
VAT		Value Added Tax
VOC	:	Vehicle Operation Cost
WB		World Bank
pcu	:	Passenger Car Unit

The following foreign exchange rate is applied in the study :

1 US dollar = 14.40 Cordovas = 125.00 Japanese Yen (October 2002), or

1 Cordovas = 8.68 Japanese Yen

CHAPTER 1 INTRODUCTION

1.1 General

This manual has been produced for the Ministry of Transport and Infrastructure (MTI), who will manage the road disaster prevention of major and rural roads in Nicaragua, by the Japan International Cooperation Agency (JICA). The Direction of Road Maintenance, General Direction of Road, in MTI (DRM) has managed and been responsibility for the maintenance works of all roads controlled by MTI. Therefore, in order to achieve the reliable maintenance works, all roads under DRM should be maintained in accordance with this manual.

Maintenance works for road disaster prevention are one of the fundamental factors in increasing the socio-economic performance of a nation. Therefore, activation of the populace and safety control of the road users are dependent on the results of the premeditated maintenance. Efforts that every day does not slacken are important for securing the stable transportation of products. Due to his duty, DRM, Engineers, inspectors, technicians and maintenance staffs should execute road maintenance work based on same policy and methods.

This series of road disaster prevention manual are composed of four parts as follow.

Part I : Inspection Manual
Part II : Planning Manual
Part III : Design/ Execution Works Manual
Part IV : Maintenance Manual

This is Part III "Design/ Execution Works Manual".

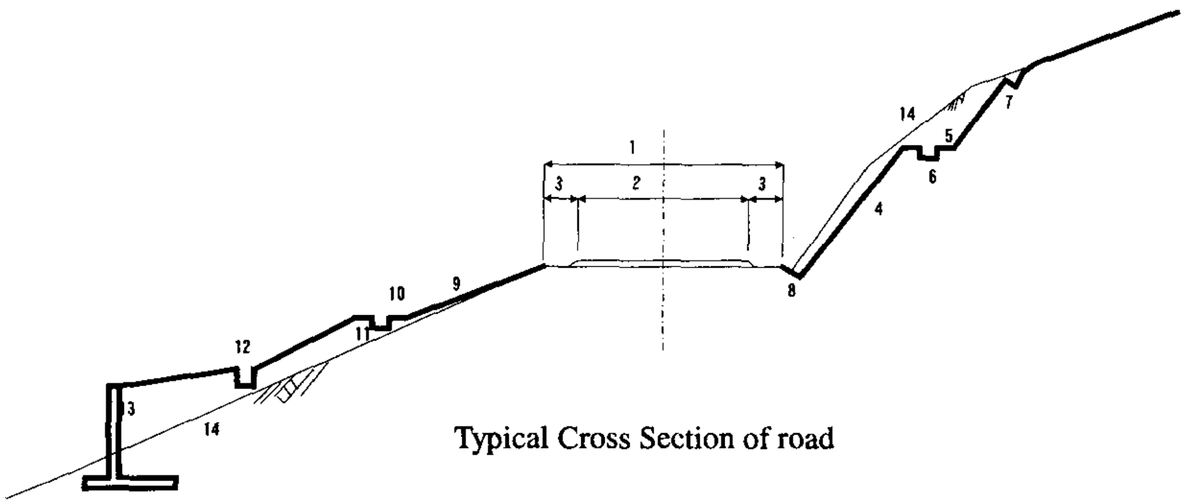
This Manual has taken account of natural conditions, road geometries and environmental condition. Engineers, Inspectors, Technicians and maintenance staffs should be kept on doing maintenance.

1.2 Glossary of Terms

This Chapter contains a glossary of terms that are used in this manual.

1.2.1 Cross section

The typical road cross section is as the following figure. Almost cut slopes, embankments and ditches, etc. are not enough safeguard against failure. Therefore, this manual contains proposals shown in following figure as bold lines.



Typical Cross Section of road

Key;

1. Roadway
2. Carriageway
3. Shoulder
4. Cut Slope
5. Berm
6. Berm Ditch
7. Crest Ditch
8. Roadside Drain
9. Embankment Slope
10. Berm
11. Berm Ditch
12. Berm Ditch
13. Structure
14. Existing Slope

1.2.2 Glossary of Terms

The main "Glossary Terms" are as follows.

AHP This is one of evaluation method for selecting the high priority disaster spots. AHP is an abbreviation of the Analytic Hierarchy Process.

Catchment Area The area from which water runs off by gravity to a collecting point.

Culvert A duct, usually rectangular or circular, for carrying surface water under the road.

Gabion The steel mesh cage filled with cobble stone or crushed stone. This is mainly used for revetment, foot protection and rockfalling protection.

Disaster Critical Spots Disaster critical spots should be defined in consideration of the following items to the disaster potential spots:
- Disaster scale/ records at area of spots,
- Necessary spots for emergency,
- Critical spots for third persons,
- Topographic data by preliminary topographic survey, and
- Sketch of site condition.

Disaster Potential Spots Disaster potential spots are defined when there are:
- boulders on slope surfaces,
- many cracks on rock surfaces,
- small rock fallings, and
- historical disaster records regarding rock-fall, rock collapsing, slope slide, scouring of bridge foundation.

Disaster Prevention Spot Where countermeasures against disaster are proposed, Which addressed the following:
- Stability level of damage spots,
- Traffic volume of objective road,
- Environmental evaluation,
- Natural condition,
- Benefits/ Rough cost estimate,
- Restoration level of damaged spot, and
- Development situation.

Emergency Countermeasure
- It means that a serious and dangerous spot must be improved immediately.
- The lifetime of countermeasures should be until the next rainy season or less than a half year.
- It is necessary to decide upon the implementation of temporary countermeasures or permanent ones during the lifetime of the emergency countermeasures.

Emergency Inspection	**<Time of Year>**: The Emergency Inspection must be carried out just before any forecast hurricane or heavy rain. **<Spots>** : Slope spots previously damaged, seepage water spots on slope and severe scouring spots at bridge foundations, must be carefully inspected and be written on the survey sheets by Inspectors. **<Frequency>** : Just before hurricane or heavy rain.
Inspector	Inspector means a member of Inspection Team. Inspection team is composed of a Engineer and two assistants.
Periodic Inspection	**<Time of Year>**: The Periodic Inspection must be carried out before the rainy season (usually around September) or after earthquake occurred. **<Spots>** : At least, whole slopes of disaster potential spots, and around the bridges at disaster potential spots must be inspected and be written on the survey sheets by Inspectors. **<Frequency>** : Once every year
Permanent Countermeasure	- The lifetime of countermeasures should be least twenty (20) years during the maintenance work. - An adequate budget for permanent countermeasures should be safeguarded at all times.
Routine Inspection	**<Time of Year>**: The Periodic Inspection must be carried out as general inspection throughout the year. **<Spots>** : Whole slopes and bridges on the objective major road is inspected and be written on the survey, if some abnormality occur. **<Frequency>** : Once for a week
Screening	The objective of screening is as follows: - Objective inspection of vulnerable spots, - Early detection of vulnerable spots, and - Characteristic grasp of vulnerable spots.
Temporary Countermeasure	The lifetime of countermeasures should be at least ten (10) years during the maintenance work.

1.3 Relating Law

Each regulation for construction work of disaster critical spots is described in this Section. There are two regulations for construction work and for its transportation of materials and machines.

1.3.1 Law 337

National Committee has managed the National system for the Prevention, Mitigation and Disasters in Nicaragua. The following contents have extracted from the Creator Law of National system.

Chapter 1: General Dispositions

Art. 3 Basics Definitions

Numeral 7 Disasters:

In all situations that cause intense alterations for the social, physical, ecological and cultural society components, taking to imminent danger the human life and the personal and national goodness, surpass the local answer capacity to give efficiently attention to the consequences; it could be from a natural origin or caused by the man.

Numeral 8: Natural Disasters

This damages are caused by any natural phenomenon, this could be a hurricane, a twister, storm, high tide, inundation, tsunami, earthquake or volcanic eruptions, land slide, forest fire, agriculture blight, dried and others that as result will affect the population, the infrastructure and some productive sectors from the different economical activities, in a high scale that overcome the capacity for local answers and require the regional help; at the request of one or more of the affected parts to complete the able resources efforts on it, so that the damages and the loss could be mitigate.

Numeral 12. Disasters Prevention

It is call to the group of activities and measures from a technical and legal character that has to be done in a Socio- economical development Planning process, so that the loss of humans life and damages on the economy could be avoid as a consequence of the natural disasters.

Art. 7 National System Functions

Part 1.
Design, ratify and execute the disasters prevention plan.

Part 10
To establish the agreement for Scientific-Technical cooperation for countries with more experience on it.

Chapter II

From the National Commitment of the National System for Prevention, Mitigation and disasters attention

Art. 9. National Commitment of the National System.

The national commitment of the National system, from now on is call National Commitment; it is the ruling instance and the one who can establish the political, planning, direction and the system coordination all over their activities.

Art. 10. National Commitment integration.

The national commitment joint to the State ministries or their represent, is going to be presided by the president of the republic or the vice president. This National Commitment has a permanent character.
The sessions works of the national commitment have to be on the running time at least two times in the year and they will regulated themselves with the Rules established on the present law. This commitment is going to be conformed as follows:

1. President of the Republic or a representative
2. Secretary of Defend , companied with the Chief of the national army
3. Secretary of Interior , companied with the chief of the national police.
4. Secretary of state
5. Secretary of Treasure and public credit.
6. Secretary of Foment, Industry and business.
7. Secretary of health
8. Secretary of Transport and Infrastructure
9. Secretary of environment and Natural resources

10. Secretary of the Family
11. Secretary of Education, Culture and sport.
12. Director of Territorial Study institute.

Art. 11 Commitment functions

For the present law and their ruling, it is function of the National commitment the following aspects:

1. Definitions of the national system politics
2. Approve the national plan for the national system
3. Propose to the president of the republic the declaration of the disaster conditions.
4. Approve the annual purpose for the national disaster fond.

Propose the adoption of required measures and instruments to make useful the objectives of the national system, such as territorial order and education, and more.

5. Creation of the procedures on instruments for the control and distribution of the international help.
6. Approve the norms and regulation propose of the territorial order for the disasters prevention.
7. Convoke, such as adviser, to the governmental and non governmental organisms.
8. Approve the items and contents of the study that has to be include on the education programs of the Department of Education, culture and Sports, such as the others institutions of the technical education and superior, about prevention, mitigation, and disasters attention.

In the Department of Transport and Infrastructure exist a technical joint unity for disasters that are direct dependant from the Superior direction of the MTI and in case that disasters occur is attended by the General Director of Constructions Norms and urban Development.

1.3.2 NIC 2000

Sub division 100
Section 105 Work reach

1. General

105.07 Dispositions about the Traffic Control

The contractor can not close to the traffic for any reason publics routs or stretch or bridge without a previous writing approve by the engineer. Neither can start with the constructions works that for any reason left the public road on non adequate conditions for the traffic flow, with out a previous temporary construction approved by the engineer based on the commodity and security aspects.

Other wise it is arrange on a different way on the draws, preventive signs should be installed far away from the project limits, at least 150 meters from each side. And at least 150 m form another project site where the constructions works interfere with the public traffic that use the route.

During the night should be working flashing beacon, lanterns. Electrical and reflective instruments and any other approved light sign in the places where it is necessary.

Where it is necessary and the places where the engineer said, should be use a standard bearer , or pilots cars or routs savers with the purpose to guide and arrange the traffic and pedestrian circulation. The workers should be wearing uniforms or specials jackets and pennant or manual signs so that they could be easily seen by the drivers during the day and the night.

When the works are done on adjacent areas of lanes to open traffic areas, the borders of the lanes or of the pavement should be defined trough portable definers placed on the whole length and parallel to the border.

105.06 Traffic Maintenance

1. Construction of the Road by band.

Specially in case of paving or re-paving, the contractor could, if the engineer approve, proceed to work with band, leaving free a space with a enough wide for the secure and comfortable traffic pass and controlling trough the standard bearer or pilots car; on both opposites routs of traffic circulation.

Ruling for the load control and dimensions of the load carrying vehicles that transit on the Road network of Nicaragua (MTI) March 2002

Art. 9 It is establish that the carried load should respect the following aspects.

1. No load could be more than 1.0 m from the back side of a vehicle.
2. Any loaded or unloaded vehicle could exceed the follow dimensions:

Wide: 2.60 m.
Height: 4.15 m. (starting form the running surface)
Length: a) 2 axes : 11.0m.
b) 3 axes: 12.0 m.
c) half tow truck : 17.35m.
d) others combinations: 18.3 m.

Art. 19

When for any reason of general interest, had to be occasionally transported, heavy machines or other invisibles objects, on load carry vehicles allowed to use the country road network which load and dimensions exceed the indicated on appendix that are stipulated on this ruling, a special permission is granted by the Road General Direction at the request of the owner of the special load at least previously 3 days before the carry of the load, which has limited urgency just for the particular trip.

Art. 20

In each special permission it is going to be specify the type of load, the rout that is going to follow and the appropriate time, the circulation speed on the roads and specially on bridges, accompaniment of radio squad and others protections measures of the road network and safety of the others users.

Art. 42

Motorized vehicles or their combinations should have pneumatic tires or dispositives with enough elastic surface. It is prohibit to use metallic objects that are prominent on the running surface of the tire. The tires pressure on none case can exceed the load of 8.4 kg/cm^2. It is prohibit to circulate with chains or metallic bands.

1.3.3 Law for Vehicles and Traffic

Art. 61

It is totally prohibit to carry objects that are prominent from the external sides of vehicles and every time that they are prominent form the posterior side of the vehicle, they should be provide with a red scarf, if it is during the day; or a red light if it is during the night.

Note: Law approved on may 10, 1938

CHAPTER 2 DESIGN STANDARD

2.1 General

The design manual is composed by the method of designing the countermeasure, which is selected by "Planning Manual for Road Disaster Prevention" and the description of the quality control materials.

Firstly, a countermeasure of the slope is described about the method of judging stability before the plan.

Next, the design of the countermeasure to the falling rock is described. Moreover, the stability inclination at the cut of slope is described.

The design of the countermeasure of the prevention of the scour of the bridge foundation is described at the end.

Moreover, the quality of the material, which lays a countermeasure, is described about the quality.

2.2 Design Standard of Road Disaster Prevention Countermeasures

2.2.1. Stability of Bedrock

1) Concept for Weathering of Cut Slope and its Classification

In general, the soil and rock as newly exposed by cutting works will produce looseness through release of stress, or the strength will be decreased due to the deterioration as time passes. Accordingly, the stability of cut slope will vary complicatedly in relation to the nature of rocks, soil, and sedimentation and weather conditions. It is necessary therefore to give macroscopic evaluation in terms of geological and topographic views in broad area in survey and design of cutting works and stability works for slopes and inclined plane. For example, it is indispensable to carry out the survey of change in the existing slope and inclined plane in the area which is liable to landslide, or large-scale collapse or falling rocks. Especially, water gives much effects upon the stability of cut slope and inclined plane so partial treatment for surface waters and spring in order for the stability of cut slope and inclined plane. And regional weather characteristics should be effectively utilized.

Weathering will range for long years geologically and, in case of cutting, a problem lies with the decrease in strength due to swelling through the release of stress. This is regarded as (1) primary swelling. Meantime, a long-term's repetition of wet and dry is regarded as (2) secondary weathering. These (1) and (2) are considered as the factors of stability in principle.

Table 2.2.1 Meaning of Weathering

Meaning of Weathering	
Terminology	**Explanation**
Primary Weathering (Geological Weathering)	Conditions where the strength is gradually decreased by weathering (physical and chemical) due to the external natural force in long years.
Looseness	Decrease in strength by way of swelling, elastic and plastic deformation along with the release of stress at the time of cutting.
Secondary Weathering (Deterioration)	Phenomenon where the strength is rapidly decreased by way of the external force (repetition of wet and dry and leaching of surface waters) on the portion which has newly become the face of slope after cutting.

Especially, the bedrocks liable to effects by the factors as above (1) and (2) are called soft rocks and those not liable thereto are classified as hard rocks. It is indispensable to grasp the characteristics of soft rocks in the region with cut slope and inclined plane in studying the stability of cut slope and inclined plane.

The bedrocks with collapse factors are as follows:

Table 2.2.2 Bedrocks with Collapse Factors

Factors of Collpase	Kind of Bedrocks
Geology weak to encroachment of water etc.	Pumicious volcanic sand, terrace sand, and granitic sand
Soil and sand with low consolidation or highly weathered rocks	Valcanic ash sand, pyroclastic material, colluvial soil and highly weathered granite
Rocks with quick weathering	Mudrock, tuff, shale, slate, perpentine, schists
Rocks with many cracks	Schists, shale, serpentine, granite, andesite, chert
Rocks liable to collapse through dip slope	Schists, slate, etc.
Structurally weak stratum	Fault fractured zone, land slide site, site after collapse

In the above Table, such bedrocks as schists, slate and chert etc. are those metamorphic rocks distributed like a belt in northeast-southwest near from Las Manos in NIC-15, and known as black schists or crystalline schists. Granite is distributed in further northwest or metamorphic rock. Mud rocks and andesite are the Tertiary sedimentary rocks as distributed from east to southeast of the middle mountain range. Tuff and andesite are the volcanic roaks as distributed along NIC-1, NIC-3, NIC-26, and NIC-24. It is difficult to distinguish the name of rocks but designers of slope should be able to distinguish at least the difference between metamorphic rock, granite, sedimentary rock or volcanic rock. At that time, a geological map will be effective.

Table 2.2.3 Characteristics of Rocks

Name of Rock	Explanation
Sedimentary Rock	Sedimentary rocks like mudstone and sandstone are those clastic soil as sedimented and hardened mainly under water and are classified as conglomerate, sandstone and mudstone according to its size. Generally, sedimentary rocks are originally possessed of old stratum on its bottom and cracks are developed in many cases along or in parallel with layered joint. If this bedded joint is inclined sharply and clayey, there may occur sliding by cutting.
Igneous Rock	Igneous rock is those magma with high temperature but cooled and hardened. They will make various rocks according to the way of cooling and difference between chemical composition. Those rocks as cooled gradually in the deep earth's crust are called plutonic rock and will make rhyolite, andesite, and basalt in the order of more silica. In general, igneous rock is with homogeneity isotrophy but plutonic rock is a mass of large crystal and volcanic rock is with small crystal or not visible.
Metamorphic Rock	Metamorphic rock is those igneous or sedimentary rocks which are altered with heat and pressure. Those granite with isotropy is called gneiss and those sand or clay rocks with superior direction under pressure are called as crystalline schists. There are various kinds according to mineral composition. The black schist in the north is also a kind of metamorphic rock.
Fault	Fault is corresponding with the face of shear failure and there caused relative gap at the border with such face. Accordingly, in many cases, rocks near the fault have made fractured zone with a certain width. In such fractured zone, rocks are crushed in pieces and may make fault clay in an extreme case. In general, fractured zone is loose and water can penetrate easily so it may make a route for ground water in many cases. Water penetration will erode into crushed rocks scientifically and physically which may cause the decrease in strength and collapse. In these areas, small pieces of rocks fall constantly; therefore, the slope should be gentle as much as possible.

The following figures show the conception how the rockbed, which come out on the slope depending upon the positions of the slope and weathered zone, may change:

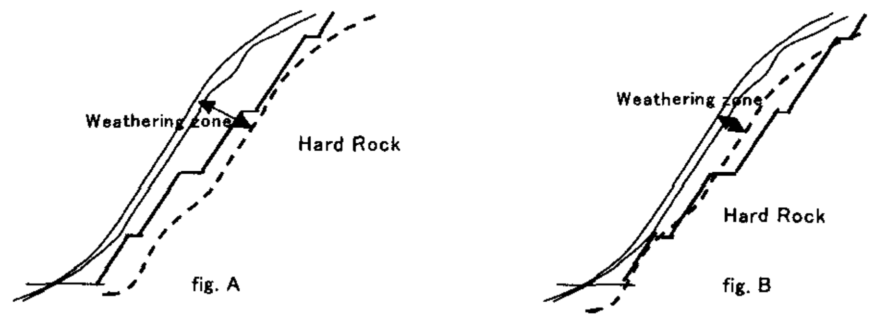


Fig. 2.2.1 Relative Position between Weathered Zone and Cut

Fig. A shows how the slope come into the weathered zone while in Fig. B, the slope is coming into the weathered zone partially but the upper slope is located within the hard rock. In Fig. A, the slope is within the weathered zone and the whole of the slope is liable to small-scale collapse or falling rock along with the progress of weathered on the whole slope. In Fig. B., the slope is located within the hard rocks with a little "looseness" and rocks fall very seldom. It is general that the conditions of slope may vary due to the change in the thickness of weathered zone even though actually the same rocks are distributed.

The weathering conditions of the bedrocks for the slope are confirmed as follows:

Table 2.2.4 Classification of Weathering according to the Hardness of Bedrock

1.	Fresh	When the rocks are broken, its color is fresh. It cannot be cut easily even with mudstone or tuff. In many cases, the slope is stable.	When hit with a hammer, a clear or dull sound is heard. It can be broken with a strong strike of hammer. It will be broken along with the bedding and cracks. It cannot be broken with a flat small rock piece but can be broken with muddy rock or silty rock in both hands barely.
2.	Slightly Weathered	It becomes brown along cracks. When sctached with a hammer, it will leave a mark. As a whole, fresh color is left. On the slope, floating and drifted rock may fall and there may cause spalling.	
3.	Moderately Weathered	When the rocks are broken, fresh color is left in the center and the weathered brown color around the center. Weathered in less than half of the area, there may cause rock falling and peeling off of skin.	A dull sound is heard when hit. The point of hammer can be pierced. It can be broken easily irrespective of crack and bedding. Small piece of rock can be broken with hands
4.	Highly Weathered	When the rocks are broken, fresh color is left slightly. Or, even it has the shape of rock mass, it will become like soil. Hard parts of the slope will be overhung with peculiar unevenness.	
5.	Completely Weathered	All of the parts are soil. In the slope, small collapse or shallow sliding may occur.	A hammer will be stuck. Rock piece is broken with fingers.

2) Method and Sample of Rock Classification in Slope

The weathering classification as stated in the preceding Clause is a kind of rock classification in view of the decrease in strength. The visible rock classification according to the purpose of structure will be effective in case of slope face. However, this information is obtained through site survey by way of "appearance of rock" and sounding with a hammer. Therefore, the survey results may be varied with the views of a surveyor. In case of slope for road, tuff and muddy rock may affect the stability of slope in many cases. These rocks are combined with two factors, that is, hardness and secondary decrease in strength and Nicaraguan rocks are classified into 100kg/cm^2 more by Unconfined Compressive test and 100kg/cm^2 less thereby the former is I, the latter is II. And soil/sand is III. Furthermore, the rocks are classified into A and B according to the secondary decrease in strength as the loosing rate. Rocks are classified into either A or B, with A being rocks that large.
Meanwhile, Loosen quality B Rocks that small is loosen slowly.
Both of them are combined as follows for rock classification and the boundary between them were studied.

Table 2.2.5 Concept for Rock Classification

<table>
<tr><td colspan="2" rowspan="2">Rock Quality Classification according to Hardness</td><td colspan="3">Hard ←→ Soft</td></tr>
<tr><td>I</td><td>II</td><td>III</td></tr>
<tr><td rowspan="2">Rock Quality Classification according to loosing Rate
Large ↑
↓
Small</td><td>A</td><td>I A</td><td>II A</td><td>III</td></tr>
<tr><td>B</td><td>I B</td><td>II B</td><td></td></tr>
</table>

a) Quantification of Rock Quality Classification according to Hardness

For the sake of objectivity of the rock quality classification, the hardness classification was decided as quantification by the use of the laboratory test results through the core of boring survey. For quantification, such materials as slope conditions with unconfined compression strength of rock test and unit weight, i.e, slope with rock fall or, repetion of small-scale collapse or both of them were collected and arranged. The following table shows the results of actual analysis:

Table 2.2.6 Arrangement of Laboratory Test Results (Sample)

Nic-1 Km: From MTI	No.	Boring holes	Depth (m)	Grain size analysis Gravel (%)	Sand (%)	Fine grained soil (%)	Liquit limit (%)	Plastic limit (%)	Plastic index	Soil classification	natural water content (%)	Specific gravity	Unite weight (g/cm^3)	Unconfined compression test (kg/cm^2)
60.9	01A290	1	1.3m	50	34	16	53	36	17	GM	17.40	2.14	2.63(11.45~11.50)	45.0(14.6~14.7m)
73.2	01A280	boring 1	1.3m	0	28	72	46	30	16	ML	22.90	2.38	1.63(10.0~10.2m)	63.0(10.0~10.2m)
			3.7m	12	39	49	65	43	22	SM	21.80	2.19	2.14(15.2~15.24m)	-
		boring 2	1.2m	0	28	72	46	30	16	ML	23.00	2.24	1.39(6.14~6.35m)	-
			2.2m	17	61	22	52	41	11	SM	-	2.24	1.85(14.6~14.7m)	31.0(6.2~6.3m)
			4.5m	16	64	20	54	43	11	SM	-	-	Impossible	
		boring 3	1.0m	Impossible								-	1.53(9.8~9.9m)	51.85(9.5~9.7m)
			14.2m	Impossible								-	1.53(14.0~14.2m)	66.0(14.1~14.3m)
		boring 4	-	Impossible								-	Impossible	
		boring 5	1.4m	Impossible							21.75	-	-	16.0(10.8~10.9m)
		boring 6	1.0m	Impossible								-	Impossible	
168.4	01A240	1	1.8m	40	37	23	50	28	22	GC	26.63	2.26	1.50(6.4~6.5m)	24.0(6.4~6.5m)
			4.1m	0	80	20	42	35	7	SM	15.0	2.24	1.50(15.0~15.2m)	49.0(15.0~15.2m)
168.6	01B230	1	1.0m	22	50	28	40	25	15	SC	-	2.36	1.57(3.5~3.7m)	36.0(3.5~3.6m)
			1.8m	0	70	30	39	23	16	SC	8.90	2.25	1.45(15.0~~15.2m	23.0(15.0~15.2m)
171.3	01B170	1	1.6m	33	33	34	52	32	20	SM	8.98	2.90	1.82(6.3~6.4m)	144.(6.1~6.3m)
			6.4m	Impossible							8.74	2.40	2.62(15.0~15.1m)	256(14.8~15.0m)
175.0	01B150	1	1.0m	21	54	25	47	29	18	SM	11.41	2.77	1.18(7.2~7.3m)	71.0(7.2~7.3m)
			1.8m	39	47	3.5	35	26	9	SM	10.50	2.41	2.85(13.6~13.7m)	222(13.55~13.77m
176.0	01B120	1	2.7m	0	34	66	57	30	27	MH	5.76	2.35	2.09(11.1m)	-
			8.3m	0	66	34	48	28	20	ML	4.65	2.23	2.14(14.0m)	86.0(14.0~14.1m)
178.7	01A110	1	1.3m	27	31	42	54	31	23	SM	22.19	2.46	2.17(3.7~3.8m)	-
			3.8m	Impossible							21.0	2.32	2.60(14.2~15.0m)	732(14.0~15.0m)
204.7	01B070	1	2.7m	31	52	17	22	16	6	SC-SM	18.1	2.56	2.72(7.5m~7.6m)	445(7.4~7.6m)
			7.6m	Impossible							19.0	-	2.60((14.6~14.7m)	354(14.6~14.8m)
214.7	01A050	1	1.8m	29	52	19	35	23	12	SC	15.98	2.61	2.30(8.9~9.1m)	202(8.8~8.9m)
			2.3m	Impossible							4.03	2.58	2.19(15.0~15.1m)	255(15.1~15.2m)

Impossible:The core's Condition is Almost Pebble Type.

Exam.:Depth of Sample(4.0m~5. 0m)

As shown in the Table below, unconfined compression strength on a cross axle and unit weight on a vertical axle are put together with the conditions of the slope face. As the results, many of the unconfined compression strength of tuff show the value of less than 100 kg/m^2. It also turned out that the face of slope had skin peeling and overhung thereby rock fall and small-scale collapse were induced in many cases. Many of the unit weight showed around 1.9 tf/m^3 but it is also one of the special qualities of volcanic products that some of the tuff had very strong hardness even with the value around 1.5tf/m^3.
As the results, the group in dotted line and classified in I and II.

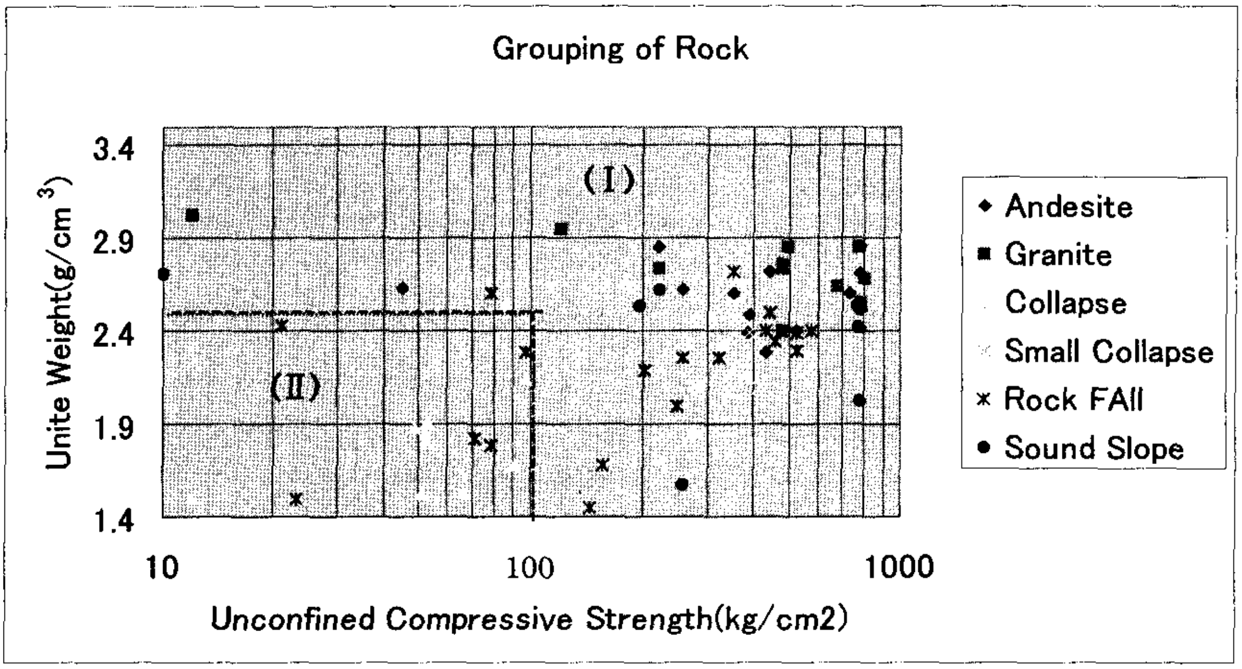


Figure. 2.2.2 Grouping of Rock

b) Quantification for Secondary Strength-Decrease Classification

The degree of formation for "Looseness of Surface Layer" most typically represents the secondary decrease in strength of bedrocks in the slope. The looseness of surface layer means the weakened parts in the slope with the effects of such external forces as weathering and erosion of rain water after cutting and up to the present time. The special feature lies with the hardness where it can be digged with the point of hammer (pick hammer) in usual ways. Days after the slope face should be confirmed. It is considered that "Formation Speed for Loosened Layer" will be slowed as time passes thereby an indicator α is obtained with the following formula to show the speed of formation.

α = (thickness of surface loosened layer in cm.) $\div$ log (time passed after cutting)
(Sedimentary in Geotechnical Engineering 1987 by Japanese Society in Soil Engineering).

In this study, the N-value of tuff among the boring survey done for each slope was noted and the layer of less than 3 blow times in penetrate amount of the initial 10cm was sought. The value was multiplied by 3 and the layer of N<9 was decided as "Loosened Surface Layer". When the penetrate amount exceeds 10cm., it will push in the underground gravel without exception and the N-value increases suddenly thereby it should be difficult to distinguish the loosened layer. For the index representing the secondary decrease in strength of the loosened surface layer, an expansion rate and liquid limit may be available in addition to the above α index and N-value. But for a site work, it should be a high possibility of tuff with quick "formation speed of loosened layer" if weathered soil of tuff obtained by digging the slope face is taken in a sample bottle and dissolved with water, and if the deposit is nearly filled with fine grained soils or silt. Or if even tuff or mudstone is collapsed like rock mass of weathered zone is dissolved in water (slaking phenomenon), then surely a clue for distinguishing A and B can be obtained. The following Table shows the thickness of "loosened surface layer" as a sample among the looseness due to weathering and as obtained through N-value.

Table 2.2.7 Loosened Surface Layer obtained from N-Value N < 5 ~ 9

NIC-1													
ID NO.	Distance from MTI(km)	Thickness of Weathering Bed (m) N:Value of Standard Penetration Test						Type of Soil's Clafissication	Clafissified Type of Weathering Bed	Passing Days from Completion:T	Velocity of Weathering a=a/logT (a:cm)	Sub-Clafissication a>12 A a< 9 B	Clafissication of Rock
		N> 5−9 : a	30>N	50>N>30	Subtotal (m)	N> 50−100	Total (m)						
A290	60.9	0.1	0.9	0.0	1.0	1.8	2.8	GM	Ⅲ	21.240	2.3	B	Ⅱ B
A280	73.2	0.3	0.7	1.5	2.5	1.6	4.1	ML−SM	Ⅲ	〃	6.9	B	Ⅱ B
A240	168.4	0.2	1.8	0.5	2.5	1.8	4.3	SM−GL	Ⅲ	15.480	4.8	B	Ⅱ B
B230	168.6	0.6	0.4	0.5	1.5	1.7	3.2	SC−SM	Ⅲ	〃	14.3	A	Ⅱ A
B170	171.3	0.0	0.0	1.0	0.5	2.7	3.2	SM	Ⅲ	〃	0.0	B	Ⅰ B
B150	175.0	0.2	0.3	0.0	0.5	2.7	3.2	SM	Ⅲ	〃	4.8	B	Ⅰ B
B120	176.2	0.4	0.7	0.5	1.6	2.1	3.7	ML−MH	Ⅲ	〃	9.1	B	Ⅱ B
A110	178.7	0.8	0.7	0.0	1.5	4.2	5.7	SM	Ⅲ	〃	19.1	A	Ⅰ A
A070	204.7	0.1	0.9	0.0	1.0	3.6	4.6	SC−SM	Ⅲ	15.120	2.4	B	Ⅰ B
A050	214.7	0.3	0.2	0.0	0.5	2.7	3.2	SC	Ⅲ	〃	7.2	B	Ⅰ B

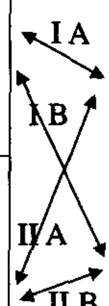
3) Rock Classification and Cut Slopegrade through Observation of Cut Face

The stability investigation table is those as arranged by grasping many factors as the size of slope collapse with natural ground conditions (especially geological structure) and the size of slope, slopegrade and others. Moreover, it is the method of rock classification which has integratedly classified rocks by paying attention to the original hardness of rocks and its durability. This method will make it effective to study the countermeasures by ascertaining how the slope is collapsed depending upon the height and slopegrade, i.e., if it is the landslide collapse or surface exfoliation collapse, or rock fall collapse. The preceding Chapter has stated about the rock classification by way of quantification. This time, the actual rock classification on the site is arranged through observation as follows:

Table 2.2.8 Rock Classification by Observation of Cut Face

(1) Rock Classification by Hardness

Rock Classifi -cation	Appearance of Rock	Sounding with Hammer
I	Fresh and hard. Texture and structure is confirmed completely.	Igneous rock has clear or dull sound when struck. It is so hard that a hammer is flipped. It will be partially broken with a strong blow of hammer. Sedimentary rock, i.e., shale is broken from schistosity. Mudstone or tuff can be dressed as sample in a hand size.
II	New rock with low hardness. Or, softened rock with weathering. In case of weathering, fine texture of rock is disappearing.	Igneous rock has has a dull sound when struck and considerable weathering is seen. Sedimentary rock is stuck with the point of hammer and easily broken irrespective of crack and bedding. Flat small piece can be broken with hand.
III	Non-hardened sedimentary rock or rock with weathering or strong alteration. It does not show the mass of rock but be handled rather as soil and sand.	It is broken like falling to pieces, or the point of hammer will stick in it. Small piece will be broken with fingers.



(2) Rock Classification according to Secondary Change

Classif -cation	Characteristics of Natural Ground or Soil
A	Secondary decrease in strength will surely occur if left as it is. Liable to slaking with much weathered fine soil.
B	Under normal situations, the secondary decrease in strength will not occur making a problem in the stability of slope face. No slaking. Weathered sandy soil.

Combination of (1) and (2)
① I B
② II B ③ I A ④ I B
⑤ III

Based upon the above and utilizing the Stability Investigation Table, Figure 2.2.3 Analysis for Slopegrade of the Loosening Area in Weathered Zone (Sample) has been prepared. It is obtained by subdividing the soft rock and the group "A" may be subdivided again taking into account the regional characteristics.

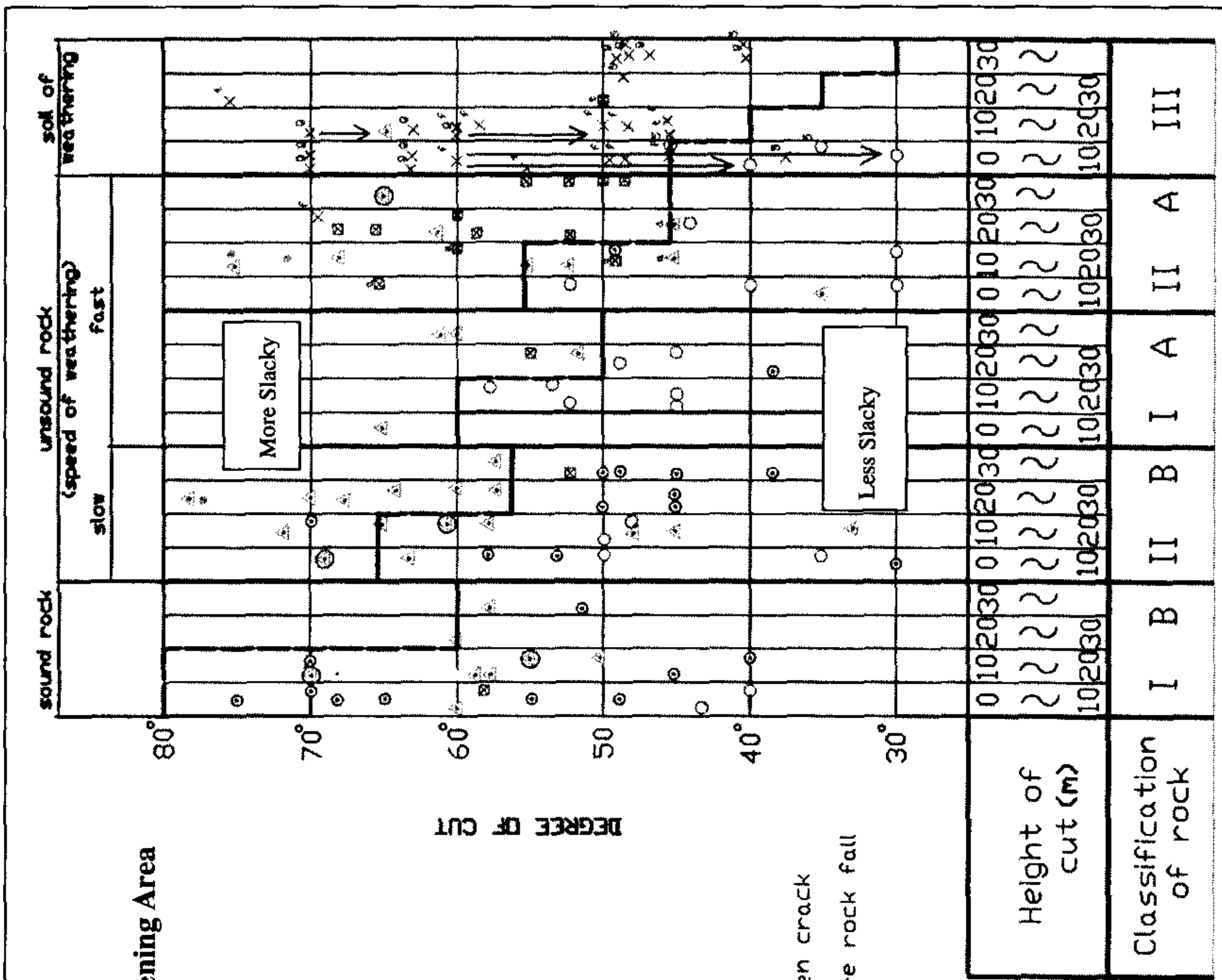


Figure 2.2.3
Analysis for Slope grade of the Loosening Area in Weathered Zone (Sample).

- × collapse
- shallow collapse
- rock fall & small collapse
- rock fall & small collapse and open crack
- sound cutting slope but there are rock fall
- andesite (rock fall)
- sandy granite
- NIC 5 (talus)

4) Method of Stability Analysis and Sample

The tuff belonging to II A of the rock classification as stated in the preceding Chapter is under the situations with advanced weathering thereby strength is decreased. But in some other cases, the slope was slid with heavy rain. Stability calculation is necessary for such slope for formulating the countermeasures.

a) Process for Stability Calculation

The most generally used is the safety factor by way of stability calculation as the index showing the stability of slid slope. The safety factor Fs is a ratio between the force T sliding along the surface with the weight of slid earth mass and the shearing force on the sliding surface as against it.

$$Fs = \frac{N}{T} = \frac{\Sigma C \cdot \ell + (\Sigma W \cdot \cos\theta - \Sigma U \cdot \ell) \tan\phi}{\Sigma \sin\theta}$$

Where, C : Cohesion of sliding surface (t/m^2)
ϕ : Angle of shearing resistance of sliding surface (friction angle)
ℓ : Length of sliding surface of each block (sharp inclination over sliding surface slope angle of 45 is regarded as tension crack but not included in "l" as the length of sliding surface.)
W : Weight of each block (t/m)
θ : Sliding surface angle under the center of gravity of each block.
U : Pore water pressure under the center of gravity of each block (t/m^2)

Σ means the division method (divide each block according to the change in topography and sliding surface, calculate for each block and total), which is most generally used for land slide and suited for more complicated topography and sliding surface.

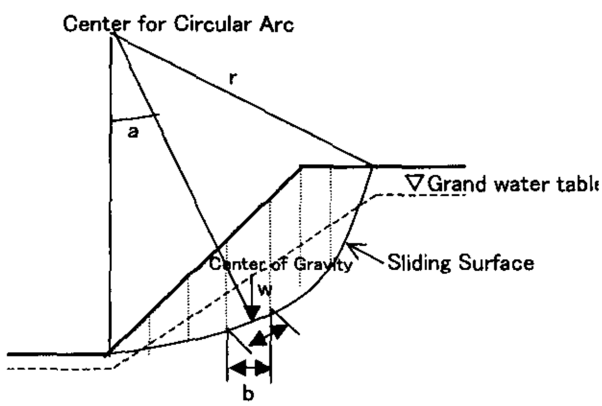


Table 2.2.4 Model for Circular Arc Sliding

The special feature for the stability calculation of land slide lies with the fact that the sliding surface has already been decided with its past record for slide. Accordingly, it is not necessary to carry out such general method as an assumption for sliding surface with trial and error thereby seek a sliding surface showing the minimum safety rate. The stability calculation for landslide is as follows:

i) Decide the type of landslide
ii) Judge if it is activated now or not
iii) Decide the current safety factor through a. and b.

Table 2.2.9 Current Safety Factor

Activity	Classification			
	Bedrock Landslide	Weathered Rock Landslide	Colluvial Soil Landslide	Clayey Soil Landslide
Not Active	1.10	1.05	1.03 ~ 1.05	1.0 ~ 1.03
Active	0.99	0.95 ~ 0.99	0.93 ~ 0.95	0.9 ~ 0.93

iv) Decide necessary conditions for stability calculation through the survey section of the slided land

Weight of Earth Mass $\gamma s \fallingdotseq 1.8 \sim 1.9 t/m^3$, where γ is unit weight of earth mass. Take a value near $\gamma s = 2.0 t/m^3$ when it is near to bedrock landslide.

It will make a linear formula of C and tan ϕ by

$$C = (\Sigma W\cos\theta - \Sigma U \cdot \ell)\tan\phi \ / \ \Sigma\ell + Fs\,\Sigma W\sin\theta \ / \ \Sigma\ell$$

The other side of C and should decided but normally C is decided through the depth and cohesion of the sliding surface as in the following Table.

Table 2.2.10 Depth and Cohesion Power of Sliding Surface

Depth of Sliding Surface (m)	Cohesion C (t/m^2)
5m	0.5
10m	1.0
15m	1.5
20m	2.0
25m	2.5
30m	3.0

The best way for obtaining pore water pressure lies with actual survey on the site. In case of impermeable layer, a head should be the pore water pressure, or 1/3 of the head should be made as the pore water pressure as one of the ways in case of permeable layer only. In general, graphical method is used for drawing a flow net.

c) Sample of Stability Calculation

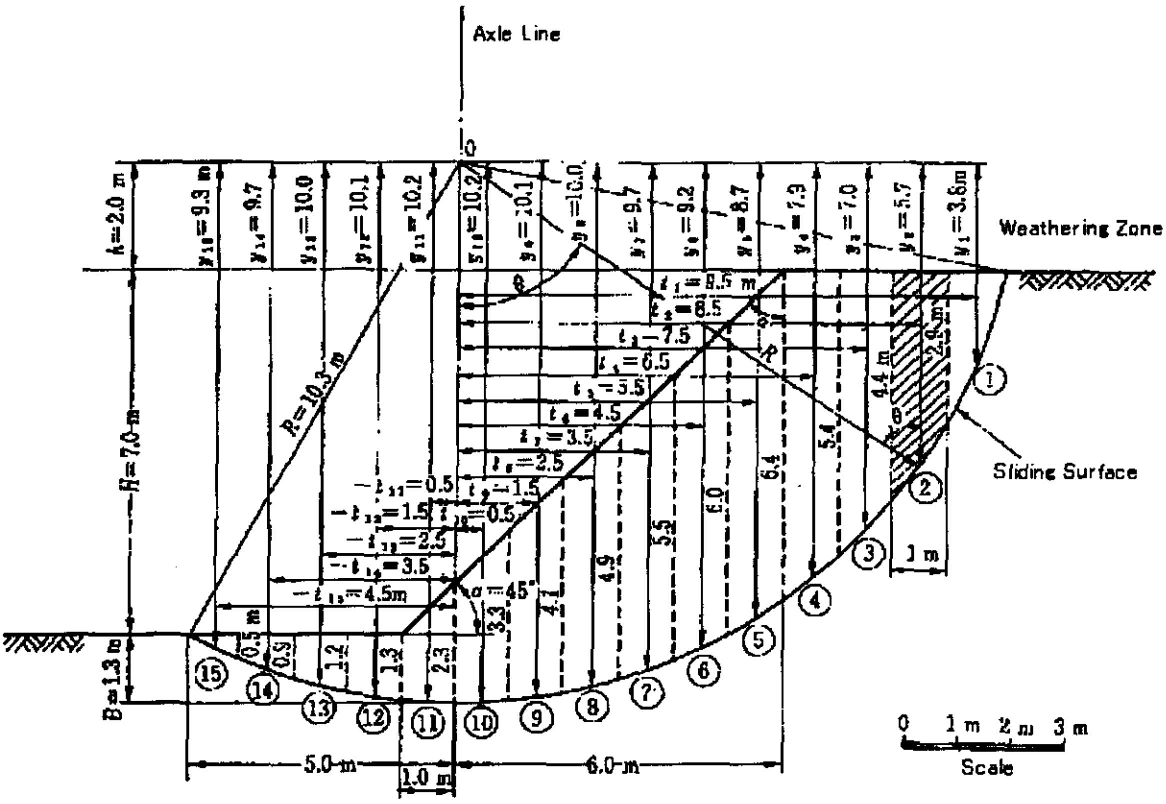


Figure 2.2.5 Stability Analysis

Table 2.2.11 Stability Analysis Calculation of the Figure 2.2.5 as above

No.	Section Area of Slender Piece ΛA (m³)	Weight of Slender Piece	Horizontal Distance from Axle Line until Slenceder Piece (m)	Moment M=ΛWxt	cos θ = y ÷ R	ΛW x cos θ (t)	
1	1/2x2.9x1.0= 1.45	2.47	9.5	23.5	3.8 ÷ 10.3 = 0.369	0.91	Right side of Axle Line
2	1/2x(2.9+4.4)x1= 3.65	6.21	8.5	52.7	5.7 ÷ 10.3 = 0.553	3.44	
3	1/2x(4.4+5.4)x1= 4.90	8.33	7.5	62.5	7.0 ÷ 10.3 = 0.680	5.67	
4	1/2x(5.4+6.4)x1= 5.90	10.03	6.5	65.3	7.9 ÷ 10.3 = 0.767	7.71	
5	1/2x(6.4+6.0)x1= 6.20	10.54	5.5	58.1	8.7 ÷ 10.3 = 0.844	8.90	
6	1/2x(6.0+5.5)x1= 5.75	9.78	4.5	44.0	9.2 ÷ 10.3 = 0.893	8.74	
7	1/2x(5.5+4.9)x1= 5.20	8.84	3.5	30.9	9.7 ÷ 10.3 = 0.942	8.33	
8	1/2x(4.9+4.1)x1= 4.50	7.65	2.5	19.1	10.0 ÷ 10.3 = 0.970	7.42	
9	1/2x(4.1+3.3)x1= 3.70	6.29	1.5	9.4	10.1 ÷ 10.3 = 0.980	6.17	
10	1/2x(3.3+2.3)x1= 2.80	4.76	0.5	2.4	10.2 ÷ 10.3 = 0.990	4.72	
11	1/2x(2.3+1.3)x1= 1.80	3.06	-0.5	-1.5	10.2 ÷ 10.3 = 0.990	3.03	Left Side of Axle
12	1/2x(1.3+1.2)x1= 1.25	2.13	-1.5	-3.2	10.1 ÷ 10.3 = 0.980	2.09	
13	1/2x(1.2+0.9)x1= 1.05	1.79	-2.5	-4.5	10.0 ÷ 10.3 = 0.970	1.74	
14	1/2x(0.9+0.5)x1= 0.70	1.19	-3.5	-4.2	9.7 ÷ 10.3 = 0.942	1.12	
15	1/2x0.5x1.0= 0.25	0.43	-4.5	-1.9	9.3 ÷ 10.3 = 0.902	0.39	

M0= ΣM=367.9−15.3=352.6t·m   Σ ΛWxcos θ =70.4*t*

5) Simple Way for Obtaining a Safety Factor through Chen's Calculation Table

Chen assumed the logarithmic spiral, analyzed and showed the results a sin the following figure, where the stability coefficient is indicated as the marginal height Hc. Therefore, in case that the stability coefficient of N = Hc・ γ /c is obtained corresponding to φ、α、β, the safety factor for the marginal height Hc is obtained as Fc = Hc/H = cN/ γ x 1/H.

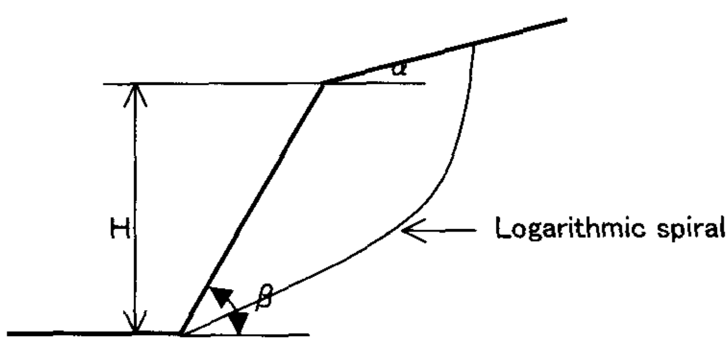


Figure. 2.2.6 Chen's Sliding Slope

In case that a safety rate for H = 10m, β = 45°, α = 5° γ = 2.0t/m^3 c = 2.0t/m^2 is obtained by referring to the above figure, Fc = 16.04/10 = 1.60 is obtained through Hc = 16.04 x c/γ = 16.04 x 2 = 16.04m corresponding to ϕ = 20°, α = 5°, β = 45° of Table 2.2.12.

Table 2.2.12 Stability Coefficient of CHEN

ϕ°	α°	β°					
		90	75	60	45	30	45
0	0	3.83	4.57	5.25	5.86	6.51	7.35
5	0	4.19	5.14	6.17	7.33	9.17	14.80
	5	4.14	5.05	6.03	7.18	8.93	14.62
10	0	4.59	5.80	7.26	9.32	13.53	45.53
	5	4.53	5.72	7.14	9.14	13.26	45.15
	10	4.47	5.61	6.98	8.93	12.97	41.56
15	0	5.02	6.57	8.64	12.05	21.71	
	5	4.97	6.49	8.52	11.91	21.50	
	10	4.90	6.39	8.38	11.73	21.14	
	15	4.83	6.28	8.18	11.42	20.59	
20	0	5.51	7.48	10.39	16.18	41.27	
	5	5.46	7.40	10.30	16.04	41.06	
	10	5.40	7.31	10.15	15.87	40.73	
	15	5.33	7.20	9.98	15.59	40.16	
	20	5.71	7.97	11.80	21.35	115.50	
25	0	6.06	8.59	12.75	22.92	120.00	
	5	6.01	8.52	12.65	22.78	119.80	
	10	5.96	8.41	12.54	22.60	119.50	
	15	5.89	8.30	12.40	22.37	118.70	
	20	5.81	8.16	12.17	21.98	117.40	
	25	5.71	7.97	11.80	21.35	115.50	
30	0	6.69	9.96	16.11	35.63		
	5	6.63	9.87	16.00	35.44		
	10	6.58	9.79	15.87	32.25		
	15	6.53	9.67	15.69	34.99		
	20	6.44	9.54	15.48	34.64		
	25	6.34	9.37	15.21	34.12		
	30	6.22	9.15	14.81	33.08		
35	0	7.43	11.68	20.94	65.53		
	5	7.38	11.60	20.84	65.39		
	10	7.32	11.51	20.71	65.22		
	15	7.26	11.41	20.55	65.03		
	20	7.18	11.28	20.36	64.74		
	25	7.11	11.12	20.07	64.18		
	30	6.99	10.93	19.73	63.00		
	35	6.84	10.66	19.21	60.80		
40	0	8.30	14.00	28.99	185.60		
	5	8.26	13.94	28.84	185.50		
	10	8.21	13.85	28.69	185.30		
	15	8.15	13.72	28.54	185.00		
	20	8.06	13.57	28.39	184.60		
	25	7.98	13.42	28.16	184.00		
	30	7.87	13.21	27.88	183.20		
	35	7.76	12.95	27.49	182.30		
	40	7.61	12.63	26.91	181.10		

2.2.2 Design of Countermeasure for Falling Stone

1) Category of Countermeasure for Falling Stone

A falling stone countermeasure aims at protecting road user and road facilities against the disaster such as a falling stone. There is falling stone prevention work such as removal and fix of loose stone on the slope which have the possibility of the falling stone, and falling stone protection work which protect with facilities installed to the road edge from the falling stone in the countermeasure that it is installed the facilities. The size of the falling stone made the target is decided on the occasion of the selection of countermeasure. Then, it must ascertain possibility about the countermeasure with protection work from the jumping height and the rolling distance. When a countermeasure with protection work is unacceptable from the result of the calculation, it must enforce a countermeasure by prevention work.

2) Calculation of Jumping Height and Rolling Distance

a) Slide Movement

The slide distance "S" along the slope within "t" second and slide speed "V" after "t" second are shown at the next formula.

$$V=V_0+gt\times(\sin\theta-\mu\times\cos\theta)$$
$$S=V_0t+gt^2/2*(\sin\theta-\mu\times\cos\theta)$$

Where:

θ : Angle of Gradient
μ : Coefficient of Equivalence Friction
V_0: Initial Speed

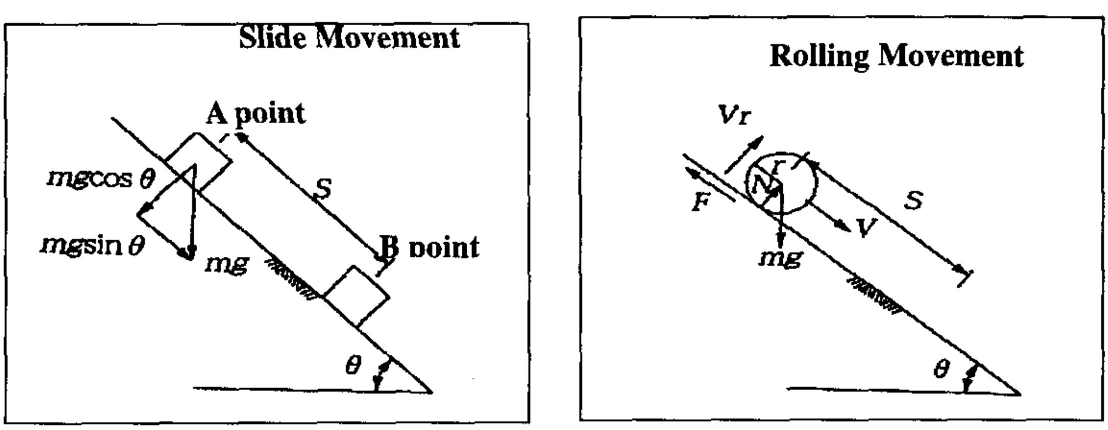


Figure. 2.2.7 Mechanism of Rolling stone movement

When a falling stone falls out of the slope, a falling stone takes the resistance of the slight unevenness, grass and trees except for the friction. This resistance is supposed to be in proportion to the falling stone speed, and made a viscous resistance coefficient "Ck". It is as the following when the above formula is rewritten by using this Ck.

$$V=a/C_k+(V_0-a/C_k)*e^{-Ckt}$$
$$S=a/C_kt+1/C_k*(V_0-a/C_k)*(1-e^{-Ckt})$$

Where:

$$a=g\times(\sin\theta-\mu\cos\theta)$$

a is acceleration in the slope direction. And, the condition which it begins to fail is as the following.

$$\tan\theta>\mu$$

b) Rolling Radius

A speed "V" and a distance "S" after "t" second is as the following when the ball of the mass "m" and the radius "r" falls with rotating without sliding.

$$V=V_0+r^2/(k^2+r^2)\times gt\times\sin\theta$$
$$S=V_0t+r^2/2*(k^2+r^2)\times gt^2\times\sin\theta$$

Where:

k : Inertia Radius

When viscous resistance is taken into consideration, it becomes the same formula as the slide movement. But, acceleration is as the following.

$$a=r^2/(k^2+r^2)\times g\times\sin\theta$$

As for a condition to fall down without sliding;

$$r^2/(k^2+r^2)\times\tan\theta\leqq\mu$$

c) Jumping Movement

The coordinate (X_d, Y_d) of the drop point of a the jumping object in the first speed "V" and the angle "β" from 1 point (X_o, Y_o) is as the following.

$$X_d=X_0+2V_0^2 \times \cos^2\beta/g \times (\tan\theta - \tan\beta)$$
$$Y_d=Y_0+(X_d-X_0) \times \tan\theta$$

A speed element (V_x, V_y) and a coordinate (x, y) after "t" second in consideration of the air resistance coefficient "ak" are as the following.

$$V_x=V_0 \times \cos\beta \times e^{-akt}$$
$$V_y=g/ak+(V_0*\sin\beta - g/ak) \times e^{-akt}$$

$$x=x_0+V_0 \times \cos\beta\,(1-e^{-akt})/ak$$
$$y=y_0 + gt/ak + (V_0 \times \sin\beta - g/ak)1-e^{-akt}/ak$$

As for the speed V_v in the slope vertical direction after " t" second from the jump start;

$$V_v=V_{v0}-gt \times \cos\theta$$

The amount of maximum jump is found by V_v=0.

d) Collision Movement

A speed element "Vv2" in the slope right angle direction and a speed element "Vh2" in the slope direction after the collision are as the following when the incoming angle β 1, the incoming speed V1 as before colliding to the slope and the reflection angle β 2, the reflection speed V2 as after colliding were given.

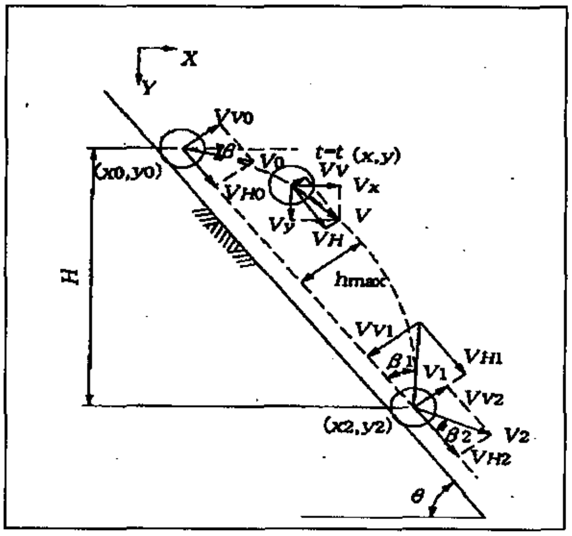


Figure.2.2.8 Jumping Movement and Colliding

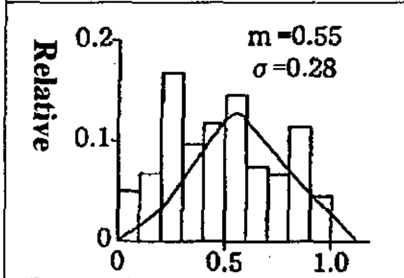
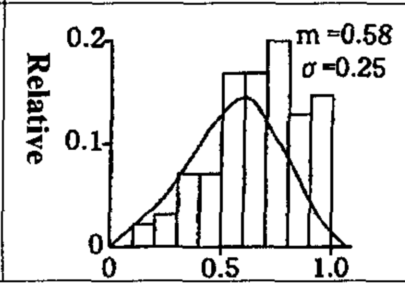
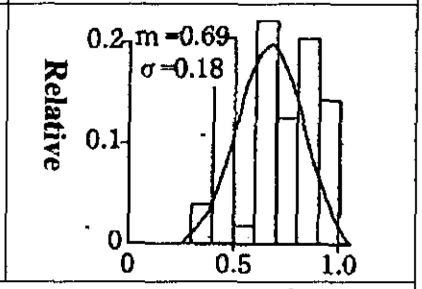
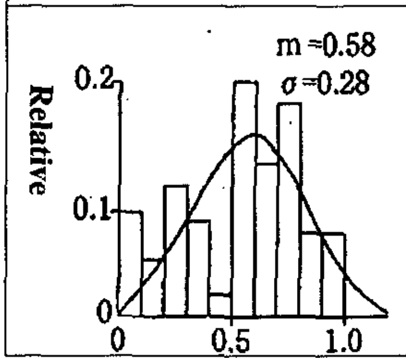
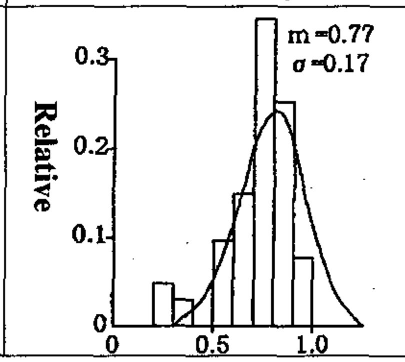
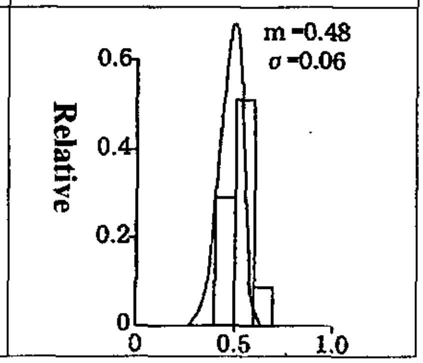
$$V_{v2}=e \times V_1 \times \sin\beta_1,\ V_{h2}=\rho \times V_1 \times \cos\beta_1$$

Where;

e : Normal Line Rebound Coefficient

ρ : Tangent Rebound coefficient in the Slope Direction of the Speed

Table 2.2.13 Probability Density Function of Various Coefficient

		Rock Slope
Normal Line Rebound Coefficient: e	**Tangent Rebound coefficient: ρ**	**Friction Coefficient: μ**
		
		Talus Slope
Normal Line Rebound Coefficient: e	**Tangent Rebound coefficient: ρ**	**Friction Coefficient: μ**
		

e) Switchover from the Rotation Movement to the Jumping Movement

In case of rotation movement, a falling stone jumps caused by the rise in the speed. A drop speed to shift from this rotation movement to the jumping movement is defined as the limit speed V_{cr}.

$$V_{cr} > V$$

f) Case Study

Simulation was enforced on the following condition in accordance with the movement mechanism of the above falling stone. The result of the simulation is shown in the Appendix -1.

Table2.2.14 Fixed Number for Simulation

Item		Mark	Value	Remark
Radius of Falling Boulder	m	r	-	—
Resistance Coefficient	—	Ck	0.100	Test Data
Resistance Coefficient of Air	—	ak	0.001	Doctrine Value
Coefficient of Equivalence Friction: μ	Average	m	0.690	Test Data (Random Number)
	Standard Deviation	ρ	0.180	
Repulsive Coefficient: e	Average	m	0.275	Test Data (Random Number)
	Standard Deviation	ρ	0.280	
Damping Coefficient: p	Average	m	0.580	Test Data (Random Number)
	Standard Deviation	ρ	0.250	
Critical Speed: Vcr	Average	m	4.690	Test Data (Random Number)
	Standard Deviation	ρ	2.020	

3) Design of Prevention Work for Falling Stone

Falling stone prevention work made the target this time is removal of loose stone, slope cut, concrete flame, shotcrete and drainage work. As for each person's outline, it is as the following.

a) Removal of Loose Stone

It gets rid of loose stones in slope, and the danger of the falling stone is avoided.

b) Slope Cut

The danger of the collapse is avoided by cutting an applicable slope in the stable slope. The stable slope of the every soil classification is shown in the Figure2.2.9.

c) Concrete Flame

As for the concrete frame, it was used to renaturation to the slope inside the natural park. Because it is establishment to the rock slope, it isn't made the target of the structure calculation.

d) Shotcrete

It fairs the target slope, and concrete is sprayed there. The weathering, erosion of the slope is prevented by this. The standard of the shotcrete thickness is as the following.

Flatness: 10cm
Unevenness: 15cm

e) Drainage Work

A drainage structure is installed on the slope shoulder, berm step and toe of slope. The weathering, erosion of the slope is prevented by this.

Typical Cross Section

Figure 2.2.9 Recommendation Slope Grade for Cut

For Cut

Cut Slope Standard in Nicaragua

Functional Classification		Miner Collector	Major Collector	Miner Arterial	Principal Arterial	Special Arterial
Number of Lane		2	2	2	2	4
Future Average Daily Traffic (vpd)		-400	400 - 1,800	1,800 - 3,000	-3,000	Over 3,000
Side-slope	On Sound Rock	0 - 1/2 : 1	0 - 1/2 : 1	0 - 1/2 : 1	0 - 1/2 : 1	0 - 1/2 : 1
	Unknown Soil	1 : 1	1 1/2 : 1	1 1/2 : 1	2 : 1	2 : 1
	Well Compacted Soil	1 : 1	1 1/2 : 1	1 1/2 : 1	2 : 1	2 : 1
	Not Well Compacted Soil	1 1/2 : 1	1 1/2 : 1	2 : 1	2 : 1	2 : 1

Recommendable Cut Slope Standard in Nicaragua

Classification		Height of cut (m)	Degree of Cut θ(°)	1/tan θ	n	:	1
hard rock	I B	10 ≧ H	80	0.1763	0.2	:	1
		10 < H ≦ 20	80	0.1763	0.2	:	1
		20 < H ≦ 30	60	0.5774	0.6	:	1
		H > 30	60	0.5774	0.6	:	1
soft rock	II B	10 ≧ H	65	0.4663	0.5	:	1
		10 < H ≦ 20	65	0.4663	0.5	:	1
		20 < H ≦ 30	55	0.7002	0.8	:	1
		H > 30	55	0.7002	0.8	:	1
	I A	10 ≧ H	60	0.5774	0.6	:	1
		10 < H ≦ 20	60	0.5774	0.6	:	1
		20 < H ≦ 30	50	0.8391	1.0	:	1
		H > 30	50	0.8391	1.0	:	1
	II A	10 ≧ H	55	0.7002	0.8	:	1
		10 < H ≦ 20	55	0.7002	0.8	:	1
		20 < H ≦ 30	45	1.0000	1.0	:	1
		H > 30	45	1.0000	1.0	:	1
soil/sand	III	10 ≧ H	45	1.0000	1.0	:	1
		10 < H ≦ 20	40	1.1918	1.2	:	1
		20 < H ≦ 30	35	1.4281	1.5	:	1
		H > 30	30	1.7321	1.8	:	1

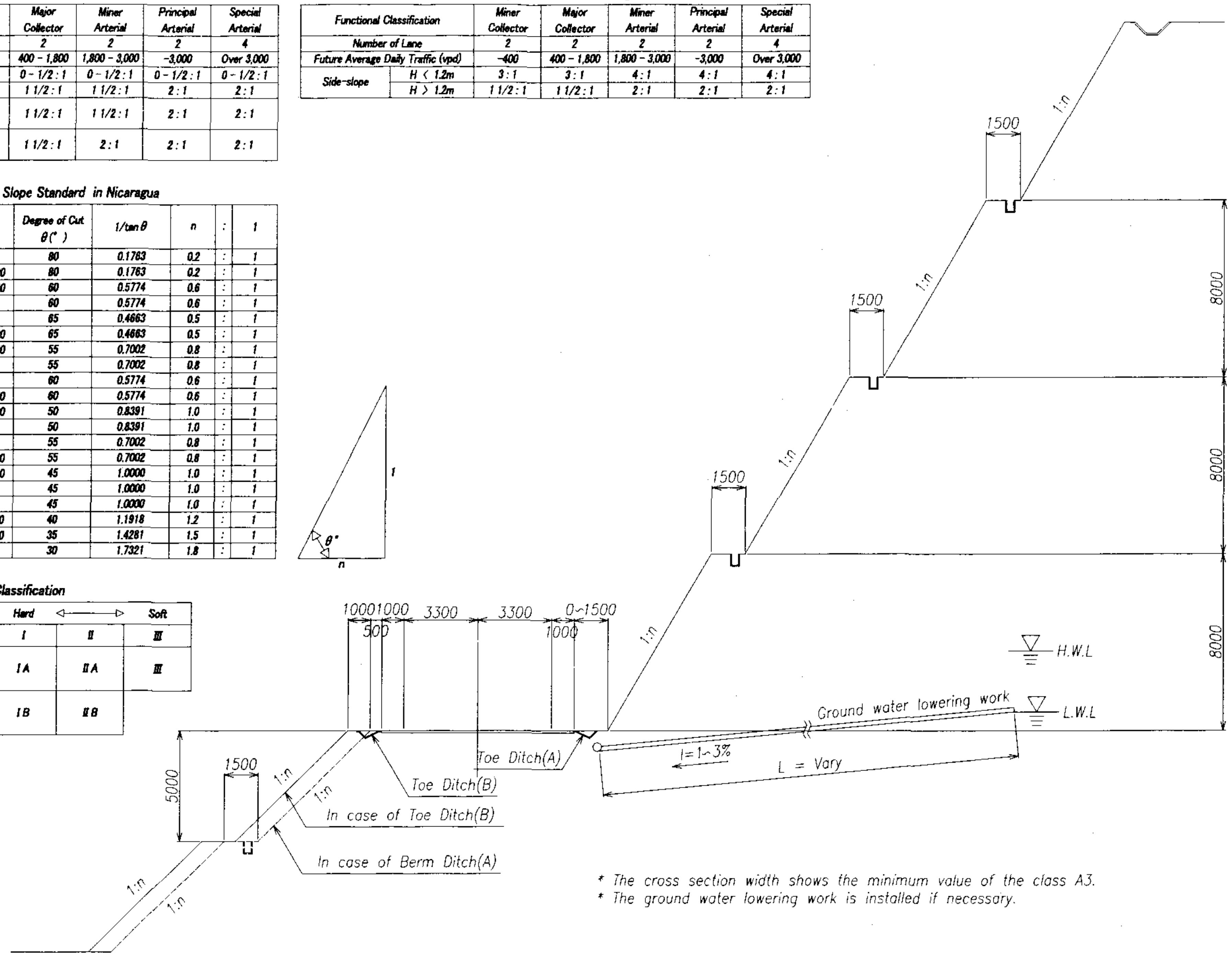
Concept for Rock Classification

Rock Quality Classification according to Hardness		Hard ◁——▷ I	II	Soft III
Rock Quality Classification according to the loosing rate	A	I A	II A	III
Large ↕ Small	B	I B	II B	

For Embankment

Cut Slope Standard in Nicaragua

Functional Classification		Miner Collector	Major Collector	Miner Arterial	Principal Arterial	Special Arterial
Number of Lane		2	2	2	2	4
Future Average Daily Traffic (vpd)		-400	400 - 1,800	1,800 - 3,000	-3,000	Over 3,000
Side-slope	H < 1.2m	3 : 1	3 : 1	4 : 1	4 : 1	4 : 1
	H > 1.2m	1 1/2 : 1	1 1/2 : 1	2 : 1	2 : 1	2 : 1



ORIENTAL CONSULTANTS CO., LTD. JAPAN ENGINEERING CONSULTANTS CO., LTD.	CONTENIDO: / UBICACION: / SITIO:	PROYECTO: STUDY OF VULNERABILITY REDUCTION FOR MAJOR ROADS IN THE REPUBLIC OF NICARAGUA	CALCULO: / LEVANTO: / RESPONSABLE TECNICO:	DIBUJO: / FECHA: November 2002 / ESCALA: S = 1:200 / HOJA N°: 1 / 1

4) Design of Protection Work for Rolling Stone

Falling stone protection work made the target this time is only prevention net. But, as for the protection wall which should be taken into consideration by the examination of countermeasure, a result of a calculation of the necessary form by the falling stone diameter is shown.

a) Prevention Net

The prevention net represses the falling stone which lost the combination power with ground by the wire mesh and the frictional power of ground. The strength of each parts must stand up to formed tension and prudence. A safety factor is made 2.0 to the cutting load of the wire rope.

i) Design of Main Rope

The strength of the main rope covers falling stone weight in the 1 span of auxiliary rope and prudence. The load "W_A " which a main rope takes is calculated by the following.

$$W_A = K \times (W1 + W2)$$

Where;

W1: A falling stone load (tf) for the auxiliary rope 1 span of slope length.

$W1 = W_{11} + W_{12} + W_{13} + \cdots W_{1n}$

W2: The prudence (tf) of the net in l.

$W2 = Wn \times l \times H$

Wn: The prudence (tf/m2) of the unit area.

L: Main rope interval (m).

H: Prevention net length (m).

K: Compensation by the slope angle.

$K = \sin\theta - \mu \times \cos\theta$

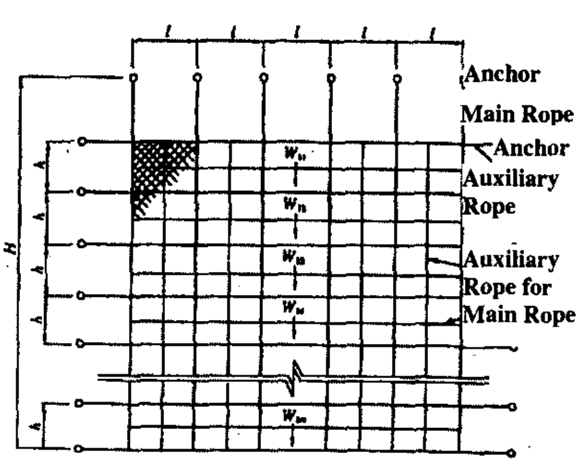


Figure. 2.2.10 Design of Prevention Net

θ : Slope angle (degree)

μ : Frictional coefficient of the falling stone and ground. (=0.5)

The rupture strength (Tb) of the rope has only to have a safety function (Fs) beyond 2.0 against the calculated action load.

$$Fs=T_b/W_A>2.0$$

ii) Design of Auxiliary Rope

An auxiliary rope receives prudence for the bottom side 3 span in the slope direction and a falling stone load as the uniform load. The load (W_B) which an auxiliary rope takes, and a uniform load (w_b) are calculated by the following.

$$W_B=K \times (W1'+W2') \text{ (kN)}$$
$$w_b=W_B/l \text{ (kN)}$$

Where;

W1': The falling stone load (tf) of the slope surrounded by l and h.
W2': The prudence (tf) of the prevention net surrounded by l and h .

The pendency amount (f) of auxiliary rope is made 10% of the 1 span length.

$$F=0.1 \times l \text{ (m)}$$

As for the tension (T) of the auxiliary rope;

$$T=w_b \times l^2/(8\times f) \text{ (kN)}$$

The rupture strength (Tb) of the rope has only to have a safety function (Fs) beyond 2.0 against the calculated tension T.

$$Fs=T_b/T>2.0$$

iii) Design of Wire Mesh

The load which wire mesh takes follows the load which an auxiliary rope takes. The tension (P_{an}) of the wire mesh has only to have a safety function (Fs) beyond 2.0 against the calculated uniform load (wb).
It is calculated by the following.

$$Fs= P_{an} /w_b>2.0$$

b) Protection Wall

The protection wall is made as a gravity type retaining wall. In this basic theory, the movement energy of the falling stone is changed to the deformation energy of the supporting bedrock, and absorbed, and a falling stone is made to stop. As for the details of this calculation, because it is complicated, the retaining wall form is examined referring to the following result of a calculation. Various fixed numbers that used for calculation are shown in Appendix-2.

i) Calculation Example -

Protection Wall Type A: refer to Appendix-2

Size of falling Stone: 1.7kN (0.5m in diameter)

Form of Slope: Slope Height 10m, Slope Grade 30grade

ii) Stability Analysis in a Time of Bump

(1) Calculation of Speed of Falling stone

$$V_0=\sqrt{2\times g\times(1-\mu/\tan\theta)\times H}$$

$$=\sqrt{2\times 9.80\times\{1-0.18/\tan(30)\}\times 10.000}$$

$$=11.614(\text{m/sec})$$

(2) Calculation of Protection Wall

Weight of effective length (L=10.000m)

$Ww = 1/2\times(b1+b2)\times H\times L\times\gamma c = 1/2\times(0.500+1.500)\times 2.000\times 10.000\times 23.000 = 460.00(\text{kN})$

Moment of inertia

$I=Ww/(3\times g)\times(b1^2+b2^2)/2+H^2-1/2\times(b2-b1)/(b1+b2)\times H^2-1/3\times(2b1+b2)^2\times H^2+(b1^2+b2^2+b1*b2)^2\}/(b1+b2)^2\} = 20.13$

Secondary moment of bottom

$I_0 = b2^3 \times L/12 = 1.500 \times 1.500 \times 1.500 \times 10.000 / 12 = 2.81$ (m4)

Bottom area

$A = b2 \times L = 1.500 \times 10.000 = 15.000$ (m2)

Height of gravity center

$S = H/3 \times (2b1+b2)/(b1+b2) = 2.000/3 \times (2 \times 0.500+1.500)/(0.500+1.500) = 0.833$ (m)

Distance of gravity center and bottom center(left side is plus)

$dx = -H/6 \times (2b1+b2) \times (Nf-Nr)/(b1+b2)$

$= -2.000/6 \times (2 \times 0.500+1.500) \times (0.500-0.000)/(0.500+1.500) = -0.208$ (m)

Coefficient of ground reaction

$Kv = \alpha E_0/0.3 \times (A^{1/2}/0.3)^{-3/4} = 3783 \times N \times A^{-0.375} = 3783 \times 30 \times 15.000^{-0.375}$

$= 41{,}108$ (kN/m^3)

Shear spring constant

$Ks = A \times Kv/4 = 15.000 \times 41{,}108 / 4 = 154{,}155$ (kN/m)

Gyration spring constant (Gradient of ab in fig. 2.2.11)

Kr = My/(?y-?$_0$) = 420.660 /(0.00463+0.00083) = 77,044 (kNm)

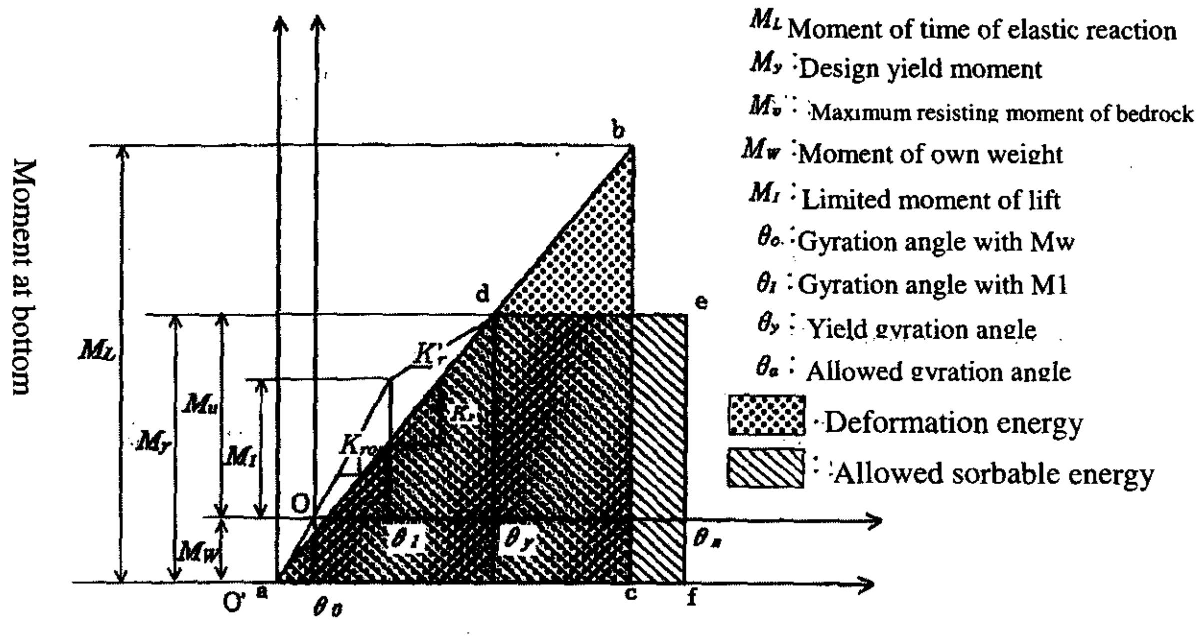


Figure. 2.2.11 Curve of Displacement and Load

Distance of gyration center and gravity center (Z_1)

$e0^2 = Kr/Ks = 77{,}044 / 154{,}155 = 0.500$

$i0^2 = I/m = I \cdot g/Ww = 20.130 \times 9.8/460.000 = 0.429$

$$Z_1 = (S^2+e0^2-i0^2)/2S+\sqrt{(s^2+e0^2-i0^2)^2/4S^2+i0^2}$$
$$= 1.259$$

(3) Calculation of Speed of Point (A) on Protection Wall after Bump

Distance of gyration center and bottom

$L1 = Z_1-S = 1.259-0.833 = 0.426$ (m)

Distance of gyration center and top

$L2 = L1+H = 0.426+2.000 = 2.426$ (m)

Distance of gyration center and bump point

$L = L1+h = 0.426+1.800 = 2.226$ (m)

Revision coefficient

$$\alpha' = 4(b2\times L2-B1\times L1)(L2^2+L1\times L2+L1^2)-3(B2-B1)(L2+L1)(L2^2+L1^2)/\ 6L^2(b1+b2)H$$
$$= 4\times 3.426\times 7.100-3\times 17.303/6\times 4.955\times 2.000\times 2.000$$
$$= 45.389/118.920 = 0.382$$

Speed of protection wall after bump

$V = 2\times W\times V_0/(W+a'\times Ww) = \quad 2\times 1.7\times 11.614/(1.7+0.382\times 460.0) = 0.223$(m/sec)

V_0: speed of falling stone (m/sec)

W : Weight of falling stone (kN)

Ww: Effective length (kN)

(4) Calculation of Turning Angle and Displacement with Bump

Conversion gyration spring constant (Kr1)

$Kr_1 = Ks(e0^2+L1^2) = 154{,}155\times(0.500+0.426\times 0.426) = 105{,}053$ (kNm)

Dynamic displacement of bump point (δ d)

$$\delta_d = \sqrt{\alpha'\times W\times L^2\times V^2/\ Kr_1\times g}$$

$= \sqrt{0.382 \times 460.0 \times 2.226 \times 2.226 \times 0.223 \times 0.223 / 105{,}053 \times 9.80} =$ 0.00649(m)

Turning angle of protection wall (θ_L)

$\theta_L = \delta_d / L = 0.00649 / 2.226 = 0.00292$ (rad) = 0.167 (degree)

L: Distance of bump point and gyration center

Displacement of bottom

$\delta_L = \delta_d (1 - h/L) = 0.00649 \times (1 - 1.800/2.226) = 0.00124$ (m)

(5) Calculation of Deformation Energy with Bump

Gyration allaxis energy

$E_{ML} = 1/2 \times Kr \times \theta_L^2 = 1/2 \times 77{,}044 \times 0.00292 \times 0.00292 = 0.33$ (kJ)

Horizontal energy

$E_{HL} = 1/2 \times Ks \times d_L^2 = 1/2 \times 154{,}155 \times 0.00124 \times 0.00124 = 0.06$ (kJ)

(6) Calculation of Allowed Sorbable Energy

Moment of own weight

$Mw = dx \times Ww = -0.208 \times 460.000 = -95.68$ (kNm)

dx: Distance of gravity center and wall center

Ww: Weight of effective length

Limited moment of lift

$M_1 = Ww \times b2/6 \quad = 460.000 \times 1.500 / 6 = 115.00$(kNm)

b2: Bottom width

A yield moment when the bedrock of the bottom becomes the allowable bearing capacity.

When the bedrock of the bottom becomes the allowable bearing capacity, the horizontal load by the falling stone is looked for by the trial calculation.

Hr = 233.7 (kN)

Moment of horizontal load at bottom center (Design yield moment)

$My = Hr \times h = 233.700 \times 1.800 = 420.66$ (kN·m)

h: Falling height

Maximum resisting moment of bedrock at bottom center

$Mu = My + Mw = 420.660\text{-}95.680 = 324.98$ (kN·m)

Eccentricity distance of resultant work point of own weight and horizontal load

$E = Mu / Ww = 324.980 / 460.000 = 0.706$ (m) $\geqq b2/6 = 0.250$ (m)

Distribution of ground reaction

Deltaic distribution

Maximum ground reaction

$q_{max} = 2\times Ww / \{3\times(b2/2\text{-}e)\times L\} = 2\times 460.000 / \{3\times(1.500/2\text{-}0.706)\times 10.000\}$

$= 697.0 \leqq Qa = 700.0$ (kN/m²)

Initial Gyration spring constant (Gyration spring constant of M<M1)

$Kr_0 = I_0\times Kv = 2.810\times 41{,}108 = 115{,}513$ (kN m/rad)

Yielding gyration grade

$\Theta y = (2\times Mu/M_1\text{-}1)\cdot M_1/Kro =$ (2×324.980/115.000-1)×115.000/115,513

$= 0.00463$ (rad) $= 0.265$ (degree)

Gyration grade of Mw(moment of own weight)

$\theta_0 = Mw / Kr0 = -95.680/115{,}513 = -0.00083$(rad) $= -0.048$(degree)

Gyration spring constant

$Kr = My / (\theta y\text{-}\theta_0) = 420.660 / (0.00463+0.00083) = 77{,}044$ (kN · m)

Allowed gyration grade

$\Theta a = \mu\times\theta y$ ($\theta a \leqq 2.0$ degree)

$= 5.0\times 0.00463 = 0.02315$ (rad) $= 1.326$ (degree) $\leqq 2.0$(degree) ….. OK!

Allowed sorbable energy

$E_M = 1/2\times My(\theta y\text{-}\theta_0) + My\times(\theta a\text{-}\theta y)$

$= 1/2\times 420.660\times(0.00463+0.00083)+420.660\times(0.02315\text{-}0.00463)$

$= 8.94$ (kJ)

(7) Stability of time of bump

Gyration allaxis energy

E_{ML}=**0.33** (kJ)

Allowed sorbable energy

E_M =**8.94** (kJ)

Judge

$E_M > E_{ML}$ ..... OK!

iii) Stability analysis of protection wall

(1) Loading calculation

(a) Weight of protection wall (per 1m)

W = 1/2×(b1+b2) ×H× γc = 1/2×(0.500+1.500)×2.000×23.000 = 46.000 (kN)

(b) Height of gravity center (Y)

Y = H/3×(2b1+b2)/(b1+b2) = 2.000/3×(2×0.500+1.500)/(0.500+1.500) = 0.833

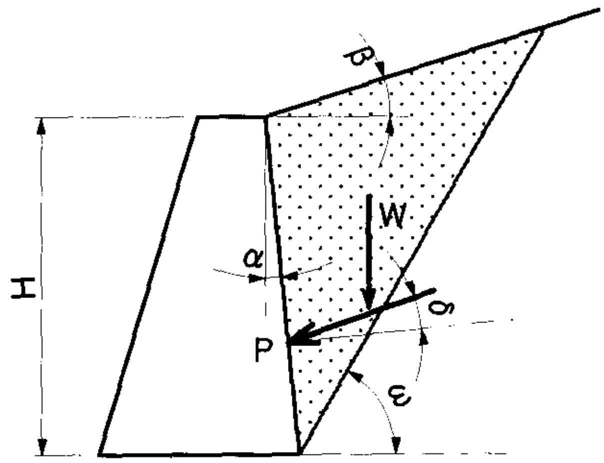
(c) Position of gravity center (X: distance from toe of bottom)

X = B2/2+H/6×(2b1+b2) ×(Nf-Nr)/(b1+b2)

= 1.500/2+2.000/6×(2×0.500+1.500)×(0.500-0.000)/(0.500+1.500) = 0.958 (m)

(2) Calculation of earth load (time of accumulation)

Pa = Ws×sin (ω - ϕ)/cos (ω - ϕ - δ -a)



Where;

Ws: Weight of soil blad (tf/m)

ϕ : Angle of internal friction (degree)

α : Angle of back side and vertical (degree)

β : Grade of accumulation (degree)

δ : Friction angle (degree)

ω : Angle of sliding surface (degree)

H: Wall height (m)

Calculation condition of earth load

Wall height: H=2.00 (m)

Unit weight of accumulation soil: γ s=20.00 (kN/m^3)

Angle of internal friction: ϕ =35.00 (degree)

Angle of back side and vertical: α =0.00 (degree)

Friction angle (d=2/3×f): δ =23.33 (degree)

Grade of accumulation (degree): β =30.00 (degree)

Angle of sliding surface: ω =47.80 (degree)

An angle of sliding surface finds the angle that earth load (Pa) becomes the biggest by the trial calculation.

Sliding Angle	Weight of soil blad	Earth load	Remarks
ω (°)	Ws(kN)	Pa(kN)	
47.6	77.251	17.1518	
47.7	76.682	17.1526	
47.8	76.119	17.1528	Max
47.9	75.561	17.1525	
48.0	75.010	17.1516	

Calculation of earth load

$Ws = 1/2\times \gamma s\times H^2 \times \cos(\omega\text{-a})\cos(\text{a-}\beta)/\sin(\omega\text{-}\beta)\cos^2\alpha$

= 1/2×20.00×2.000^2×cos(47.80)×cos(-30.00)/ sin(17.80)×cos(0.00)^2

= 76.119(kN/m)

$\omega - \alpha$ =47.80 (degree)

$\alpha - \beta$ =-30.00 (degree)

$\omega - \beta$ =17.80 (degree)

$\omega - \phi$ =12.80 (degree)

$\delta + \alpha$ =23.33 (degree)

$\omega - \phi - \delta - \alpha$ =-10.53 (degree)

Maximum earth load

$Pa = W\times\sin(\omega-\phi)/\cos(\omega-\phi-\delta-\alpha)$ = 76.119×sin(12.800)/cos(-10.53)

= 17.153(kN/m)

Horizontal earth load

Ph = Pa×cos(d+a) = 17.153×cos(23.33) = 15.751(kN/m)

Vertical earth load

Pv = Pa×sin(d+a) = 17.153×sin(23.33) = 6.793(kN/m)

Working position of earth load

X = B2-Y×Nr (Nr: Backside grade of wall)

= 1.500-0.667×0.000 = 1.500(m)

Working height of earth load

Y = 1/3×H = 1/3×2.000 = 0.667(m)

(3) Working force on bottom

(a) Regular time (Own weight)

Category	Load (kN)		Distance (m)		Moment(kNm)	
	Own Weight	Inertia	Horizontal	Own Weight	Inertia	Horizontal
	V	H	X	Y	Mr	Mo
Own weight	46.000	-	0.958	-	44.068	-
Total	46.000	-	-	-	44.068	-

(b) Time of accumulation (Own weight + soil accumulation)

Category	Load (kN)		Distance (m)		Moment(kNm)	
	Own Weight	Inertia	Horizontal	Own Weight	Inertia	Horizontal
	V	H	X	Y	Mr	Mo
Own weight	46.000	-	0.958	-	44.068	-
Earth load	6.793	15.751	1.500	0.667	10.190	10.506
Total	52.793	15.751	-	-	54.258	10.506

(c) Time of earthquake (Own weight + Inertia)

Category	Load (kN)		Distance (m)		Moment(kNm)	
	Own Weight	Inertia	Horizontal	Vertical	Friction	Falling
	V	H	X	Y	M r	M o
Own weight	46.000	6.440	0.958	0.833	44.068	5.365
Total	46.000	6.440	-	-	44.068	5.365

Inertia: $H = Kh \times W = 0.140 \times 46.000 = 6.440$

(4) Stability Analysis

(a) Regular time

Falling

$d = \Sigma Mr/SV = 44.068 / 46.000 = 0.958$ m

d: Distance of toe and working point of resultant force

$e = B/2-X = 1.500/2-0.958 = 0.208$ m

e: Eccentricity distance from bottom center B: Bottom width = 1.500 (m)

Allowed value $B/6 = 0.250$ m$\geqq$0.208 m ..... OK!

Bearing capacity

$Q1 = \Sigma V/B \times (1+6e/B) = 46.000/1.500 \times (1+6 \times 0.208/1.500)$

$\fallingdotseq 56.181$ kN/m² $\leqq$ Qa=700kN/m² ..... OK!

Q2 = ΣV/B×(1-6e/B) = 46.000/1.500×(1-6×0.208/1.500)
= 5.152 kN/m²≦Qa=700kN/m² ….. OK!

(b) Time of accumulation (Own weight + soil accumulation)

Falling
d = (SMr-SMo)/SV = (54.258-10.506)/ 52.793 = 0.829 m
e = B/2-X = 1.500 /2-0.829 = 0.079 m
Allowed value B/3=0.500 m≧0.079 m・・・・OK

Sliding
Fs = μs×SV／SH = 0.600×52.793/15.751 = 2.01
Fs: Safety factor for sliding μs: Coefficient of friction of bottom
Allowed value Fsa=1.50 ≦2.01 ….. OK!

Bearing capacity
Q1 = ΣV/B×(1+6e/B) = 52.793/1.500×(1+6×0.079/1.500)
=46.317 kN/m²≦Qa=600kN/m² ….. OK!
Q2 = ΣV/B×(1-6e/B) = 52.793/1.500×(1-6×0.079/1.500)
= 24.074 kN/m²≦Qa=600kN/m² ….. OK!

(c) Time of earth quake (Own weight + Inertia)

Falling
d = (SMr-SMo)/SV = (44.068-5.365)/ 46.000 = 0.841 m
e = B/2-X = 1.500 /2-0.841 = 0.091m
Allowed value B/3=0.500 m≧0.091 m….. OK!

Sliding
Fs = μs×SV／S = 0.600×46.000/6.440 = 4.29
Allowed value Fsa = 1.50≦4.29 ….. OK!

Bearing capacity
Q1 = ΣV/B×(1+6e/B) = 46.000/1.500×(1+6×0.091/1.500)
=41.829 kN/m²≦Qa=450kN/m² ….. OK!
Q2 = ΣV/B×(1-6e/B) = 46.000/1.500×(1-6×0.091/1.500)
=19.504 kN/m²≦Qa=450kN/m² ….. OK!

2.2.3 Design of Countermeasure for Structures

1) Live Load

(HS2D-44 for one- or two-way) + 25%

2) Substructures

The method of Massive masonry walls, reinforced concrete walls and reinforced concrete walls on columns, which made of the same material, will be applied to substructure

3) Superstructures

The method of reinforced concrete T-beams with slab, which made of the same material, steel I-beams with reinforced concrete slab and reinforced concrete slab, will be applied to superstructure.

4) Foundations

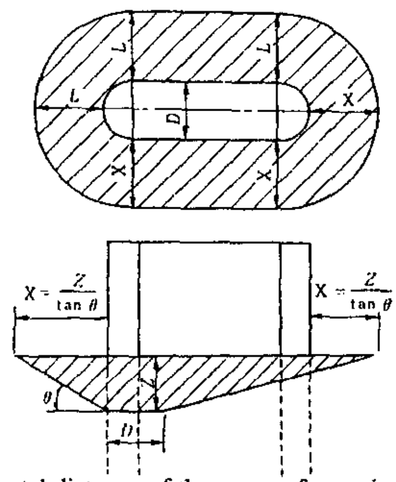
The method of massive masonry or concrete and reinforced concrete will be applied to foundation.

5) Estimation of Scouring Range

The depth of scouring can be estimated based on the result of experiment conducted by the National Institute for the Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport (former Public Works Research Institute) (Figure 2.2.13).

However, the case, which calculates in this table, is a range of $ho/D<3.5$.
(ho: Mean water depth in flood, D: Width of pier).

This calculated value is a standard, and it is important to confirm the size of the scour by the measurement on the site.
The calculation example is shown as follows.



X: Horizontal distance of the range of scouring
Z: Maximum depth of scouring
θ :Angle of repose
D: Width of pier

Figure 2.2.13 Area of Scoring

Width of river : W=31.6m
Width of pier : D= 1.1m
Velocity of High water level : V=60.12
Mean water depth in flood : ho=2.67m
Average grain diameter of riverbed materials : dm=3.0mm

ho/D=2.43
$Fr = (V/(W \cdot ho))/\sqrt{g \cdot ho} = 0.14$
Ratio of depth and grain diameter
ho/dm=890

Z/D can obtain ho/D from relation
(Figure2.2.14-Figure2.2.17)
between ho/dm and Fr as a parameter.

Z/D =0.8
Z =0.96m

The relation between the angle of repose θ and average grain size is shown by Figure.2.2.18
Angle of repose θ =32°
Tan θ =0.62
X=Z/tan θ =1.54m

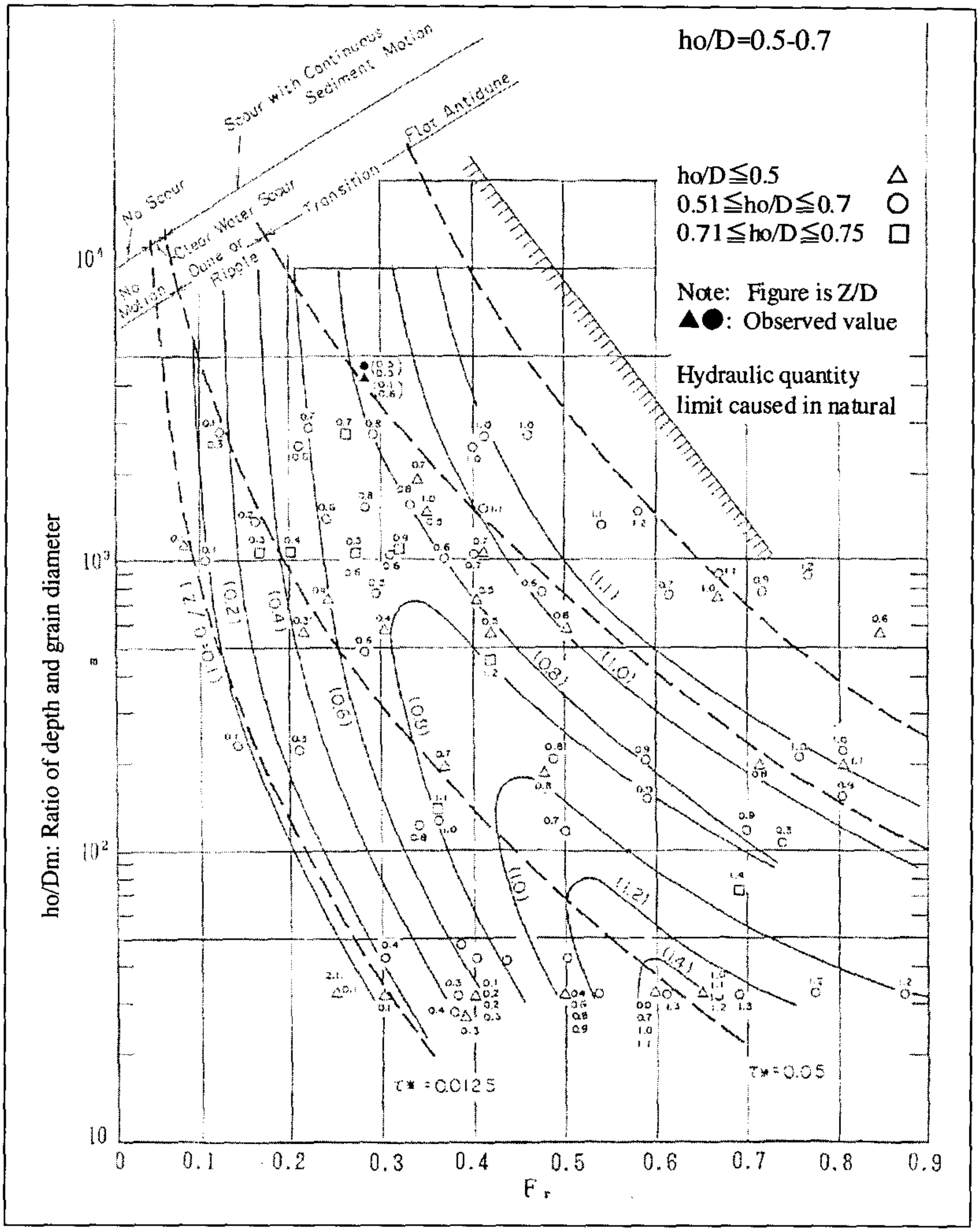


Figure 2.2.14 Assumption of Depth of Scour (ho/D= 0.5-0.7)

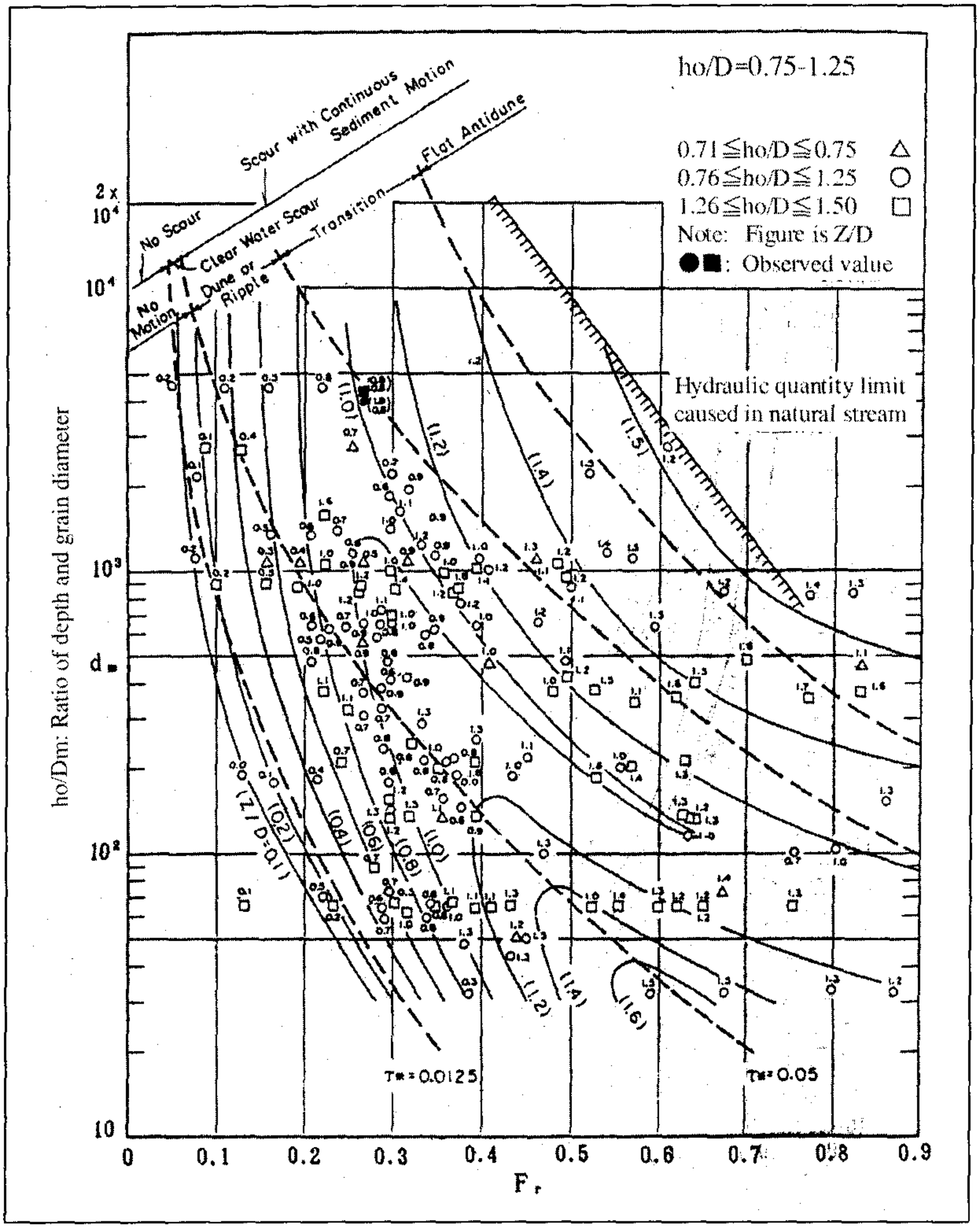


Figure 2.2.15 Assumption of Depth of Scour (ho/D= 0.75-1.25)

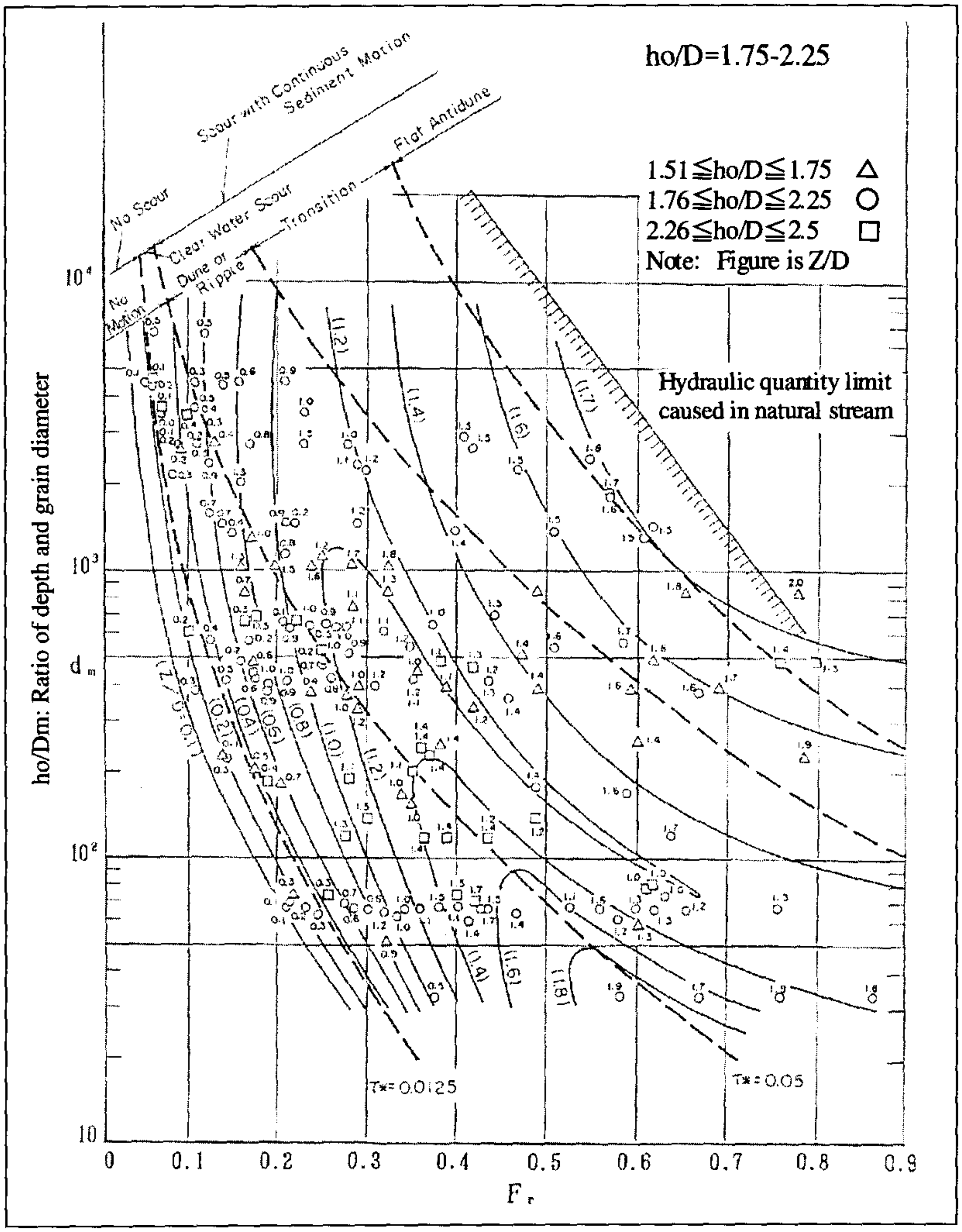


Figure 2.2.16 Assumption of Depth of Scour (ho/D=1.75~2.25)

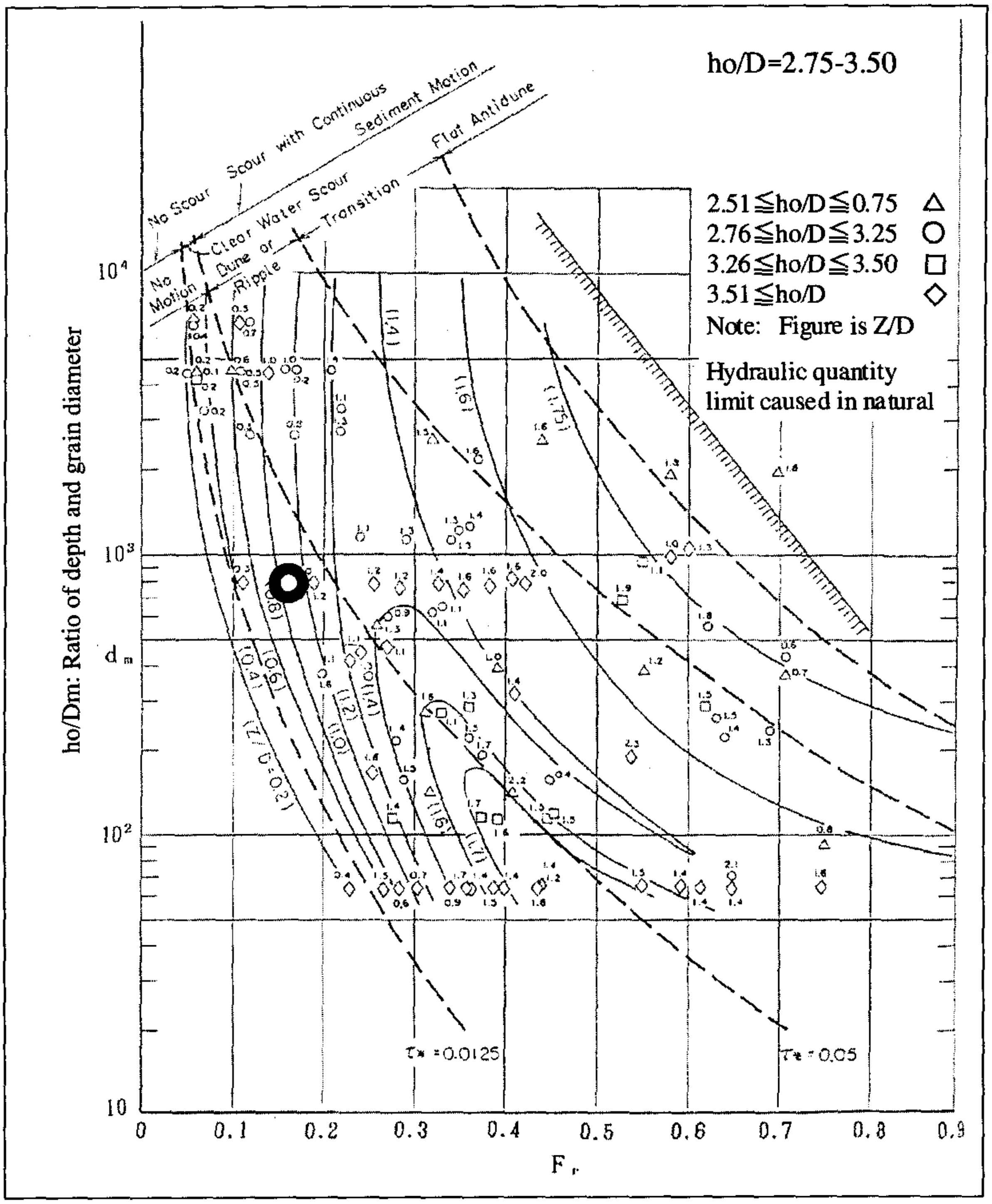


Figure 2.2.17 Assumption of Depth of Scour (ho/D=2.75~3.5)

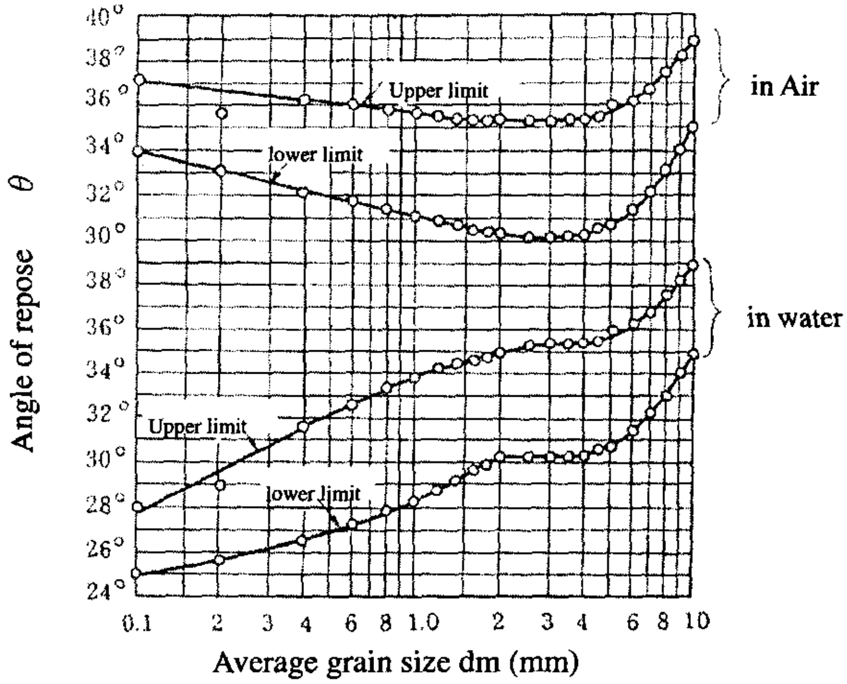


Figure 2.2.18 Relation Between Average Grain Size and Angle of Repose

2) Relation between Size and Flow Velocity of Rubble-Mound and Block

When the rubble and concrete block are used, the weight and size of those materials differs with the velocity of water flow. The reference value of relation between weight of block and velocity of water flow is shown in Figure 2.2.19 and Table2.2.15.

Figure 2.2.19 Relation between Size of Rubble and Velocity of Water Flow

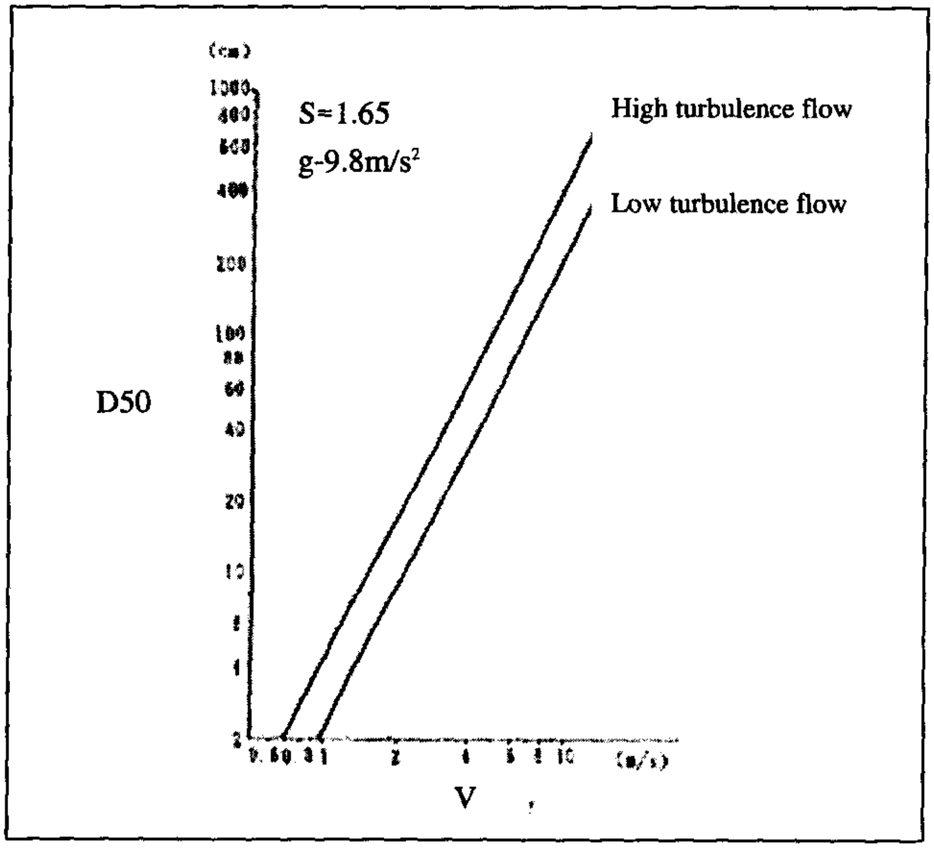


Table 2.2.15 Relation between Weight of Block and Velocity of Water Flow

Shape	Weight of Block (Ton)	Velocity of Water Flow (m/s)
Flat type	1.0	2.5
	2.0	3.0
	3.0	3.5
	4.0	4.0
	5.0	4.5
	6.0	5.0

2.3 Quality Control Materials

1) Concrete

Specifications for structural concrete are given in Section 602 of the NIC-2000.

Section 602 gives details about this product, classes of concrete, classification of the different materials that form concrete, sampling and tests to be made, requirements that the components of concrete must meet for construction, measurements methods and bases for payment.

2) Pre-stressed concrete structures

Section 603 of the NIC 2000 describes this product. It indicates the pre-stress method; advisory services; the requirements to be met by the components of concrete, such as grout, cement, steel, reinforcement steel, pre-stressed steel and elastomeric support pads; tests to be made; pre-stressing methods; post-stressing methods; anchoring devices; requirements for construction; pre-stressing equipment; pouring yards, concrete-embedded devices; placement of steel; pre-stressing; pouring; curing; post-stressing; steel adherence; non-adhered steel; management, installation, measurement method, bases for payment.

3) Reinforcement steel

Section 604 of the NIC2000 describes this material; the requirements it must meet; construction requirements; the protection it must have; folding, placing and tying of steel; measurement method and bases for payment.

4) Reinforcement

Specifications for reinforcement steel are given in Sections 604 and 1009 of the NIC-2000.

5) Gabions

Specifications for gabions are given in Section 918 of NIC-2000. This section describes the product; gives a definition of it; describes the characteristics of its components; indicates requirements for construction; gives details about assembly and installation; indicates the measurement method; and establishes bases for payment.

6) Masonry

Specifications for masonry are given in Sections 608 and 913 of NIC-2000. This section describes the product; defines its extent; indicates the different types of masonry works; establishes the characteristics of the materials that form the product; indicates the size and shape of stones, the carving of the surface stone for base, the surface of joints, stratification and mortar bricks. It also indicates requirements for construction; measurement methods and bases for payment. For the maintenance of roads, highways and bridges, use is made of material specifications contained in the SIECA handbook.