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REPUBLIC OF THE PHILIPPINES
MINISTRY OF PUBLIC WORKS & HIGHWAYS

THE FEASIBILITY STUDY
OF
PHILIPPINE ROAD DISASTER PREVENTION PROJECT

FINAL REPORT

AN APPROACH ON ROAD DISASTER PREVENTION

(VOLUME V)

JUNE, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

Since early 1970's the Government of the Republic of the Philippines (GOP) has stepped up its thrust on road development as one of the national goals in promoting regional interrelation and communications and the balanced urban and rural developments.

The expansion of the national road network has reached a respectable development level. However, its dependability and serviceability in some sections attracted the attention of the users as well as of the public. Traffic interruptions caused by disaster should be immediately solved in order not to hamper to socio-economic activities in the country.

Cognizant of the problem, the GOP has envisioned the formulation of a long term road disaster prevention program and requested technical assistance from the Government of Japan (GOJ), through the Japan International Cooperation Agency (JICA), to undertake the Feasibility Study of the Philippine Road Disaster Prevention Project (The Study). The scope of work of the Study involves among others a general review on disaster prevention measures to be adopted in the future. In compliance thereto, this report entitled "An Approach on Road Disaster Prevention" was prepared compiling the findings based on the research works conducted in the course of the Study.

The roads investigated under the Study are the Maharlika Highway in Luzon, Samar and Leyte Islands, and the three (3) roads leading to Baguio: Kennon Road, Naguilian Road and Marcos Highway. The emphasis of the Study was given to causes and problems on cut slope failures, embankment slope failures, rock falls, landslides, debris flows, and others. Large scale riparians and sabo works were excluded.

Since the investigation is confined only to the specified areas, this report may, therefore, have some deficiencis, particularly on the following:

i) All types of disasters may not always be covered.

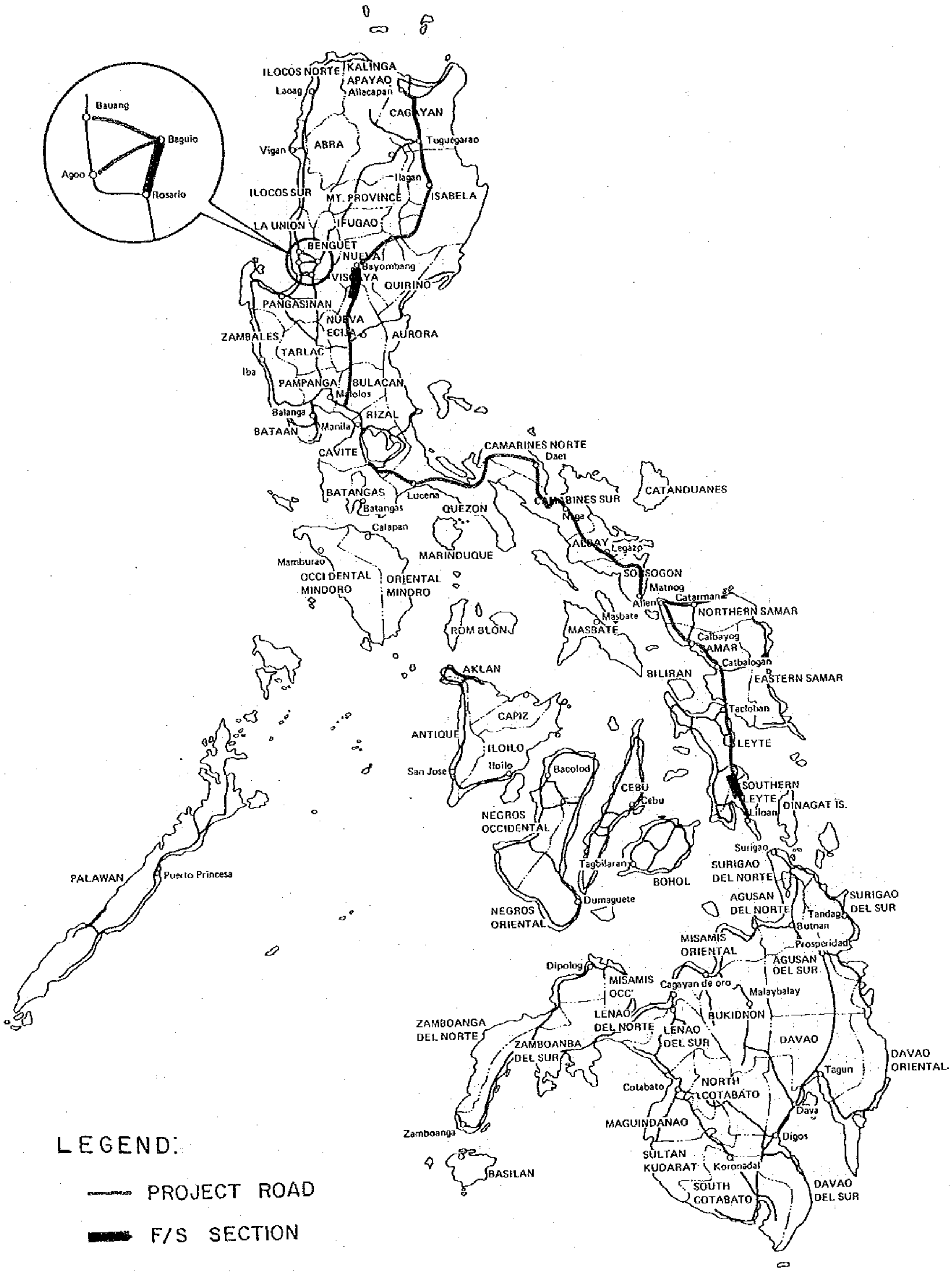
ii) Items to be checked for the evaluation of disaster potential may not necessarily be sufficient, and

iii) Applicability of recommended countermeasures could not be verified on areas other than the Study area.

However, this report intends to instigate engineering discussion among those who are engaged in the field of road engineering encompassing disaster prevention during road planning, design and construction stages.

Therefore, this report is sincerely desired to be positively utilized, whenever applicable, for the development of the road engineering.

LOCATION MAP



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PART I GENERAL

CHAPTER 1 INTRODUCTION

1

As mentioned in the Preface, the subject of the Feasibilty Study of the Philippine Road Disaster Prevention Project (The Study) is to examine disasters of roads which have been constructed. In line with this objective of the Study, this report was drawn up only with the aim to propose prevention measures for disasters of existing roads. However, the engineering fundamentals discussed in this report may be also instructive for planning, design and construction of new roads.

Prevention measures dealt with in this report are limited to those which may be considered as reasonable size from the view point of a road project. Large scale riparian and sabo works which shall be coped with as river control or hillside work projects were not discussed accordingly. Also, bridges and roadway including related structures such as, pavement, side ditches, cross pipes are likewise were not touched.

This report is composed of the following five (5) parts.

PART I : GENERAL

PART II : IDENTIFICATION AND SURVEYS

PART III: DESIGN OF SLOPES AND SLOPE PROTECTION WORKS

PART IV : COUNTERMEASURES FOR ROAD DISASTERS

PART V : ADMINISTRATION AND MAINTENANCE

Road disasters are classified in accordance with their nature as described in Chapter 2 of PART I - CLASSIFICATION OF ROAD DISASTERS.

Potentials of disaster spots are evaluated in accordance with the established rating method, with some modifications whenever deemed necessary, discussed in Chapter 3 of PART II - IDENTIFICATION OF ROAD DISASTERS.

The methodology of the surveys and analysis required for identified types of road disaster are presented in Chapter 4 of PART II - SURVEY FOR ROAD DISASTERS.

The outline of design of cut slope, embankment slope, drainage, protections works and retaining wall, which are the most fundamental methods as countermeasures, are mentioned in Chapter 5 to Chapter 9 of PART III - DESIGN OF SLOPES AND SLOPE PROTECTION WORKS.

The types, the purposes and the application of countermeasures and the procedure in selecting the most appropriate countermeasure for its different types of disaster are discussed in Chapter 10 to 14 of PART IV - COUNTERMEASURES FOR EACH TYPE OF DISASTERS.

The recording of disaster and traffic control as well as information system during the occurrence of disaster are mentioned in Chapter 15 of PART V - ADMINISTRATION.

Required maintenance works for road disasters including periodical and emergency cases are covered in Chapter 16 of PART V - MAINTENANCE.

CHAPTER 2 CLASSIFICATION OF ROAD DISASTERS

2

2.1 General

Classification of road disasters is first determined as a basis in the road disaster prevention study inasmuch as each type would require different survey procedures and different countermeasures to be adopted.

In this report, road disasters are classified into six main types based on the findings on the course of the Study, namely, i) cut slope failure, ii) embankment slope failure, iii) fall, iv) landslide, v) debris flow and vii) others. These were further divided into sub-types based on the shapes and the causes of the failures.

2.2 Cut Slope Failure (including natural slope failure)

Cut slope failure is classified into two types, surface failure and deep failure, based on the shapes of failures and then further sub-divided into classes depending on the causes of failure tabulated in Table 2-1.

1) Surface Failure

Surface failure is a shallow failure on the slope surface. This can be sub-divided into three classes depending on the following causes: i) erosion, ii) weathering and iii) structural weakness as shown in Table 2-1 (1) and (2).

These are mainly the results of an action of surface water flowing down the slope surface due to heavy rain.

2) Deep Failure

Failures which are occuring at considerable deep places in the slope are sub-divided into three classes as based on the causes and the shape of slide, i) scouring, ii) rotational failure and iii) translational failure are as shown in Table 2-1 (3).

The scourings are mainly observed at the slope of thick soil or highly weathered rock. The cause is the concentration of surface water flowing down the slope.

The rotational failures are also mainly observed at the slope of thick soil or highly weathered rock. The cause is a reduction in the shear strength brought about by seepage of water into the body of the slope.

Translational failure occurs at the rock slope with faults, or at developed bedding planes or border planes between the firm bedrock and the overlaying soil. The failure occurs along these weak structural planes. The failure is also caused by water seepage in the body of the slope.

2.3 Embankment Slope Failure (including natural slope failure)

Embankment slope failure is also classified into two types, surface failure and deep failure, based on the shape of failure and further sub-divided into classes in accordance with the causes of the failure, as shown in Table 2-2.

1) Surface Failure

   Surface failure is a shallow failure on the slope surface caused by erosion due to surface water constructed with sandy soil

2) Deep Failure

   Failure which appears at the deep place of the embankment. This is sub-divided into two categories based on the causes of failure, namely, i) scouring and ii) saturation failure.

Scouring results from concentration of surface water flowing down the slope. These are observed to occur at many sites with poor drainage.

In sections running along river banks and sea shores, scouring brought about by river stream or sea wave occurs at sections with insufficient slope protections.

Saturation failure is a circular slide caused by reduction of the shear strength of the fill due to saturation brought about by seepage of surface water or groundwater into the embankment. Those types of failure are observed predominantly sites of embankment on inclined grounds or at semi-embankment-cut sections.

2.4 Fall

Fall is divided into two types: rock fall and debris fall, based on slope materials as shown in Table 2-3.

Rock fall is a free fall of detached rocks from a sloped surface of rockbed with developed cracks, joints, etc.

Debris fall, on the other hand, is a free fall of unsupported pebbles, cobbles, etc., from a sloped surface of debris or talus.

2.5 Landslide

Landslide is a movement of materials forming the slope which is caused by loss of balance between shear strength and movement force along the specific slide planes. Landslides occur owing mainly to geological weakness and elevation of ground water level.

It is difficult to differentiate clearly between a slope failure and a landslide. However, each can be distinguished in accordance with the characteristics of occurrence and movement as shown in Table 2-6.

TABLE 2-6 DIFFERENTIAL CHARACTERISTICS OF SLOPE FAILURE VERSUS LANDSLIDE

Factors	Type of Disaster	
	Slope Failure	Landslide
1. Geology	Minimal interrelation with geology	Particularly connected to specific geology such as tertiary mudstone, tuff, etc.
2. Topography	Relatively steep slope	Relatively gradual slope 15% to 20%.
3. Cause	Heavy rains concentration of surface water, etc.	Elevation of groundwater level.
4. Occurrence	Sudden	Continuous and recurring
5. Speed of Movement	Rapid	Slow (0.01 mm to 10 mm/day)
6. Scale	Relatively Small	Relatively large

Landslide can be sub-divided into rock landslide and soil landslide as shown in Table 2-4.

1) Rock Landslide

Rock landslide is a movement which occurs along structural weak planes, such as faults and bedding planes, in the deep places of rockbed. Speed of the movement is relatively faster than that of soil landslide.

2) Soil Landslide

Soil landslide is a movement of colluvial soil and clayey soil with weak shear strength or along the border plane between the firm rockbed and the said soil. The movement is slow and continuous or recurring.

2.6 Debris Flow

Debris flow is a flow of deposits on a stream bed which resembles the movement of viscous fluid in velocity distribution. This is caused by the current force of the stream and deposits on the stream bed brought about by failures of hillside in the basin. Debris flow is divided into two types, debris flow and mud flow, based on the size of flow materials as shown in Table 2-5.

1) Debris Flow

This is defined as a flow of deposits with large size of stones.

2) Mud Flow

Contrary, this is a flow of deposits composed mainly of soil.

2.7 Others

There are other disasters not classified above, such as submergence due to flooding, settlement of embankment, etc. There was no particular classification made for these.

Road disasters generally occur owing to a combination of two or more causes. Therefore, there are considerably many cases that are uncertain as to which type to choose. However, in order to simplify, it is common that one definite type is selected taking notice of the predominant cause.

TABLE 2-1 (1) CLASSIFICATION OF CUT SLOPE FAILURE

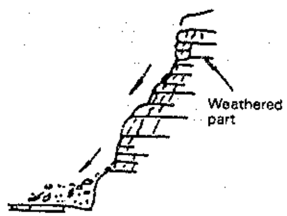
Classification	Description	Type: Type	Type: Description	Illustration	Soil & Rock Susceptible To Failure	Remarks
Surface Failure (C - SF)	Shallow failure on surface of slope caused by erosion, weathering and structural weakness.	(1) Erosion (C-SF(E))	Erosion due to heavy rainfall which often forms gullies on slope surface.	 	Surface, Soil, Volcanic ash soil, masa, sand and gravel. Volcaniclastic material, Tuff, weathered shale and chert, Agglamerate, etc.	(1) Erosion occurs mainly on bare slope lacking in vegetation. (2) If left as is may develop into large scale slope failure.
		(2) Weathering Failure (C-SF(W))	Shallow failure of weathered parts on slope surface.		Soft rocks and easily weathered rocks, Mudstone, Tuff, weathered shale and schist, etc.	

TABLE 2-1 (2) CLASSIFICATION OF CUT SLOPE FAILURE

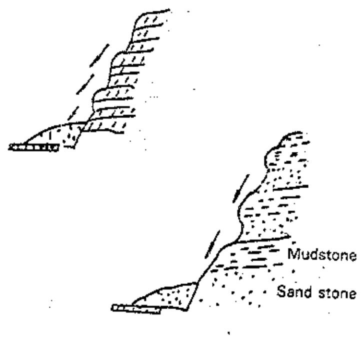
Classification	Description	Type: Type	Type: Description	Illustration	Soil & Rock Susceptible To Failure	Remarks
		(3) Structural Weakness Failure (C-SF(S))	Shallow failure caused by structural weakness, such as developed cracks, joints, bedding faults and border planes in alternate strata of soft rock.		(1) Schist, diabase, serpentinites, granite Andesites, quartz, porphyries, sandstone, etc. (2) Alternate strata of sandstone and siltstone.	

TABLE 2-1 (3) CLASSIFICATION OF CUT SLOPE FAILURE

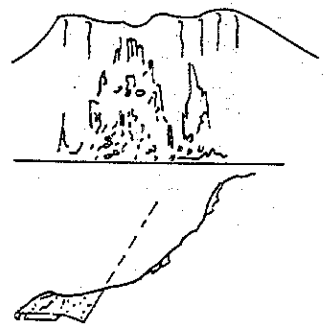
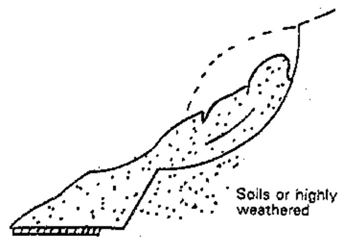
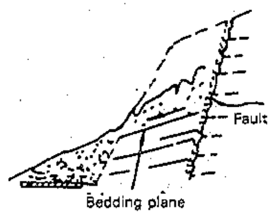
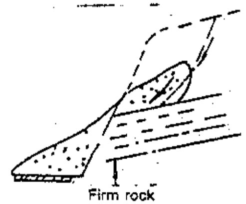
Classification	Description	Type: Type	Type: Description	Illustration	Soil & Rock Susceptible To Failure	Remarks
Deep Failure (C - DF)	Deep failure caused by scouring.	(1) Scouring (C-DF(S))	Scouring due to concentration of surface water on slope.		Soil, all kinds of soft rocks.	
		(2) Rotational Failure (C-DF(R))	Failure along circular slide plane which occurs mainly in slope of weak shear strength.		Sandy Soil, Clayey soil, Talus, Metamphic rocks.	
		(3) Translational Failure (C-DF(T))	Failure which occurs along the structural weakness of slope such as faults, bedding planes and border planes between firm bedrocks and overlaying detritus or soil.		(1) Sandstone, Mudstone, Slate, Alternate strata of above rocks, granites, porphyry, etc.	When joint or bedding planes incline towards slope surface, this type of failure occurs easily.
					(2) Talus, Sand & Gravel, Volcanic ash soil etc., on bedrock.	When ground water level is high, a large scale failure may occur.

TABLE 2-2 CLASSIFICATION OF EMBANKMENT SLOPE FAILURE

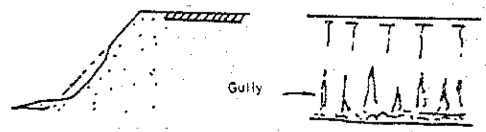
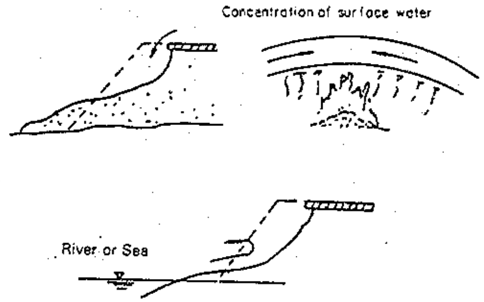
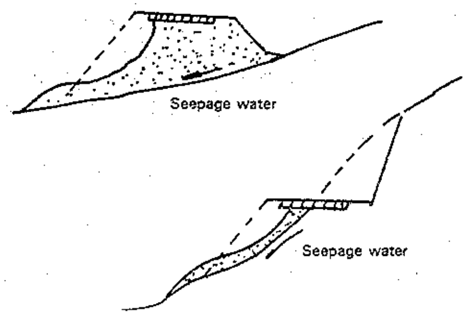
Classification	Description	Type: Type	Type: Description	Illustration	Soil Susceptible To Failure	Remarks
Surface Failure (E - SF)	Shallow failure due to erosion.	Erosion (E-SF(E))	Erosion due to heavy rainfall which often forms gullies on slope surface.		Sandy soil, Masa etc.	
Deep Failure (E - DF)	Deep failure caused by scouring or saturations of embankment.	(1) Scouring (E-DF(S))	Scouring caused by concentration of surface water, or movement from river stream, waves, etc.			This type of failure is mainly seen in curve or sagging sections in road alignment and approaches of bridge.
		(2) Saturation Failure (E-DF(P))	Failure due to saturation caused by seepage of surface or ground water into embankment.			This type of failure mainly occur in embankments on inclined ground or semi-embankment-cut section.

TABLE 2-3 CLASSIFICATION OF FALL

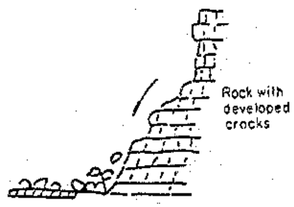
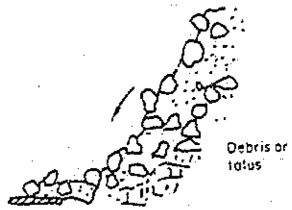
Classification	Description	Type: Type	Type: Description	Illustration	Soil & Rock Susceptible To Failure	Remarks
Falls (C - F)	Free fall of rocks, cobbles etc., detached from a surface of steep slope.	(1) Rock Fall (C-F(R))	Free fall of detached rocks from a surface of slope of bedrocks with developed cracks, joints and beddings.		All kinds of rocks with developed cracks joint and beddings.	
		(2) Debris Fall (C-F(D))	Free fall of unsupported pebbles, cobbles and boulders from a surface of slope of debris or talus.		Talus, Volcaniclastic materials, etc.	

TABLE 2-4 CLASSIFICATION OF LANDSLIDE

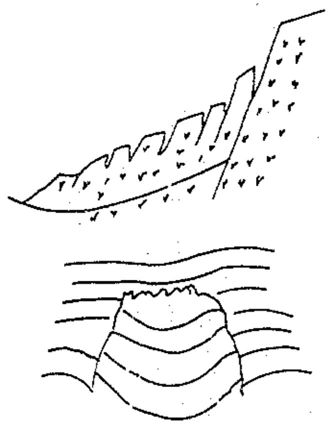
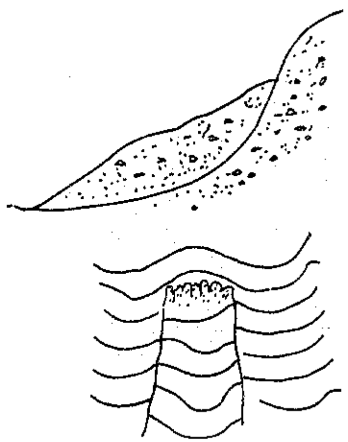
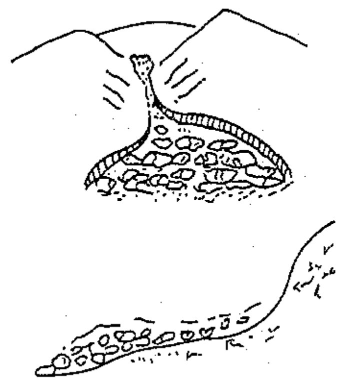
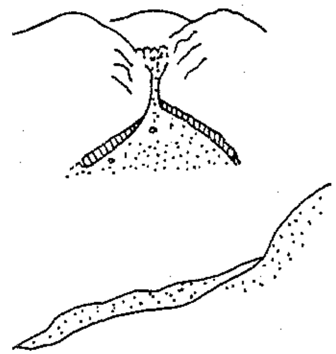
Classification	Description	Type: Type	Type: Description	Illustration	Soil & Rock Susceptible To Landslide	Remarks
Landslide (L.S)	Movement of huge mass at moderate to slow speed.	Rock Landslide (L.S-R)	Movement which occurs along structural weakness in rock or in weathered rock of weak shear strength. (Moderate to rapid sometimes)		Neogene, crystalline schist, etc. Mainly in fault fracture zone.	(1) It is difficult to forsee the occurrence of landslide due to structural weakness, since it happens suddenly. (2) Landslide in weathered rock shows intermittent movement.
		Soil Landslide (L.S-S)	Movement which occurs in colluvial soil and clayey soil or along border plane between firm rock and the said soils. (Slow)		Colluvial soil, clayey soil, the said soils with gravel.	This type of landslide shows continuous movement.

TABLE 2-5 CLASSIFICATION OF DEBRIS FLOW

Classification	Description	Type: Type	Type: Description	Illustration	Soil & Rock Susceptible To Debris Flow	Remarks
Debris Flow (D,F)	Flow movement of deposit on the stream bed resembles those of viscous fluids in distribution of velocities.	(1) Debris Flow (DF-D)	Flow movement of deposit with large stones.		Fault fracture zone, Neogene, weathered granite, volcaniclastic etc.	
		(2) Mudflow (DF-M)	Flow movement of soil and mud without large stones.		Fault fracture zone, Neogene, weathered granite, volcaniclastic, etc.	

PART II IDENTIFICATION AND SURVEY OF ROAD DISASTERS

CHAPTER 3 IDENTIFICATION OF ROAD DISASTERS

3

3.1 General

Identification of road disaster is composed of two works, namely: i) identification of spots with disaster potential, and ii) evaluation of disaster potential of each identified spot.

3.2 Identification of Spots with Disaster Potential

Spots with disaster potential are identified by field reconnaissance. Factors influencing disaster potential are recorded on the check tables prepared for each disaster type. An example of check table by each disaster type is shown in Table 3.1 to 3.5.

Prior to field reconnaissance, the following works were undertaken.

- data collection and analysis on the topography and geology.
- data collection and analysis on the meteorology.
- collection and analysis of disasters' records.

3.3 Evaluation of Disaster Potential

To evaluate disaster potential, a rating method presented in Tables 3.6 to 3.10 was used.

The disaster potentials of each spot were classified into; A (high potential); B (medium potential) and, C (low potential), based on the result of the total rating in the evaluation.

The method in the evaluation follows basically the method identifying disaster spots currently established by the Ministry of Construction in Japan with some modifications to reflect local characteristics of roads in the Philippines.

The factors and criteria for rating may be modified through further studies, since these were only determined based on the study of characteristics of disasters along the definite road sections.

TABLE 3-1 CHECK TABLE OF CUT SLOPE FAILURE

				Sheet No.	
Route		Km. Post		Width	M
				Region	

Evidence of Failure		1	Kind of Slope	(1) Cut Slope (2) Natural Slope
		2	Kind of Failure	(1) Nothing (2) Surface Failure (3) Deep Failure
		3	Size of Failure	(1) $50^{m3} >$ (2) $50^{m3} \sim 500^{m3}$ (3) $500^{m3} \sim 2{,}000^{m3}$ (4) $2{,}000^{m3} <$
		4	Date Occured	Day Month Year
		5	Traffic Interruption Period	(1) 1 day > (2) 1 day ~ 7 days (3) 7 days <
		6	Counter Measure Taken	(1) Structure ( ) (2) Removal of Slide Materials (3) Others
		7	Rainfall Intensity/Day	(1) 100 mm > (2) $100^{mm} \sim 200^{mm}$ (3) $200^{mm} \sim 300^{mm}$ (4) $300^{mm} <$
Existing Slope Condition		8	Height	(1) $10^{m} >$ (2) $10^{m} \sim 30^{m}$ (3) $30^{m} \sim 50^{m}$ (4) $50^{m} <$
		9	Gradient	(1) $45^{\circ} >$ (2) $45^{\circ} \sim 60^{\circ}$ (3) $60^{\circ} <$ (4) Overhung
		10	Berm	(1) Existing Number ( ) Width ( ) (2) Nothing
		11	Slope Protection	(1) Structure ( ) (2) Vegetation (3) Nothing
Geological Condition	Rock	12	Hardness	(1) Hard Rock (2) Soft Rock
		13	Name	(1) Granite (2) Diorite (3) Diabase (4) Andesite (5) Dacite (6) Schist (7) Slate (8) Limestone (9) Schalstein (10) Tuff (11) Tuffbreccie (12) Sandstone (13) Shale (14) Mudstone (15) Conglomerate (16) Masa (17) Volcaniclasties
		14	Weathering Condition	(1) Fresh (2) Slightly Weathered (3) Highly Weathered (4) Nearly Soil
		15	Condition of Crack	(1) Sparse (2) Regular (3) Developed
		16	Direction of Crack	(1) Inclined to Mountain (2) Irregular Inclination (3) Inclined to Slope
	Soil	17	Thickness	(1) $5^{m} >$ (2) $5^{m} \sim 10^{m}$ (3) $10^{m} \sim 20^{m}$ (4) $20^{m} <$
		18	Compactness	(1) Tight (2) Slightly loose (3) Loose
Water Condition		19	Degree of Saturation	(1) Dry (2) Wet (3) Seepage (4) Spring
		20	Surface Water Concentration	(1) None (2) Low (3) High
		21	Drainage Facilities	(1) Existing ( ) (2) Nothing
Engineering Judgement		22	Impact to Road	(1) Low (2) Average (3) High
		23	Cause of Disaster	
		24	Counter Measure	
Sketch, etc.			Photo No.	

Date of Survey	Day	Month	Year	Surveyor	

TABLE 3-2 CHECK TABLE OF EMBANKMENT SLOPE FAILURE

						Sheet No.	
Route		Km. Post		Width	M	Region	

Evidence of Failure	1	Kind of Slope	(1) Embankment Slope (2) Natural Slope (3) Overflow Section (5) Others
	2	Location	(1) Approach of Bridge (2) Adjacent to River or Sea (3) Inside of Curve (4) Others
	3	Size of Disaster	(1) 50^{m3} > (2) 50^{m3} ~ 100^{m3} (3) 100^{m3} <
	4	Date Occured	Day Month Year
	5	Traffic Interruption Period	(1) 1 day > (2) 1 day ~ 7 days (3) 7 days <
	6	Counter Measure Taken	(1) Only Fill (2) Riprap (3) Other Structure ( )
	7	Rainfall Intensity/ Day	(1) 100^{mm} > (2) 100^{mm} ~ 200^{mm} (3) 200^{mm} ~ 300^{mm} (4) 300^{mm} <
Existing Slope Condition	8	Slope Height	(1) 5^{m} > (2) 5^{m} ~ 10^{m} (3) 10^{m} <
	9	Slope Gradient	(1) 45° > (2) 45° ~ 60° (3) 60° <
	10	Surface Water Concentration	(1) None (2) Low (3) High
	11	Slope Protection	(1) Nothing (2) Vegetation (3) Riprap (4) Other Structure ( )
	12	Drainage Facilities	(1) Nothing (2) Existing
Engineering Judgement	13	Impact to Road	(1) Low (2) Average (3) High
	14	Cause of Disaster	(1) Concentration of Surface Water (2) River Stream (3) Sea Wave (4) Others
	15	Counter Measure	

Sketch, etc.		Photo No.	

Date of Survey	Day	Month	Year	Surveyor	

TABLE 3-3 CHECK TABLE OF FALL

						Sheet No.	
Route		Km. Post		Width	M	Region	

Evidence of Falls		1	Kind of Slope	(1) Cut Slope (2) Natural Slope
		2	Type of Fall	(1) Debris Fall (2) Rock Fall
		3	Fallen Rock Size	(1) $20^{cm}>$ (2) $20^{cm}\sim 50^{cm}$ (3) $50^{cm}<$
		4	Date Occured	Day Month Year
		5	Traffic Interruption Period	(1) 1 day> (2) 1 day ~ 7 days (3) 7 days <
		6	Counter Measure Taken	(1) Structure ( ) (2) Removal of Fallen Rock (3) Others
		7	Rainfall Intensity/Day	(1) $100^{mm}>$ (2) $100^{mm}\sim 200^{mm}$ (3) $200^{mm}\sim 300^{mm}$ (4) $300^{mm}<$
Existing Slope Condition		8	Slope Height	(1) $10^{m}>$ (2) $10^{m}\sim 30^{m}$ (3) $30^{m}\sim 50^{m}$ (4) $50^{m}<$
		9	Slope Gradient	(1) $45^{\circ}>$ (2) $45^{\circ}\sim 60^{\circ}$ (3) $60^{\circ}<$ (4) Overhung
		10	Degree of Saturation	(1) Dry (2) Wet (3) Seepage (4) Spring
		11	Surface Water Concentration	(1) None (2) Low (3) High
		12	Berm	(1) Existing Number ( ) With ( ) (2) Nothing
		13	Slope Protection	(1) Structure ( ) (2) Vegetation (3) Nothing
		14	Drainage Facilities	(1) Existing ( ) (2) Nothing
Geological Condition	Debris Fall	15	Matrix Condition	(1) Hard (2) Soft (3) Loose (4) Loose with detached cabble
		16	Gully	(1) Rare (2) Common (3) Frequently
		17	Detached Rock or cabble	(1) Nothing (2) Supported Stably (3) Supported Unstably
	Rock Fall	18	Rock Name	(1) Granite (2) Diorite (3) Diabase (4) Andesite (5) Dacite (6) Schist (7) Slate (8) Limestone (9) Schalstein (10) Tuff (11) Tuffbreccie (12) Sandstone (13) Shale (14) Mudstone (15) Conglomerate (16) Masa (17) Volcaniclasties
		19	Weathering Condition	(1) Fresh (2) Slightly Weathered (3) Highly Weathered
		20	Condition of Crack	(1) Sparse (2) Regular (3) Developed
		21	Direction of Crack	(1) Inclined to Mountain (2) Irregular Inclination (3) Inclined to Slope
Engineering Judgement		22	Impact to Road	(1) Low (2) Average (3) High
		23	Cause of Fall	
		24	Counter Measure	
Sketch, etc.			Photo No.	

Date of Survey	Day Month Year	Surveyor	

TABLE 3-4 CHECK TABLE OF LANDSLIDE

							Sheet No.	
Route			Km. Post		Width	M	Region	
Evidence of Landslide	1	Kind of Slope	(1) Cut Slope	(2) Natural Slope				
	2	Kind of Landslide	(1) Rock	(2) Talus	(3) Soil			
	3	Size of Landslide	(1) $2{,}000^{m2} >$	(2) $2{,}000^{m2} \sim 5{,}000^{m2}$	(3) $5{,}000^{m2} <$			
	4	Date Occured	Day	Month	Year			
	5	Traffic Interruptions Period	(1) day >	(2) 1 day ~ 7 days	(3) 7 days<			
	6	Rainfall Intensity/Day	(1) 100 mm >	(2) $100^{mm} \sim 200^{mm}$	(3) $200^{mm} \sim 300^{mm}$	(4) $300^{mm} <$		
Topographic and Geological Condition	7	Existence of irregular surface with steps, sharp cliff and puddles	(1) Unnoticed	(2) Medium	(3) Remarkable			
	8	Geology	(1) Others	(2) Sedimentary Rock	(3) Highly Weathered Sedimentary Rock or Talus or Soil			
Others Condition	9	Degree of Saturation	(1) Dry	(2) Wet	(3) Seepage	(4) Spring		
	10	Gradient of Slide Plane	(1) 10° >	(2) 10° ~ 20°	(3) 20° <			
	11	Continuity of Slide Movement	(1) Unnoticed	(2) Medium	(3) Remarkable			
Engineering Judgement	12	Imapct to Road	(1) Low	(2) Average	(3) High			
	13	Cause of Landslide						
	14	Counter Measure						
Sketch, etc.						Photo No.		

Date of Survey	Day	Month	Year	Surveyor	

TABLE 3-5 CHECK TABLE OF DEBRIS FLOW

							Sheet No.	
Route			Km. Post		Width	M	Region	

Group	No.	Item				
Evidence of Debris Flow	1	Existence of Depo-sitional Toe	(1) Nothing	(2) Existing		
	2	Size of Disaster	(1) $50^{m3} >$	(2) $50^{m3} \sim 500^{m3}$	(3) $500^{m3} \sim 2,000^{m3}$	(4) $2,0000^{m3} <$
	3	Date Occured	Day	Month	Year	
	4	Traffic Interruption Period	(1) 1 day >	(2) 1 day ～ 7 days	(3) 7 days <	
	5	Counter Measure Taken	(1) Structure ( )	(2) Removal of Deposit Materials		(3) Others
	7	Rainfall Intensity/ Day	(1) 100 mm >	(2) $100^{mm} \sim 200^{mm}$	(3) $200^{mm} \sim 300^{mm}$	(4) $300^{mm} <$
Existing Stream Condition	8	Average Gradient	(1) 20° >	(2) 20° <		
	9	Area of Basin	(1) $0.24\ Km^2 >$	(2) $0.24\ Km^2 <$		
	10	Deposit on River Bed	(1) Nothing	(2) Rare	(3) Abudance	
	11	Plant Condition	(1) 50% > Occupancy Rate of Bare Land or Thin Forest (2) 50% <			
Engineering Judgment	12	Impact to Road	(1) Low	(1) Average	(3) High	
	13	Cause of Disaster				
	14	Counter Measure				

Sketch, etc.	Photo No.	

Date of Survey	Day	Month	Year	Surveyor	

TABLE 3-6 RATING OF CUT SLOPE FAILURE POTENTIAL

Condition	Factors Influencing High Potential	Judgement
Topography[1/]	High slope Slope with steep gradient	Yes = a No = b
Geology[2/]	Slope of thick and loose soil Slope of soft rock or weathered rock Slope with many or developed cracks, joints, bedding planes, etc.	Yes = a No = b
Slope Surface	Bare or few grasses slope	Yes = a No = b
Water	Concentration of surface water Existence of seepage water	Yes = a No = b
Symptom of Failure	Evidence of erosion or scouring Existence of abnormal deformation or unstable materials	Yes = a No = b
Total Rating	5a's, 4a's + b, 3a's + 2b's -------------	A
	2a's + 3b's, a + 4b's -----------------	B
	5b's ----------------------------------	C

Reference:

1/ Slope of higher than 20 m. or steeper than standard gradient may be judged as Yes.

2/ Slope of more than 5.0 m of soil layer in thickness may be judged as Yes.

Pay attention to the case that direction of bedding plane inclines to slope side.

TABLE 3-7 RATING OF EMBANKMENT SLOPE FAILURE POTENTIAL

Condition	Factor Influencing High Potential	Judgement
Topography[1/]	High slope Slope with steep gradient	Yes = a No = b
Geology	Slope of sandy soil	Yes = a No = b
Slope Surface[2/]	Bare or few grasses slope	Yes = a No = b
Water	Concentration of surface water Existence of seepage water Influence of river stream or sea wave	Yes = a No = b
Symptom of Failure	Evidence of erosion or scouring Existence of abnormal deformation	Yes = a No = b
Total Rating	5a's, 4a's + b, 3a's + 2b's --------------	A
	2a's + 3b's, a + 4b's --------------------	B
	5b's --------------------------------------	C

Reference:

1/ Slope of higher than 7.0 m. or steeper than 1.5 = 1 may be judged as Yes.

2/ Concentration of surface water is observed at many slopes inside curve or sagging section.

Seepage water and satulation are observed mainly at the embankment on inclined ground or semi-embankment-cut section.

TABLE 3-8 RATING OF FALL POTENTIAL

Condition	Factor Influencing High Potential	Judgement
Topography[1/]	High slope	Yes = a
	Slope with steep gradient	No = b
Geology[2/]	Slope of loose matrix with large size stone	Yes = a No = b
	Slope of highly weathered rock	
	Slope with many or developed cracks, joints, bedding planes, etc.	
Slope Surface	Bare or few glasses slope	Yes = a No = b
Water	Concentration of surface water	Yes = a
	Existence of seepage water	No = b
Symptom of Fall[3/]	Evidence of erosion or scouring	Yes = a
	Existence of large size supportless stones or detached rock	No = b

Total Rating	5a's, 4a's + b, 3a's + 2b's --------------	A
	2a's + 3b's, a + 4b's -------------------	B
	5b's	

Reference:

1/ Slope of higher than 20 m. or steeper than 1 = 1 may be judged as Yes.

2/ Pay attention to the case that direction of bedding plane inclines to slope side.

3/ Supportless stone or detached rock of more than 50 cm. may be judged as Yes.

TABLE 3-9 RATING OF LANDSLIDE POTENTIAL

Condition	Factor Influencing High Potential	Judgement
Location	Located in the area prone to landslide	Yes = a No = b
Topography	Land form susceptible to landslide (irregular surface with step, sharp cliff, puddle etc.)	Yes = a No = b
Geology	Neozene, tuff, supentinite, fault fracture zone, etc.	Yes = a No = b
Water	Existence of seepage water	Yes = a No = b
Evidence of Landslide	Evidence of past landslide	Yes = a No = b
Total Rating	5a's, 4a's + b, 3a's + 2b's --------------	A
	2a's + 3b's, a + 4b's --------------------	B
	5b's	

TABLE 3-10 RATING OF DEBRIS FLOW POTENTIAL

Condition	Factor Influencing High Potential	Judgement
Stream Gradient 1/	Steep gradient	Yes = a No = b
Deposits on River Bed	Abundance of loose deposits with pebble, cobble and boulders	Yes = a No = b
Basin 2/	Wide basin	Yes = a No = b
Plant and Vegetation 3/	High occupancy rate of bare land and thin forest to total area of basin	Yes = a No = b
Hillside	Existence of failure area in hillside	Yes = a No = b
Total Rating	5a's, 4a's + b, 3a's + 2 b's ------------	A
	2a's + 3b's, a + 4b's -------------------	B
	5b's ------------------------------------	C

Reference:

1/ More than 20% of average gradient of stream may be judged as Yes.

2/ More than 0.24 km^2 of basin may be judged as Yes.

3/ More than 50% of bare land or thin forest area may be judged as Yes.

CHAPTER 4 SURVEYS FOR ROAD DISASTER SPOTS

4.1 GENERAL

The surveys for road disaster spots involve the determination of the basic (elemental) factors influencing disasters through on-site topographic and geological investigations and tests of soil and rock mechanical properties. With these results and past experiences on the effects of rain and earthquake in the section or area, the disaster potential is predicted and the countermeasures are designed based on the cause and the form of failure anticipated.

4

From a practical viewpoint, surveys for road disasters can be divided into two stages, preliminary survey and detailed survey, as shown in the flow chart in Table 4.1.

(1) Preliminary Survey

A preliminary survey is carried out to identify roughly the spots with disaster potential in order to be able to plan a more specific and/or intensive investigation as may be required. At this stage, the work involved is generally a review of published data and field reconnaissance.

Factors which should be checked for rough identification of the spot with disaster potential are as shown in the check table (by disaster type) described in Chapter 3. Nevertheless, for the preliminary survey, the following basic information are to be collected:

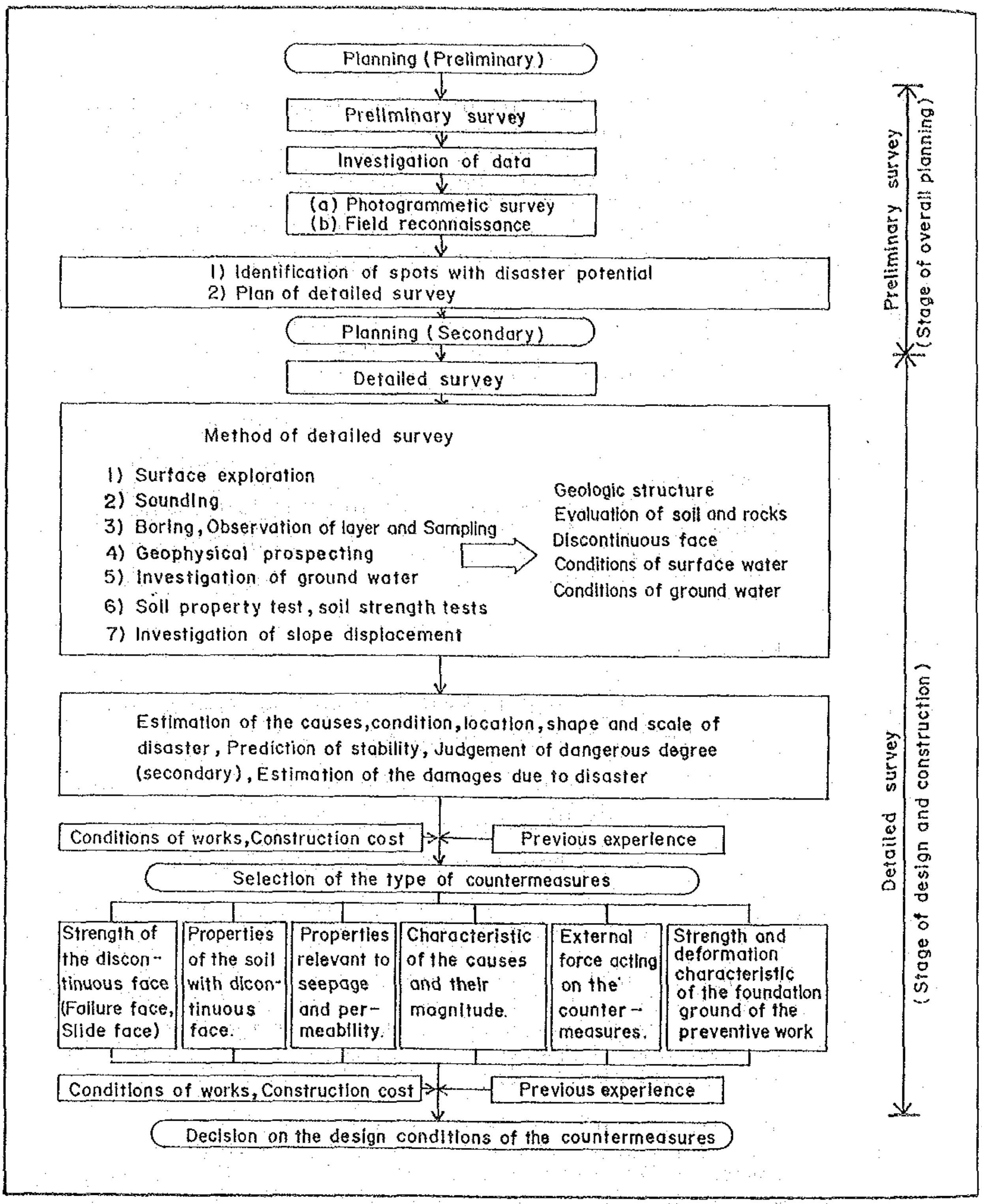
- Past disaster records due to rainfall or earthquakes
- Geological maps and topographical maps
- Aerial photographs
- Documents related to the disaster

During the field reconnaissance, initial information with regards to topography, geology, environment, spring water and vegetation as may be gathered from existing records or aerial photographs should be confirmed within the relevant disaster spot.

Special attention must be given to the condition of landslide topography and the presence of faults, fracture zones, strikes and dips of strata, valleys, river terraces, past slope failures and springs which should all be noted during field reconnaissance.

Where field reconnaissance is difficult, preliminary examination from aerial photographs will speed up the collection of information such as topography and vegetation on the periphery of the disaster spot.

Table 4.1 A Flow Chart of Survey for Road Disaster



(2) Detailed Survey

Detailed survey is carried out for the purpose of estimating causes, shapes and sizes of disasters and eventually designing countermeasures by examining the topographical and geological characteristics of the disaster spot.

The data gathered during the preliminary survey is not sufficient for planning the countermeasures, suitable techniques for detailed survey are listed below that may be adopted on the purpose:

- Estimation of position and scale of disaster; Soundings, seismic refraction, boring, strata inspection.
- Behavior of surface and underground water; Permeability test, inspection of water tables, groundwater tracing, groundwater prospecting, measurement of pore water pressure, water quality test.
- Soil and rock characteristics; Laboratory test, rock tests, boring, soundings, seismic refraction.
- Surface behaviour; Surface displacement tests with expansion meters, examination of slide surface, strain gage, measurement of pore, water pressure.

The suggested methods of investigations are shown in Table 4.2.

Estimation of slide plane of collapse is the most important objective of the detailed survey. This is carried out through an overall judgement with respect to the following four (4) points based on the results already obtained:

i) The shapes and causes of the failure on the periphery of the disaster spot.
   - Comparisons with the subjected disaster spots

ii) Investigations on discontinuities and differences.
   - Examination of the effects of discontinuities and differences with respect to strength and permeability between stratum.

iii) Estimation of slide surface by existing surface variations.

TABLE-4.2 KIND AND SURVEY ITEM OF GEO-TECHNICAL SURVEY

Survey Item \ Kind of Survey		Field reconnaissance	Seismic refraction	Electric prospecting	Boring	Auger boring	Test pit	Sounding	Soil test	Rock test	Ground water survey	Field instrumentation
Type of soil and rock		◎	△		◎	○	○	△	◎	◎		
Geological Structure	Structural weakness	◎	◎	△	○							
	Cracks and joints	○	○		◎		○			○		
	Weathering	△	○		◎		○			○		
	Thickness of top soil	○	○		◎	◎	◎	◎				
	Unconformity or discountinuity	○	◎		◎		○	○				
Strength of ground			△		○			○	◎	◎		
Strength of embankment materials								○	◎			
Physical property of embankment materials		△			○	○	○		◎			
Abnormal deformation		◎										
Surface water and seepage water		○	○		○	△	△				◎	
Ground water					○						◎	
Landslide	Location of slide plane	△	◎		◎			○				◎
	Direction and amount of movement	△										◎
	Potential	△										◎
	Quality of ground water										◎	
	Run off pass of ground water										◎	
	Level of ground water										◎	

Note: 1) Structure weakness means fault, fractured zone, bedding plane, etc

2) ◎ Most applicable ○ applicable △ supplemental

- The shape of the slide surface can often be estimated from the cracks on the top of the slope or protuberance in the middle of lower sections of the slope.

iv) Investigations of failure caused by the effect of water.

- Failure and slide are mainly caused by effect of water through erosion by surface run-offs, pore water pressure increase, decrease in ground strength due to contained water, increase in ground weight due to water contained, partial collapse from piping and progress of weathering. By investigating effect of water, the potential and the cause of the failure can be identified.

4.2 SURVEY FOR CUT SLOPE FAILURE

Since cut slope is generally composed of complicated, non-uniform geological structure, it is difficult to analyze theoretically stability of cut slope. Because of this, the slope gradient is generally determined using the standard slope gradient table which is empirically compiled mainly according to the soil geology and depth of cut slope as shown in Table 5.1.

Therefore, surveys are mainly required for the following cases.

i) Cut slopes of unstable rock and soil

Cut slopes of talus, colluvial deposits, weathered rocks, volcaniclastics and slopes which have evidence of failures are commonly unstable. It is required to obtain the information of groundwater and N-values through boring and the grain size distribution through soil test and state of stratification through seismic refraction. The results of this survey should be reflected in the design of the recommended countermeasure.

ii) Cut slopes of sandy soils, and easily eroded soils.

In order to determine the slope gradients to design protection works for such slopes made up of sandy soils which are easily eroded by the surface water. It is necessary to make a comprehensive review of the degree of solidification and the resistance to erosion by examining the N-value, and the sand and silt content by grading analysis.

iii) Cut slopes of rock quickly weathered such as mudstone and serpentinite.

For cut slopes of rocks with a low degree of endurance against weathering, the appropriate gradient of slope should be determined comprehensively evaluating the velocity of elastic waves of seismic refraction, the unconfined compressive strength of sampled cores, thickness of weathered zone and the result of the dry-wet repeating test; (and so on).

iv) Cut slopes of rocks with many fissures

The stability of cut slopes of rock with many fissures is mainly governed by the degree of fracture or by conditions of bedding, schistosity and joints. These should be fully studied through the detailed observation of the existing slopes and outcrops, and comprehensive engineering evaluation should be made based upon the core recovery (R.Q.D.), and crack coefficient. If the fissure inclines to the slope, special case should be paid in design of countermeasures since such a slope is extremely unstable.

v) Cut slopes with a large amount of groundwater

It can be said that most causes of slope failures are related directly or indirectly to groundwater. The amount of groundwater can be determined by various methods such as borings, electric surveys and pumping tests. A particular type of survey suited to the purpose should be selected and performed in response to field conditions.

4.3 SURVEY FOR EMBANKMENT SLOPE FAILURE

The gradient of an embankment or re-filling slope is normally determined based upon the standard gradients shown in Table 6.1 of Chapter 6 in response to the geology and height of embankment.

Therefore, surveys for embankment slope failure are necessary in the following cases:

- When the height of the embankment exceeds the standard gradient of Table 6.1.
- When the fill comprises soils with a high water content and a low shear strength.
- When the embankment is easily affected by spring water from the ground.

The stability of embankment in the above cases should be examined by stability calculations using the results of unconfined compression tests or triaxial compression tests on fill material which has been compacted to the specific degree.

The stability of the embankment is mainly affected by water. Therefore, extra attention should be taken in surveying condition of surface water and groundwater. Survey of a run-off path which surface water may concentrate during heavy rain is important for design of ditches and slope protection works to prevent erosion or scouring of the embankment slope.

Spring water which permeates from ground into embankment make fill slopes unstable. Therefore, the conditions of groundwater should be fully investigated particularly for the embankment on inclined ground and in valleys, partial cuts and fills or transitions of cuts and fills. The main items to be clarified with respect to groundwater are:

- Distribution of groundwater, or groundwater pressure
- Extent of permeable layer or water-bearing stratum, or extent of impermeable layer
- Direction of groundwater flow, water vein, water source

It is difficult to investigate accurately groundwater conditions from the results of a single survey, hence a comprehensive examination, using the results of a number of other related surveys including field surveys, borings, sounding and so forth is, therefore, required.

Seasonal changes in groundwater are often remarkable in many cases and it is, therefore, desirable to inventstigate also these changes.

4.4 SURVEY FOR FALL

Since a fall is a kind of cut slope failure, the surveys for falls are also carried out with the almost same manner as for cut slope failure.

Slopes susceptible to falls are as follows:

- Slopes of debris having matrix which is eroded or scoured easily, such as talus, colluvial deposits, terrace gravel, volcaniclastics, weathered gravities.
- Slopes of rocks with developed cracks, joints, bedding planes, etc.

Main survey item, therefore, is to investigate the compactness of the matrix and conditions of this fissure to evaluate potential of the falls. This can be done by visual inspection during field reconnaissance.

For design of countermeasures, the following specific surveys are required.

- Size of rocks which are expected to fall and their location (height and distance)
- Condition of slope on which rocks fall down. (hardness, irregularity, vegetation, etc.)
- Width of space between the toe of slope and carriageway

4.5 SURVEY FOR LANDSLIDE

Survey for lanslide is carried out in order to be able to:

- estimate the range of landslide movement.
- reorganize the causes of landslide.
- determine location and strength of slide plane.

For the above listed assessments, surveys such as geological and soil survey, groundwater survey and measurement survey, are undertaken.

(1) Geological and soil survey

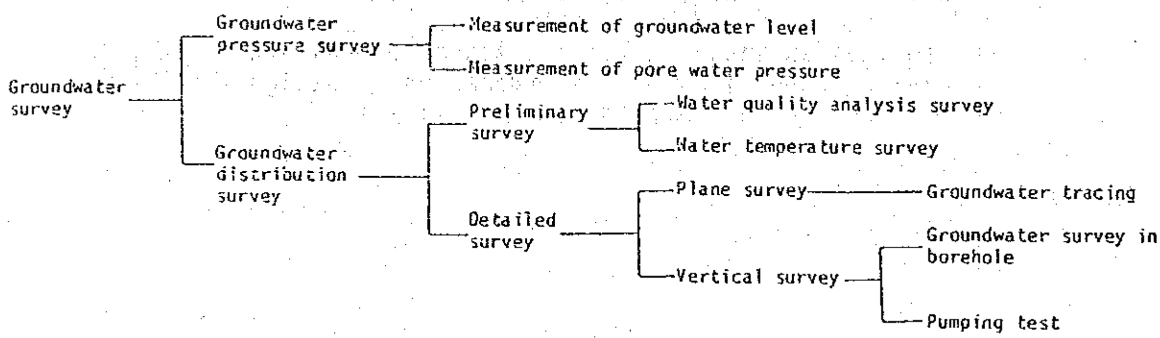
Landslide mainly occurs along the specific slide planes, such as faults, bedding plane and border planes between firm bed rocks and overlaying ditritus or soil. Therefore, geological and soil survey should be carried out to investigate location, shape, extent, and soil mechanical characteristic of the slide plane. Beside this, to obtain the overall information of landslide, strength of rocks, degree of weathering, strike and inclination of stratum, conditions of faults and fractured zone, properties of cracks and joints, etc. should be surveyed.

Boring is mainly applied for the survey mentioned above and seismic refraction sometimes is necessary. In order to determine the location and strength of the side plane, sounding survey is carried out. At least four boring should be done along the main direction of landslide movement and one of them should be located on the upper part of the main scarp of the landslide. Borehole should be drilled at least 5.0 m into the firm bedrock to recognize the slide plane. Where landslide area is wide and bedrock is unconformable, seismic refraction survey is usually applied with boring to sound shape of extended bedrock.

(2) Groundwater Survey

It is well known that landslide frequently occur after heavy rains as its movement becomes active as the groundwater level rises. In order to understand the mechanism of the landslide, the groundwater conditions such as location, fluctuation of the level, flow, run-off path, current speed, quality and temperature etc. should be investigated. Groundwater surveys can be generally classified into groundwater distribution surveys and groundwater pressure surveys. The characteristics of each survey are shown respectively in Table 4.3 below.

TABLE 4.3 GROUNDWATER SURVEY



To analyze the mechanism of landslide, it is necessary to examine the correlationships between the fluctuation of groundwater and the movement of landslide and that between the fluctuation of groundwater and rainfall.

(3) Measurement Survey

This is carried out to understand direction and speed of movement of the landslide by measurement with instruments. This is done generally with the use of instruments such as extensometers, slant-rules, displacement piles and displacements plates. From the measurements taken with these instruments, changes of strain at slide plane as well as changes of expansion and slant at the ground surface accompanied with landslide movement can be determined.

4.6 SURVEY FOR DEBRIS FLOW

Surveys for debris flow can be divided into two items corresponding to the purpose; a survey to investigate the cause and the potential of the debris flow, and, a survey to design the countermeasures.

In order to investigate the cause and the potential of the debris flow conditions of the relevant stream at its basin should be revealed.

In this work, area of the stream basin, average gradient of the stream, number of tributaries, vegetation or waste conditions on the hillside should be investigated using geological maps, topographical maps and aerial photographs which should be confirmed through the field reconnaissance.

The surveys as shown in Table 4.4 are generally carried out to examine conditions of the stream and to design the countermeasures in the detailed survey stage.

TABLE 4.4 KIND AND PURPOSE OF SURVEY FOR DEBRIS FLOW

Kind of Survey	Summary Item	Purpose
Field Reconnaissance	Examination of Stream Condition	For Design of Counter-measures
	Determination of location to perform detailed surveys such as boring, seismic refraction, etc.	Determination of site to plan a counter-measure.
Ground Survey	Longitudinal leveling and cross section survey to investigate gradient and cross section of the stream and conditions of deposits on the river bed.	Planimetric survey and levelings to design the countermeasure.
Boring	Investigation of thickness and nature of the deposits and depth of the bedrock.	Determination of foundation for the structures.
Seismic Refraction	Investigation of thickness of the deposits and depth of the bedrocks.	Determination of foundation for the structures.
Test Pit	Examine of mechanism and structure of the deposits.	
Hydrological Survey	Examine of discharge velocity, tractive force, etc.	Analysis of lateral force to the structure
Soil Test	Examine of grain distribution	

PART III DESIGN OF SLOPES AND SLOPE PROTECTION WORKS

CHAPTER 5 DESIGN OF CUT SLOPES

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5.1 General

Unlike for an embankment slope, cut slope section can hardly be designed by stability analysis alone. Since geological formulation of ground is extremely not homogeneous and the characteristics of soil vary considerably. These conditions set difficulties in predicting sliding surface, estimating accurate strength of soil and judging the decrease in the strength of the soil due to weathering.

Designing the cut slope should, therefore, be made not only by quantitative analysis but also by empirical engineering judgement based on knowledge learned on similar works. Based on past experiences in road construction, the slope and the physical characteristics on the adjacent area should be considered in the design of cut slopes.

5.2 Gradient and Shape of Cut Slopes

5.2.1 Standard Gradients of Cut Slopes

Refer to APPENDIX 2; Standard Drawing No. 1; Typical Cross Section of Cut Slope and Embankment Slope.

Gradients of cut slopes vary with the types and condition of the soil and with the height of the cut. Table 5-1 shows the standard gradients of cut slopes, empirically established, assuming no treatment or provision of slight protection work such as sodding or netting.

TABLE 5-1 STANDARD GRADIENTS OF CUT SLOPES

Soil or Rocks		Height of Cut	Gradient
Hard Rock			0.3:1 to 0.8:1
Soft Rock			0.5:1 to 1.2:1
Sand	Not dense, and poorly graded		1.5:1 or above
Sandy Soil	Dense	Less than 5 m 5 to 10 m	0.8:1 to 1.0:1 1.0:1 to 1.2:1
	Not dense	Less than 5 m 5 to 10 m	1.0:1 to 1.2:1 1.8:1 to 1.2:1
Sandy Soil mixed with gravel or rock masses	Dense, or well graded	Less than 10 m 10 to 15 m	0.8:1 to 1.0:1 1.0:1 to 1.2:1
	Not dense, or poorly graded	Less than 10 m 10 to 15 m	1.0:1 to 1.1:2 1.2:1 to 1.1:5
Cohesive Soil		0 to 10 m	0.8:1 to 1.2:1
Cohesive soil mixed with rock masses or cobble stones		Less than 5 m	1.0:1 to 1.2:1
		5 to 10 m	1.2:1 to 1.5:1

Note:

(1) Silt is classified as cohesive soil.

(2) Soil not shown in the above table shall be designed with special care.

(3) Height of cut is to be vertically measured from toe to top of slope.

(4) Ratio of Gradient: horizontal length (n) in proportion with vertical height (1).

Single Gradient of Cut Slope

Where soil is composed of an almost uniform kind in the direction of depth of cut, both longitudinal and crosswise, a single gradient of slope is recommended.

Where the kinds of soil and rock vary considerably and complicatedly, a single gradient suited for the gentliest type may be adopted, for convenience of construction, but not necessarily recommended from the economical point of view.

Different Gradients of Cut Slope

Different gradients suitable to each kind of soil and rock shall be adopted as shown in Figure 5-1.

Berm is generally provided at the joint where the gradients change.

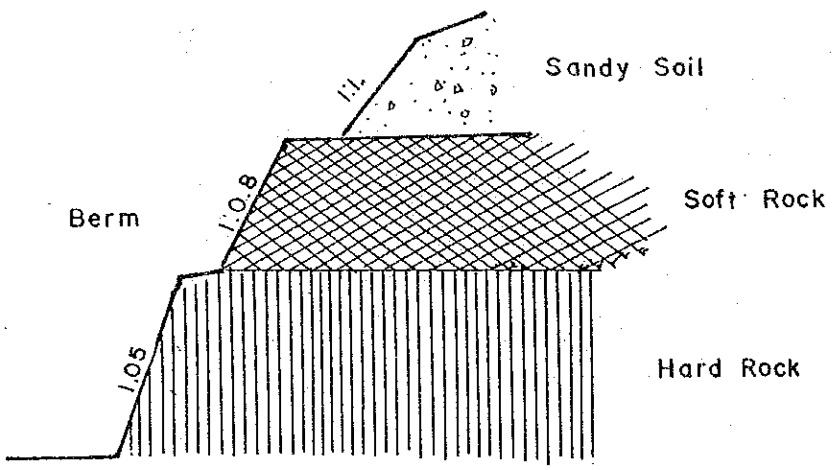


FIGURE 5-1 DIFFERENT GRADIENT OF CUT SLOPE

5.2.2 Berm

A berm of 1 m. to 2 m. in width shall always be provided somewhere at the middle when the cut slope is high.

Purpose of Berm

At the lower portion of a continuously long and large slope, discharge and running speed of surface water increased causing scouring.

By providing a horizontal berm in the middle of the slope, the running speed of the surface water can be reduced and ditch can also be constructed to prevent concentration of surface water at the lower portion of the cut slope. The ditch drains the surface water outside of the slope. A berm can also be used as a sidewalk for inspection purposes.

Location of Berm

A berm shall be provided at every 5 m. to 10 m. in height of a slope where the slope is composed of the same kind of soil or rock. In cases where the slope is composed of different kinds of soil or rocks, the berm is recommended to be provided at the boundary of gravel and rock or permeable and non-permeable strata, as shown in Figure 5-2.

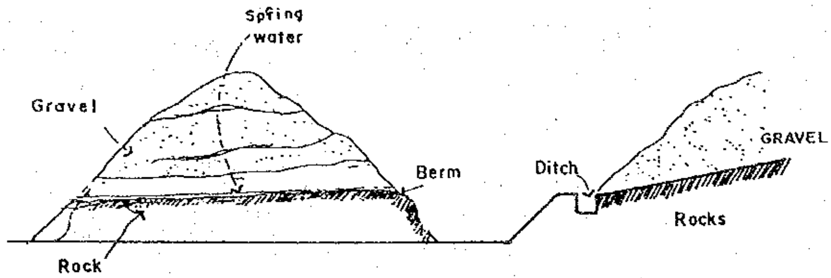


FIGURE 5-2 LOCATION OF BERM

A wide berm is recommended where the slope is long and large or where protection fences for rock fall are to be installed.

Gradient of Berm

Where a drainage facility is not provided at the cut slope, the gradient of the berm should be about 5% to 10% in order to drain water towards the bottom of slope, as shown in Figure 5-3.

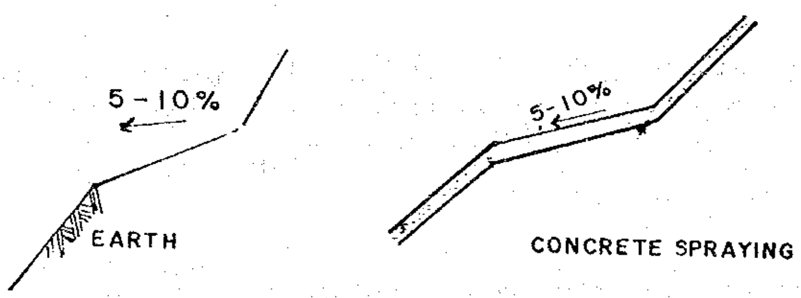


FIGURE 5-3 GRADIENT OF BERM WITHOUT BERM DITCH

Where soil or rocks are likely to be detached at some portions of the slope, or when the slope is composed of soil or rocks that are easily eroded, the gradient of the berm shall be made in the reverse direction and a ditch shall be provided to drain the water, as shown in Figure 5-4.

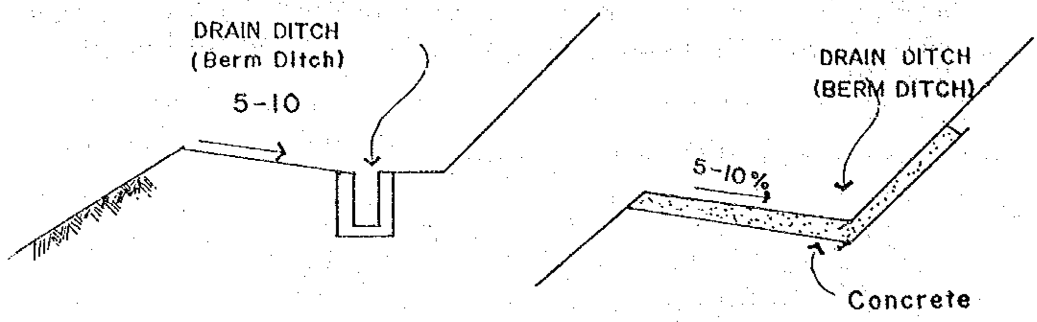


FIGURE 5-4 GRADIENT OF BERM WITH BERM DITCH

5.2.3 Rounding of Cut Slope

The cut slope shall have a gentle and rounded finish at the top and at both ends.

Top of Slope

The top of slope often collapses because it is easily eroded and vegetation can hardly grow. Round shaping is, therefore, recommended to prevent it from collapsing, as shown in Figure 5-5.

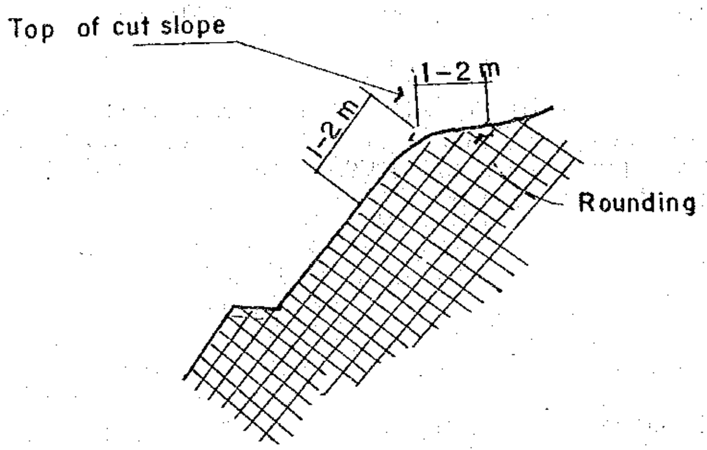


FIGURE 5-5 ROUNDING AT TOP OF CUT SLOPE

Both Ends of Slope

Where topsoil (gravel) exists thickly at the top of slope and along outer edge of bedrock as shown in Figure 5-6 (a), rounding shall be applied at both ends of slope as shown in Figure 5-6 (b).

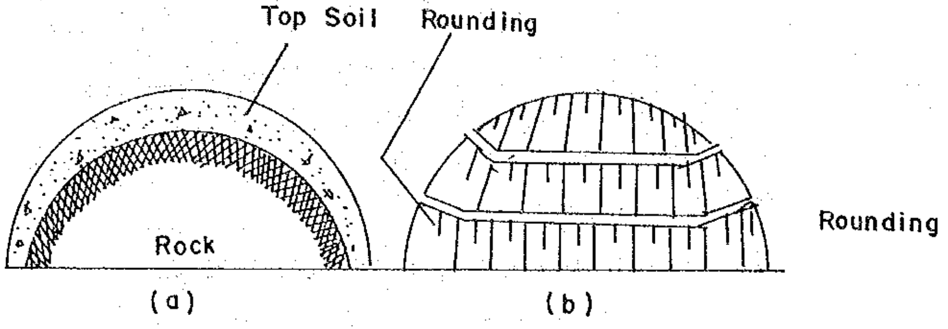


FIGURE 5-6 ROUNDING AT BOTH ENDS OF SLOPE

5.3 Stability Analysis of Cut Slopes

Stability analysis of cut slope is seldom considered in the design stage, but this is often adopted in the design of countermeasure for the cut slope that has collapsed during or after the construction. The formula mentioned in Chapter 6.3, Stability Analysis of Embankment Slope can be applied accordingly. The safety factor shall be more than 1.5 in the design of countermeasures.

5.4 Cut Slopes with High Potentiality of Failures

For the construction of cut slopes where geological features exist, as shown in Table 5-2, special attention on soil and geotechnical surveys should be taken considering the high potentiality of failures.

TABLE 5-2 SLOPES WITH HIGH POTENTIALITY OF FAILURES

Geological Features with High Potentiality of Failures	Typical Soil and/or Rock
(1) Colluvial Deposit and considerably weathered slopes	Talus Cone Weathered Slope Trace of volcanic mudflow Area collapsed in the past
(2) Sandy soil and easily erodable ground	Masa (Decomposed Grantile) Shirasu (Volcanic ash), Pit-Sand, Terraced Gravel Layer
(3) Rock easily weathered	Tertiary Mudstone, Shale, Tuff with weak solidification, Serpentine.
(4) Rock with many fissures	Schist, Gneiss, Chert, Slate, Serpentine, Basalt , Andesite, Rhyolite, Granite
(5) Dip slope structures with tissue (Rocks with cracks inclined to the same direction with cut slope)	Bedding in Sedimentary Rocks, Schistosily in Schist or Gneiss, Columnar and Plate like Joints and Igneous Rocks.
(6) Ground with groundwater	
(7) Large-sized cut slope	

5.4.1 Colluvial Deposit and Badly Weathered Slopes

In the talus cone, weathered slope, trace of volcanic mudflow and the area collapsed in the past, colluvial deposit with a low degree of solidification often exists and forms a natural slope with a gradient close to the critical angle of stability of slant. When such slope is excavated to a gradient steeper than that of the natural slope, the cut slope will become unstable and a failure may easily occur, as shown in Figure 5-7.

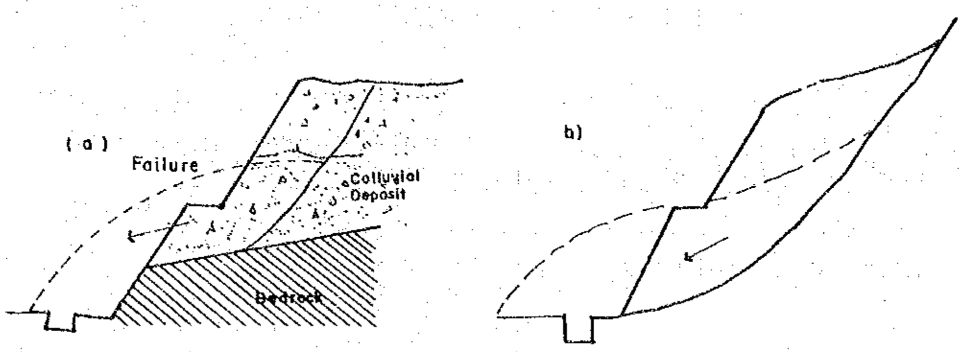


FIGURE 5-7 SCHEMATIC DIAGRAM OF SLOPE FAILURE OF COLLUVIAL DEPOSIT

As countermeasures against this kind of failures, the following methods can be considered:

Method I

Where a failure of (a) is predictable:

As shown in Figure 5-8, a wide step shall be provided near the line of bedrock, so that the sediments collapsing and falling from the above step will be easily retained on the step. The gradient of the colluvial deposit on the portion of weathered layer should be made as gentle as possible.

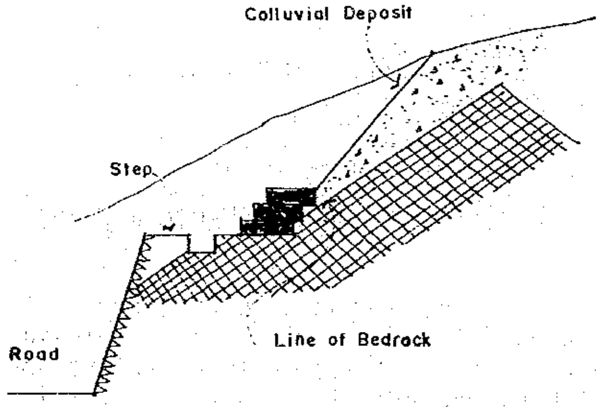


FIGURE 5-8 COUNTERMEASURE FOR SLOPE FAILURE OF COLLUVIAL DEPOSIT

Method 2

Where a failure of (b) is predictable:

In this case, the countermeasure such as large-scale removal of soil (with a slope gradient of 1.5:1 to 2.0:1 or gentler, to include berms), sufficient groundwater drainage works, or prevention works (pile against landslide) should be performed. However, all methods stated above will greatly affect the construction cost and, thus, a complete study shall be required during the design stage.

5.4.3 Sandy Soil and Easily Erodable Ground

Sediments consisting mainly of sandy soil such as masa (decomposed granite), Shirasu (volcanic ash), pit-sand or terraced gravel layer are very easily eroded by surface water, frequently resulting in rock fall, small fall or debris flow.

The erosion should be basically prevented with slope protection works or drainage works rather than coping with the gradient of the slope. Therefore, the water should be completely drained from the top to the toe of the slope. Any permeation of water from the top of the slope should be avoided whenever possible. It is important to provide an extra area of land in front of the toe of slope so as not to give any direct influence upon the road surface in the event of failure.

5.4.4 Rocks Easily Weathered

If the surface layer of a slope is composed of tertiary mudstone, shale, tuff with a low degree of solidification or serpentine, the surface gradually turns into sediment, due to the release of stresses by excavation and the repetition of drying and wetting thereafter which frequently causes slope failure as shown in Figure 5-9.

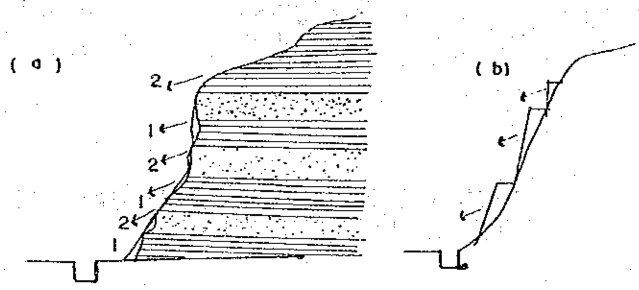


FIGURE 5-9 SCHEMATIC DIAGRAM OF SLOPE FAILURE OF ROCKS EASILY WEATHERED

For the protection of this kind of failure, one of the following precautionary measures shall be taken into consideration during the design stage.

i) A stable gradient should be provided in order to prevent slope failures in the future, even after weathering develops. In addition, a space (roadside space) to minimize damages in the event of slope failure should be provided.

ii) The slope should be tightly covered with protection works to restrict the weathering to a minimum.

For tertiary mudstone, the slope ratio, without the berms should be 0.8:1 to 1.0:1 for favourable condition and 1.2:1 otherwise.

For serpentine, a wide range of slope ratio of 0.5:1 to 1.2:1 is adopted for slopes higher than 10 m. because of the big difference in the solidification between good and poor rocks.

However, a slope ratio of 1.5:1 to 2.0:1 has been generally adopted where abnormal states during excavation have occurred.

5.4.5 Rocks with many Fissures

Bedrocks usually have many weak lines such as fault-fractured zones by tectonic motions, and column-shaped or plate-shaped joints created by the contraction during cooling. The former is often seen in the rocks of Mesozoic and Paleozoic formations (schist, gneiss, chert, slate, serpentine), while the latter is often observed in basalt, andesite, rhyolite and granite.

Typical failures of these rocks are shown in Figure 5-10.

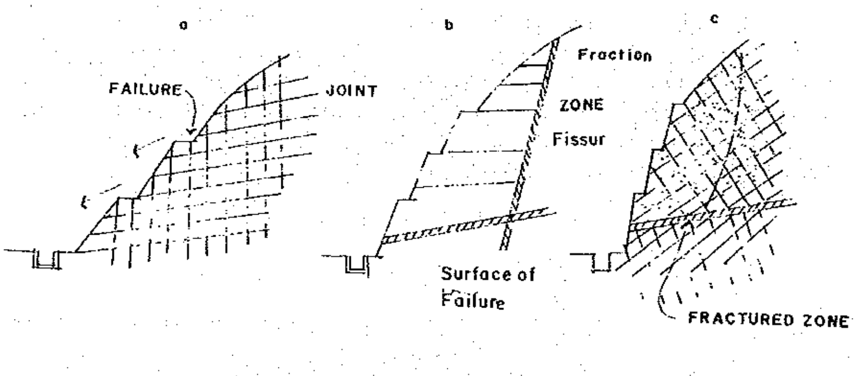


FIGURE 5-10 SCHEMATIC DIAGRAM OF SLOPE FAILURE OF ROCKS WITH MANY FISSURES

The stability of these slopes is dependent on the degree of development of fissures and the degree of fractures, and therefore an overall review should be performed based on the results of seismic survey and crack coefficient, comparing it with the actual records made for existing nearby slopes.

The relationship between the velocity of elastic wave and the gradient of slope cannot be accurately estimated because the velocity of elastic wave is greatly affected by the kind of rocks, degrees of weathering and cracks.

An example of measurement is indicated in Figure 5-11 for reference. This example shows the relationship between the results of a seismic survey performed at a proposed excavation site and the gradients of slopes actually made on the same site. Those slopes which have collapsed during or immediately after the execution of work are marked with "o" in the figure, and the boundary line between the stable zone and unstable zone is indicated with a broken line.

The slope stability is sometimes examined by determining the crack coefficient which indicates the frequency of occurrence of fissures in bedrock judged from the velocities of elastic wave of bedrock and boring cores.

The crack coefficient C_r is given by

$$C_r = 1 - \left(\frac{V_{p2}}{V_{p1}}\right)$$

Where;

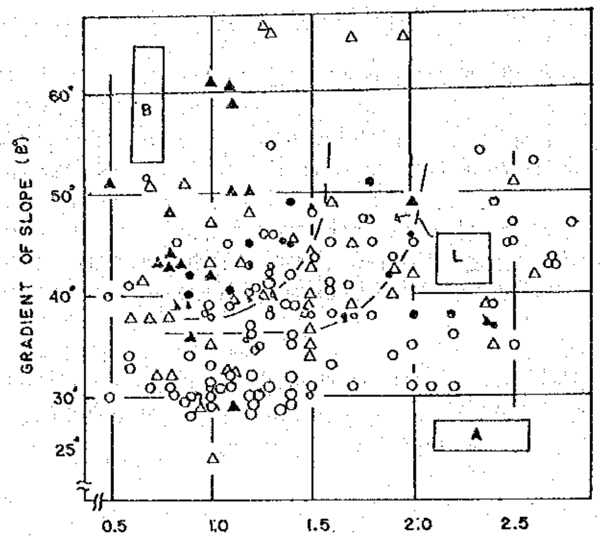
V_{p1} : Velocity of elastic wave through boring cores

V_{p2} : Velocity of elastic wave through ground

Figure 5-12 shows an example of survey conducted by the Japan Highway Public Corporation to establish the relationship between the crack coefficient and the gradient of slope. The slopes that collapsed are marked with"O" and then the boundary between the stable zone and unstable zone is indicated by broken lines.

	Mesozoic and Paleozoic Formulations	Igneous Rock
Collapsed Slope	●	▲
Stable Slope	○	△

Velocity of Electric Wave Through Ground (Km/Sec.)



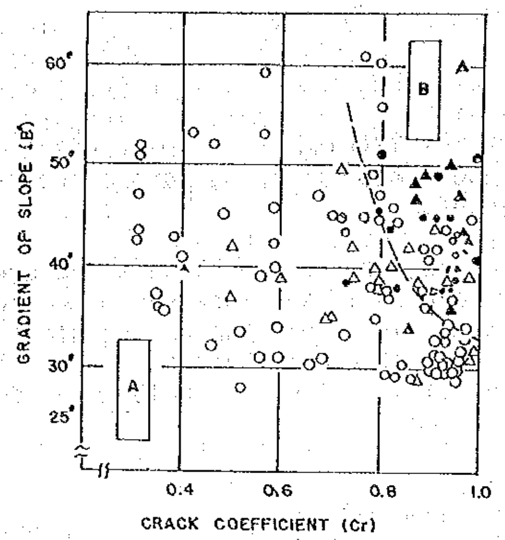
Note:

A - Stable Zone

B - Unstable Zone

L - Boundary

FIGURE 5-11 STABILITY OF SLOPE IN RELATION WITH VELOCITY OF WAVE AND GRADIENT OF SLOPE



Note:
A - STABLE ZONE
B - UNSTABLE ZONE

FIGURE 5-12 STABILITY OF SLOPE IN RELATION WITH CRACK COEFFICIENT AND GRADIENT OF SLOPE

5.4.6 Dip Slope Structure with Fissures

There are fissures developed regularly in a certain direction such as bedding developed in sedimentary rocks, schistosity developed in schist or gneiss, and column or plate-shaped joints developed in igneous rocks. The direction of slant of these fissures coincides with the direction of slant of cut slope face. This slope is called as the dip slope structure with fissures.

A typical feature of failure of a slope is shown in Figure 5-13.

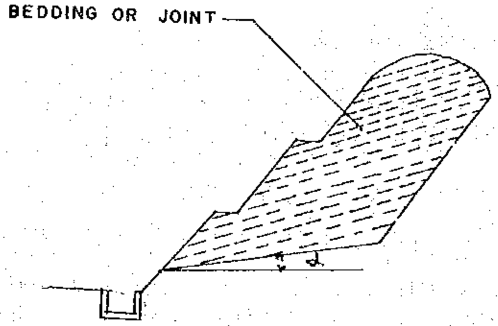


FIGURE 5-13 SCHEMATIC DIAGRAM OF FAILURE OF DIP SLOPE STRUCTURE WITH FISSURES

A gradient of slope (excluding berm) should be equal to or gentler than α . However, if the slant α of the dip slope structure is gentler than 30°, then the slope is not necessarily considered to be unstable as long as the slope ratio is smaller than 1.3:1 and thus the gradient may be determined based upon other factors, such as degree of development of fissures.

On the other hand, if the dip slope structure has a steep slant larger than 60°, the slope could not be considered to be stable in many cases even though the slope ratio is 0.6:1. Generally, it is not recommended to have a slope ratio steeper than 0.8:1 for slopes higher than 10 m. as the dip slope structure.

5.4.7 Ground with Groundwater

Where spring water exists and groundwater level is high, cut slope tends to be unstable regardless of geological condition. Thus, gradient of such slope must be gentler than the standard.

In the design of this area, drainage for groundwater should be given higher priority than the gradient of slope.

5.4.8 Large-scale Cut Slope

Failure of larger-scale and long slope may result in grave disaster. Thus, detailed survey and thorough design should be performed and construction be carried out under a safety control system perfectly organized.

Gradients of slope lower than 15 m. are covered in Table 5.1, while gradients for slope higher than these shall be determined in accordance with actual conditions taking into consideration the following points:

1) For rocks containing a large amount of montmorillonite so called a swelling rock, slope gradients shall be gentle to assure stability even after a slight development of weathering.

2) There often exists fault-fractured zone at side of mountain. Where these zones are found in deep parts after boring or seismic survey, it is necessary to examine the gradient of cut slope the taking into consideration direction and degree of fractures.

3) For cut in steep slope as shown in Figure 5-14, the ground should first be classified into sediment, soft and hard rock before cut is usually executed with gradients suited to each kind of soil.

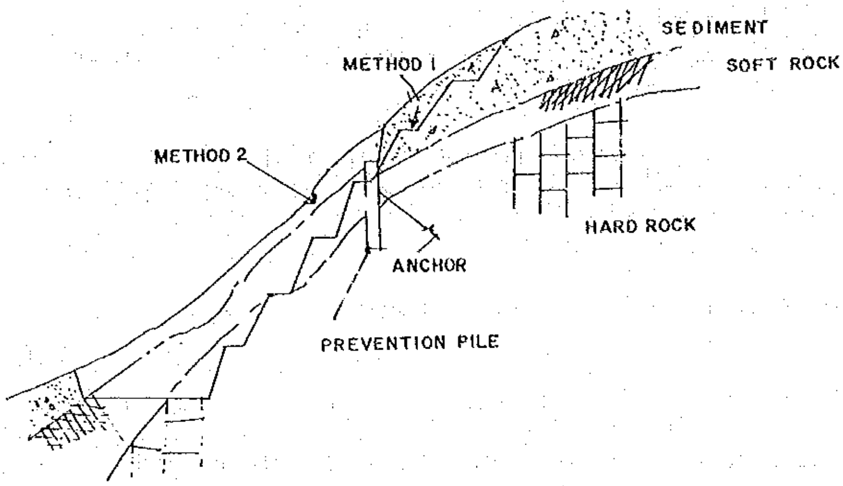


FIGURE 5-14 CUT IN LARGE-SCALE SLOPE

In case of a very steep slope, thin but high cut is forcibly made up to the top of the slope so that the unexpected large and long slopes may be constructed, as shown in Method 1 of Figure 5-14.

When the area of cut slope have to be reduced because of restriction such as vegetation and right of way, prevention works like prevention pile or other structures is recommended to protect the steep slope, as shown in Method 2 of Figure 5-4.

4) In the case of long and large slopes, steps (about 3 m. wide) for inspection and repair at 20 to 30 m. on centers in height in addition to ordinary berms should be provided.

5.5 CONSTRUCTION OF CUT SLOPE

5.5.1 General

In term of mechanization, the construction method of slopes has lagged behind comparing with that of other earthwork and still requires hand works. However, the mechanization has gradually developed recently and the mechanized methods, such as vegetation by spraying and concrete spraying are oftenly used resulting in short construction periods and higher quality of works.

Since the geological formation of slope is extremely inhomogenous and varies considerably, various types of soil or rocks or other conditions may unexpectedly found during cutting work, even if geological surveys have been performed prior to construction. Proper judgement of measures for those unexpected situations is vital in slope works.

Slope failure sometimes occurs during or just after cutting works especially when the retaining wall's gradient slope is steeper that what is standard.

Therefore, the construction of cut slope should be carefully executed in order to have the stability of slope during and after the works.

5.5.2 Construction of Cut Slope Composed of Rocks

At the start, the main portion of rock is excavated or blasted using drilling machines such as blast hole drill or drill master, and then finishing stakes should be properly placed in order to guide and show the planned line of slope as shown in Figure 5-15.

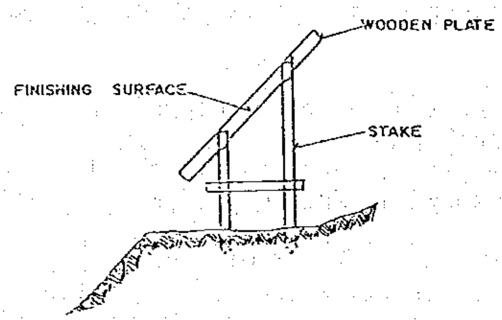


FIGURE 5-15 FINISHING STAKE

To shave off rocks up to the planned line of slope, pickage or coal pick hammer is used in case of soft rock. For hard rock, drilling along the planned line of slope should be performed with jack hammer and blastings with a low power explosive may be utilized in order to avoid loosening of bedrock.

After shaving off rocks, unstable materials likely to fall should be carefully removed with pick hammers or bars, if difficult to remove, those should be anchored to bedrock or covered with a wire net for rock fall prevention.

The unevenness on the finished surface of slope should be kept to a minimum and the depth of any concave or convex portions should be less than 30 cm. although this may vary depending upon the lithology.

5.5.3 Construction of Cut Slope Composed of Common Soil

At the start, the main portion of the common soil is excavated with machines, leaving the soil at 20 cm to 30 cm in thickness from the planned line of a slope.

Then, shaving off the common soil is done with picks or hoes following the finished surface indicated by the finishing stakes.

Although the excavation of the main body is done in short time with machines, shaving off work usually takes a lot of time. In the recent years, a grader with slide blade and a bulldozer with a special attachment for side slopes were utilized.

CHAPTER 6 DESIGN OF EMBANKMENT SLOPE

6.1 GENERAL

Road sections with embankment slope can be designed by quantitative analysis as far as necessary informations can be obtained. Information on the type of embankment materials, geological conditions of embankment foundation, topographical and geological conditions, weather and other necessary data should be thoroughly examined.

Likewise, stability analysis on embankment slope should be made whenever necessary.

6.2 GRADIENTS AND SHAPES OF EMBANKMENT SLOPES

6.2.1 Standard Gradients of Embankment Slopes

Refer to APPENDIX NO. 2; STANDARD DRAWINGS NO. 1; TYPICAL CROSS SECTION OF CUT SLOPE AND EMBANKMENT SLOPE

Gradients of embankment slopes should be designed in accordance with the kind of embankment materials, geological condition of embankment foundation, height of embankment and other conditions.

Standard gradient of embankment slope shown in Table 6-1 is generally adopted in accordance with the type and height of embankment materials used.

TABLE 6-1 STANDARD GRADIENTS OF EMBANKMENT SLOPES

Filling Materials	Height of Fill (m)	Gradient
Sand with well grading, gravel and sand mixed with gravel	Less than 5 m.	1.5:1 to 1.8:1
	5 to 15 m.	1.8:1 to 2.0:1
Sand with poor grading	Less than 10 m.	1.8:1 to 2.0:1
Rock masses (including muck)	Less than 10 m.	1.5:1 to 1.8:1
	10 to 20 m.	1.8:1 to 2.0:1
Sandy soil, hard clayey soil, hard clay (hard clayey soils and clay of alluvium)	Less than 5 m.	1.5:1 to 1.8:1
	5 to 10 m.	1.8:1 to 2.0:1
Soft clayey soil	Less than 5 m.	1.8:1 to 2.0:1

Note:

1) To be applied to embankment with sufficient bearing power of foundation ground which are not affected by inundation.
2) Embankments higher than those listed in the above table, shall be designed with special care.
3) The height of embankment should be measured vertically from toe to top of slope.
4) The ratio of gradient shows horizontal length (n) in proportion to vertical height (1).

Embankment filled with the same kind of material

- A single gradient shall be adopted at least for the portion of slope between berms.

Embankment filled with more than two kinds of materials

- For high embankment constructed using more than two different kinds of materials, a standard gradient suited to each type of soil should be applied.
- In this case, materials shall be applied effectively in accordance with their characteristics, as follows:

  1. Where height of embankment is low and there is no stability problem, gravel soil or sand is preferred to be used for the portion which affects pavement structure (about 1 m. below top of subgrade).
  2. Where there is stability problem on the embankment at soft foundation, slanted ground, or at places such as swamp where spring water may flow into embankment, sand or gravel soil containing small amount of fine-grained soil should as much as possible be used at the bottom of embankment. This will prevent any rise of water pressure inside the embankment and thus will reduce dangerof failure.

Protection of Surface of Embankment Slope

Protection by vegetation may not be expected where embankment is composed of pit-run (rounded) gravel or sand. In such case, embankment surface shall be covered with fine-grained soil as shown in Figure 6-2. This is called as a Blanket Soil.

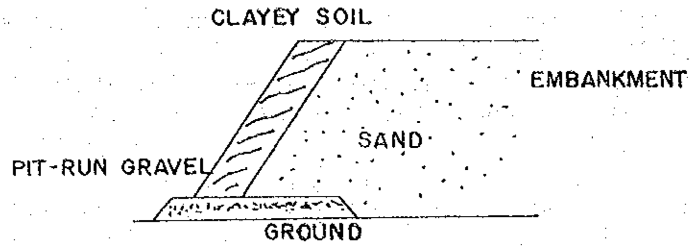


FIGURE 6-1 COVER OF EMBANKMENT SLOPE (BLANKET SOIL)

6.2.2 Berm

A berm of 1.0 to 2.0 meters in width shall be provided at every 5 to 7 m. of vertical height from top of embankment.

Purpose of Berm

Where there is a berm, ditch can be provided to prevent erosion due to rain during and after construction.

A berm may be utilized as a space when any remedy for adjusting errors in construction of embankment is required or as a construction space for countermeasures, if necessary.

It can also be utilized as inspection path.

Location of Berm

In case the height of embankment varies, for instance, embankment across narrow valley, berm may be located at every 5 to 7 m. of the mean height of embankment and not of the maximum height.

Drainage Layer near Berm

If necessary, drainage layer shall be installed about 1 to 2 m. above the berm so that spring water can easily be drained.

6.3 STABILITY ANALYSIS OF EMBANKMENT

6.3.1 Embankments to be examined by Stability Analysis

Generally, the standard gradients may be applied for embankment slope in cases which shall require examination by stability analysis.

However, gradients of embankment slope shall not be designed by stability analysis alone, since empirical engineering judgement based on past experiences of disaster using similar soil conditions and similar works in adjacent areas is applicable.

Embankments subject to stability analysis are summarized as follows.

1) Conditions of Embankment

1) Heights of embankment are higher than those shown in Table 6-1.

2) Water eontent of embankment material is high and shearing strength is low.

(Example: Volcanic ashes with high water content).

2) External Conditions

1) Where embankment is easily affected by spring water. (Example: Partially Cutting and Filling, Level Widening, Embankment on slanted ground, Embankment crossing valley).

2) Where embankment slope may be inundated or its toe eroded during flood (Example: embankment in pond).

3) Where serious damage to adjacent structure may be expected in the event of failure.

4) Where foundation of embankment is considered unstable such as soft ground or landslide area.

5) Where restoration work requires considerable period and function of road may be badly disturbed in the event of failure. (Example: Embankment on slanted ground in mountainous area where no alternative route exists.)

6.3.2 Method of Stability Analysis

To examine stability of embankment by stability analysis, soil tests for ground foundation and embankment materials shall be performed to investigate the characteristics of soil, especially shearing characteristics.

Shearing characteristics of soil is preferably examined by tests using specimens made of proposed filling materials and carried out under the conditions similar to the ground to be filled.

For the examination of the stability of the embankments mentioned in Chapter 6.3.1, a minimum factor of safety shall be calculated at first, and then the corresponding countermeasures may be proposed, if necessary.

In designing an embankment section, a minimum factor of safety calculated by the effective stress method shall be more than 1.2.

Calculation Method

Refer to APPENDIX 1; DESIGN EXAMPLE NO. 1; STABILITY ANALYSIS OF EMBANKMENT

For the analysis of stability of embankment, the slice method of circular rapture plane may be applicable.

A mass on a sliding plane (assumed as Circular Rapture Plane) is divided into several slices with appropriate width (Slice Method), as shown in Figure 6-2. The shearing force and resisting force of each slice along the circular rapture plane are totalled separately. Then, the factor of safety is determined by ratio of both shearing and resisting forces. Normally, the number of slices is more than 6 or 7.

There are two kinds of method, the effective stress method and the total stress method which require different types of tests. The former is generally adopted in analysis of design while the latter is used to check the stability of embankment during and just after the construction of embankment which was quickly constructed with fine-grained soil.

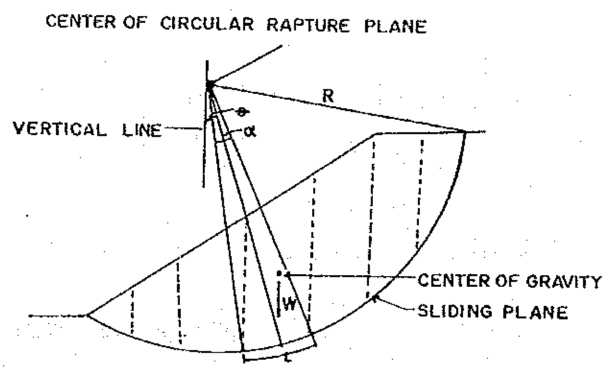


FIGURE 6-2 STABILITY CALCULATION BY SLICE METHOD OF CIRCULAR RAPTURE PLANE

Calculation Formula

1) Effective Stress Method

$$F_s = \frac{\Sigma\{c' . \ell + (W . \cos\theta - u.\ell) . \tan \phi'\}}{\Sigma W. \sin\theta} \quad - - - (6\text{-}1)$$

Where shearing stress S is given by

$S = c' + (\sigma - u) \tan \phi$

2) Total Stress Method

$$F_s = \frac{\Sigma(c.\ \ell + W.\ \cos\theta\ .\ \tan\phi)}{\Sigma W.\ \sin\theta} \quad \text{- - - -} \quad (6\text{-}2)$$

Where, shearing stress is given by

$$S = c + \sigma.\ \tan\phi$$

$$\sigma = \frac{P}{\ell}$$

$$P = W\ .\ \cos\theta$$

Where;

F_s : Factor of Safety

σ : Normal stress (t/m^2)

P : Normal reaction acting to the bottom plane of slice (t/m)

W : Weight of slice (t/m)

ℓ : Length of arc of sliding plane cut by each slice (m)

c : Cohesion (t/m^2)

ϕ : Angle of internal friction (degree)

u : Pore water pressure (t/m^2)

c' : Cohesion of soil for effective stress (t/m^2)

ϕ' : Angle of internal friction for effective stress (degree)

6.3.3 Determination of Shearing Strength

1) Shearing Tests

Shearing strength of soil shall be determined by shearing test analysis. Specimens of soil to be used for test shall as much as possible be of the same condition with those in the field because, shearing stress of soil varies depending on density, water content in percent of dry weight and degree of disturbance of sample.

Kind of Shearing Tests

The different kinds of tests are required for effective stress and total stress methods.

1) Unconfined Compression Test

This test shall be made only for clay and cohesive soil to determine q_u (unconfined compression strength).

2) Tri-axial Compression Test

Undrained Shear Test (U)

for Total Stress Method

Consolidated Undrained Shear Test (CU)

for Effective Stress Method

Consolidated Drained Shear Test (CD) or Drain Test (D)

for Effective Stress Method

Relation between σ (Total Normal Stress) and S (Shearing Stress) in Tri-axial Compression Test is ideally illustrated in Figure 6-3.

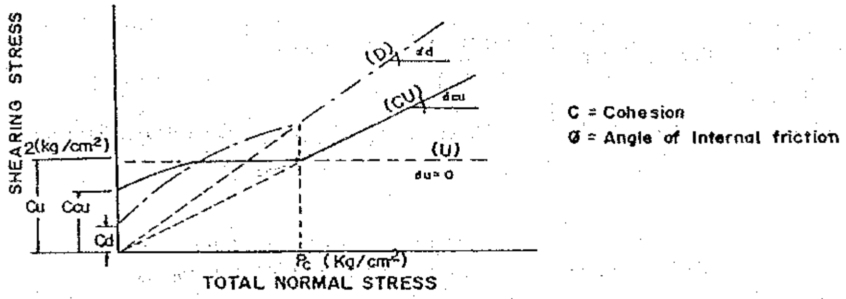


FIGURE 6-3 RELATION BETWEEN NORMAL STRESS AND SHEARING STRESS

2) Determination of Shearing Strength of Soil by Tests

1) Shearing Strength by Unconfined Compression Test (only for Cohesive Soil)

q_u is obtained from the test and S will be calculated.

$$S = C = \frac{1}{2} \times q_u$$

$$\phi = 0$$

Where;

S = Shearing strength (kg/cm^2)

C = Cohesion (kg/cm^2)

q_u = Unconfined Compression Strength (kg/cm^2)

ϕ = Angle of Internal Friction (Degree)

2) Shearing Strength by Tri-axial Compression Test

(a) Total Stress Method by Undrained Shear Test (U)

In the case of undrained shear test of unsaturated soil, the envelope of Mohr's circle arranged by the total stress as shown in Figure 6-4 will become a curve. In this case, a straight line is drawn in the figure within the range of stress to be calculated to determine C_u and $\emptyset_u$.

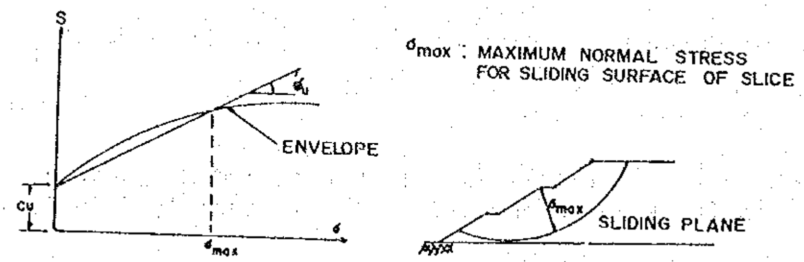


FIGURE 6-4 C_u AND $\emptyset_u$ BY UNDRAINED SHEAR TEST

(b) Effective Stress Method by Consolidated Undrained Shear Test (CU)

When using the effective stress method, the shearing constants are generally determined by the consolidated undrained shear test. Mohr's circle drawn by the total stress is translated in parallel by magnitude by pore water pressure, and then c' and $\emptyset$'are determined from its envelope, as shown in Figure 6-5.

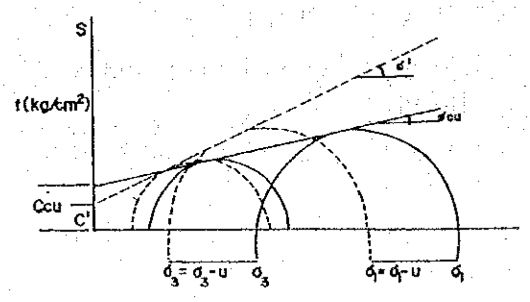


FIGURE 6-5 C' AND $\emptyset$' BY CONSOLIDATED UNDRAINED SHEAR TEST

3) Presumption of Shearing Strength

When no data from tests are available and rough analysis of stability is required, shearing strength of soil may be assumed as described below.

(a) q_u estimated by N-Value

Silty clay - - - - - - - $q_u = 0.1 + 0.15\ N$

Clay (N < 10) - - - - - - $q_u = 0.2 + 0.15\ N$

Cohesive soil - - - - - $q_u = 0.1 + 0.14\ N$

Diluvial clay - - - - - $q_u = N/5 \sim 6$

(b) Standard Value of Soil

Value shown in Table 6-2 may be used for rough analysis of the stability of embankment slope.

TABLE 6-2 STANDARD VALUE OF SOIL

	Classification	Condition		Unit Weight (t/m^3)	Angle of Int. Friction	Cohesion (kg/cm^2)
Embankment	Gravel, Sand with Gravel	Well Compacted		2.0	40	0
	Sand	Well Compacted	Poorly grained	2.0	35	0
			Poorly grained	1.9	30	0
	Sandy Soil	Well Compacted		1.8	25	< 0.3
	Cohesive Soil	Well Compacted		1.7	15	< 0.5
Natural Ground	Gravel	Dense or well graded		2.0	40	0
		Not dense or poorly graded		1.8	35	0
	Sand with gravel	Dense		2.1	40	0
		Not dense		1.9	35	0
	Sand	Dense or well graded		2.0	35	0
		Not dense or badly graded		1.8	30	0
	Sandy Soil	Dense		1.9	30	0
		Not dense		1.7	25	0
	Cohesive Soil	Hard		1.8	25	0
		Soft		1.6	20	0
	Clay, Silt	Hard		1.6~1.7	20	0
		Soft		1.4~1.5	15	0

6.3.4 Determination of Pore Water Pressure

There are two kinds of pore water pressures in embankment as mentioned below.

- Excess pore water pressures generated from execution of filling work.
- Pore water pressure due to groundwater created by rain water or seepage water from the bottom or sides of embankment.

In the stability analysis of embankment, the following considerations should be taken for each case.

(1) Excess Pore Water Pressure

The excess pore water pressure is used for examining the stability of slope during or immediately after the execution of a quickly filled embankment with fine-grained soil.

The pore water pressure shall be preferably measured on site but pressure shown in Figure 6-6 may also be used.

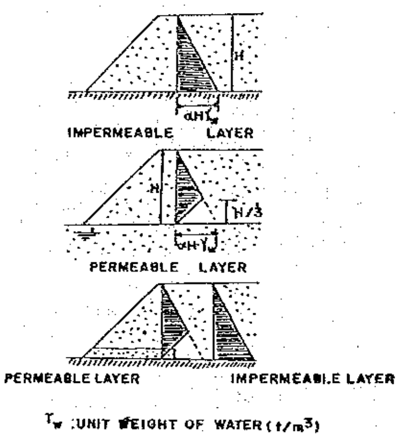


FIGURE 6-6 ASSUMPTION OF PORE WATER PRESSURE DUE TO LOAD OF FILL

α = 1.0 for clayey soil with high water content

α = 0.5 for ordinary soils

(2) Pore water pressure due to groundwater

Pore water pressure due to rising of groundwater level varies depending upon the soil and the shape of embankment and the condition of original ground. Therefore, water pressure should be determined by drawing a flow net in accordance with a graphic solution method. Also, the pore water pressure created by the percolation of rain water sometimes becomes considerably high depending upon the condition of embankment and, thus, a seepage flow could be assumed as required in the embankment for the analysis.

6.4 EMBANKMENT WITH HIGH POTENTIALITY OF FAILURE

Stability of embankment depends duly on the strength of the soil composing main body and on the embankment slope which is often affected by spring water and rainfall. Therefore, treatment of water should be a main subject for stability of embankment.

The following three cases should be designed with special care:

- Embankment on slanting ground
- Embankment on soft ground
- Embankment damaged by rain

6.4.1 Embankment on Slanting Ground

In case of embankment on slanting ground such as, embankment in valley, partial cutting and filling and a border of cut and embankment, spring water from ground frequently permeates into embankment, thereby making the slope unstable.

In those cases, drainage for groundwater should be designed to prevent groundwater from permeating into embankment. Drainage layer should also be installed in order to reduce water pressure in embankment, as shown in Figure 6-7.

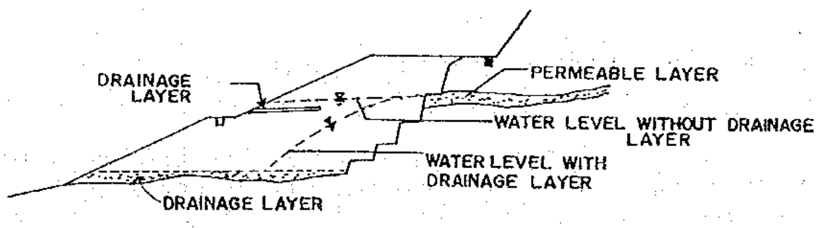


FIGURE 6-7 DRAINAGE FACILITIES FOR EMBANKMENT ON SLANTING GROUND

6.4.2 Embankment on Soft Ground

In case of embankment on soft ground, settlement occurs during filling work and sometimes even after completion of earth work. Assuming the amount of the settlement, the proper measure such as "Surplus Embankment Method" should be taken to secure the finish grade, as shown in Figure 6-8.

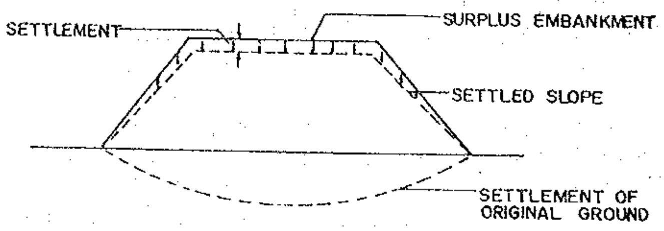


FIGURE 6-8 SURPLUS EMBANKMENT METHOD

6.4.3 Embankment damaged by rain

The failure of embankment slope occurs more frequently with sandy soil than with cohesive soil. The causes of failure are the decrease in strength of embankment materials due to moisture, erosion due to surface water, and the occurrence of pore water pressure due to non-uniform compaction of unequal materials.

To protect embankment from such failures, "Horizontal Thin Layer Compaction Method" is effective. With this method, water can easily be drained and sufficient compaction to reduce coefficient of permeability of embankment materials can be attainable.

6.5 CONSTRUCTION OF EMBANKMENT SLOPE

6.5.1 General

The causes of embankment failure are directly or indirectly connected with water such as rain and groundwater. This is true even during or just after the construction of embankment slope. Slope protection work during the construction should therefore be carefully planned.

To prevent embankment slope failure, the important element is the compaction of soil of slope as well as the selection of the suitable materials. If the compaction is not sufficient, rain water may easily infiltrate into the slope resulting in the cause of failure. Horizontal Thin Layer Compaction Method is generally accepted as an effective method.

6.5.2 Slope Protection Work during Construction

Slopes temporarily completed during construction are always most unstable and easily eroded by rain water. As soon as slope is completed, slope protections should therefore be applied. As a temporary measure until such protection works are applied or become effective, temporary drainage should be provided. A simple example as shown in Figure.

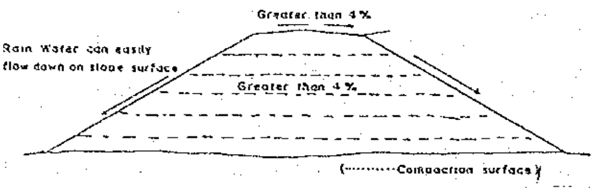


FIGURE 6-9 TEMPORARY DRAINAGE DURING CONSTRUCTION OF EMBANKMENT SLOP

6.5.3 Compaction of Embankment Slope

(1) Method of Compaction

Slope can be effectively compacted by direct compaction using compaction equipment as shown in Figure 6-10.

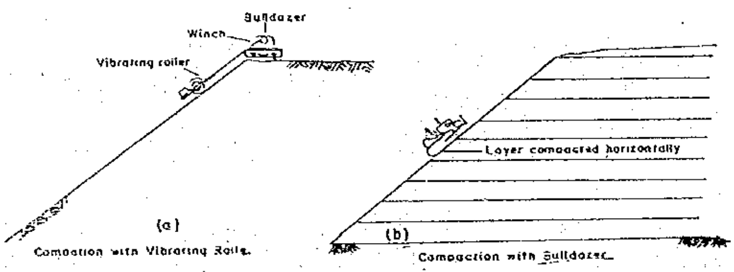


FIGURE 6-10 COMPACTION OF EMBANKMENT WITH EQUIPMENT

In case the gradient of slope is gentler than 1.8:1 a tire roller or vibrating roller toed by a bulldozer can be used.

Where the slope ratio is about 1.8:1, every layer of the embankment should first be compacted and the surface of the slope be roughly finished. Then the surface can be compacted with a vibrating roler heavier than 3 tons pulled by a bulldozer on the top of embankment, as shown in Figure 6-10 (a).

If the gradient of slope is about 1.5:1, compaction should be done with special compaction equipment such as a slope roller.

(2) Compaction of Fine-Grained Soil (cohesive soil, etc.)

Slopes designed with materials, such as, clay or volcanic ash type cohesive soil with high water content, are hardly compacted.

The construction of such kind of slope should be very carefully executed paying special attention to the stability of the slope. Any deformation of finishing stakes and swelling of slope surface during the construction should be observed.

(3) Compaction of Coarse-Grained Soil (Sandy soil, etc.)

Where the main body of embankments is composed of coarse grained soil such as gravel or sandy soil, slope is often covered with blanket soil, in which case, blanket soil should be well mixed with the material of main embankment and be compacted without leaving a clear boundary between the two materials. A typical example is shown in Figure 6-11.

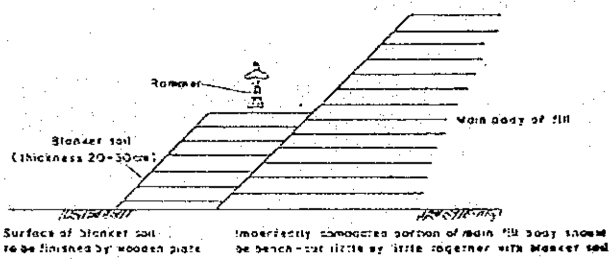


FIGURE 6-11 COMPACTION OF EMBANKMENT SLOPE

In this case the gradient of slope of about 1.8:1 should be adopted and the width of blanket soil of 2 to 3 m. be used for compaction equipment.

CHAPTER 7 DESIGN OF DRAINAGE

7.1 GENERAL

Failures of slope due to rainfall are classified into two categories; one is erosion and/or scouring of the slope surface due to surface water running down the slope; and the other is erosion due to seepage water which caused the weakening of the shearing strength of soil and the increasing of pore water pressure.

Drainage for slope protection should be designed to prevent both, taking into consideration the rainfall intensity, topography, ground surface condition, groundwater condition, soil compaction, existing drainage system, etc.

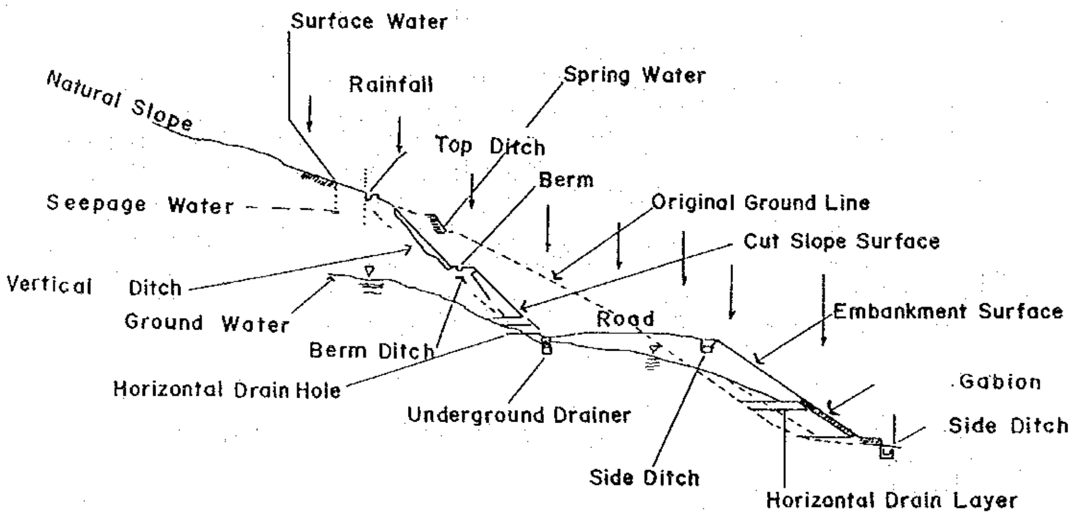


FIGURE 7-1 FLOW OF RAINFALL ON SLOPE

Generally, drainage facilities for slope may be classified as follows:

Drainage Facilities for Slope	Surface Drainage Facilities	Ditch on top of Slope
		Berm Ditch
		Side Ditch
		Vertical Ditch
	Subsurface Drainage Facilities	Subsurface Drainer
		Horizontal Drain Hole
		Horizontal Drain Layer
		Others

7.2 HYDROLOGICAL ANALYSIS

7.2.1 Design Year of Rainfall Probability

The factor influencing the design of drainage facilities is, of course, run-off due to rainfall, characteristics of which shall therefore be carefully examined. Similarly, other factors to be considered are the importance of the road and the anticipated degree of damage when actual run-off exceeds expected design discharge. Therefore, the design year of rainfall probability shall be determined giving considerations to topographic characteristics aside from the factors mentioned above. Table 7-1 presents the recommended design year of rainfall probability.

TABLE 7-1 DESIGN YEAR OF RAINFALL PROBABILITY

Required Level of Drainage	Design Year of Rainfall Probability	
	Road Surface and Small Scale Slope	Important Drainage Facility
High	3 years	more than 10 years
Average	2 years	7 years
Low	1 year	5 years

Required level of drainage may be decided in accordance with the importance of the road.

7.2.2 Calculation of Run-Off

Refer to APPENDIX 1: STANDARD DRAWING NO. 5; STONE AND BLOCK PITCHING

Run-off is calculated by the following Rationale Formula.

$$Q = \frac{1}{3.6 \times 10^6} \cdot C \cdot I \cdot A$$

Where:

Q = Run-off (m^3/sec)

C = Coefficient of run-off

I = Rainfall Intensity within time of concentration (mm/h)

A = Catchment Area (m^2)

Coefficient of run-off

The coefficient of run-off varies on the condition of ground surface, slant, soil, duration of rainfall, etc. The standard value of coefficient of run-off shown in Table 7-2 may be used for the calculation of run-off.

The "C" value in the Rationale Formula reflects this variation in the terrain.

Rainfall Intensity

The value of rainfall intensity (mm/h) is found from the Rainfall Intensity Curve. Time of concentration for the different surface characteristics of the catchment is shown in Figure 7-2 (1) to 7-2 (4).

The catchment should be divided into separate areas, a_1 to a_n, where the corresponding value of I will be constant, hence:

$$Q = I \times (c_1 a_1 + c_2 a_2 + c_3 a_3 + \dots\dots\dots)$$

Where a_1 to a_n are the number of each sub-areas

c to c are the corresponding coefficients of run-off

Time of Concentration

$$t = t_1 + t_2$$

Where:

t = Time of Concentration

travel time in minutes of water from the farthest point to the point where run-off is to be calculated.

t_1 = Inlet time from slope to water course (Refer to Figure 7-2).

t_2 = travel time from water course to the point where run-off is to be calculated.

$$t_2 = \frac{\ell}{60 \cdot V}$$

ℓ = Horizontal length of water course (m)

v = Average velocity in water course (m/sec)

Catchment Area

The catchment area to be considered may be determined by one of the following methods:

(a) Direct field survey using conventional survey instruments;

(b) Use of topographical maps together with field surveys to check details, e.g., artificial barriers such as terraces, ponds, etc;

(c) Aerial photography.

TABLE 7-2 COEFFICIENT OF RUN-OFF

Kind of Ground Surface			Coefficient of Run-Off
Surface of road	Pavement Gravel road		0.70 to 0.95 0.30 to 0.70
Shoulder, slope, etc.	Fine-grained soil Coarse-grained soil Hard rock Soft rock		0.40 to 0.65 0.10 to 0.30 0.70 to 0.85 0.50 to 0.75
Lawns on sandy soil	Gradient	0 to 2% 2 to 7% More than 7%	0.05 to 0.10 0.10 to 0.15 0.15 to 0.20
Lawns on cohesive soil	Gradient	0 to 2% 2 to 7% More than 7%	0.13 to 0.17 0.18 to 0.22 0.25 to 0.35
Ridge Intermediate area Park with lawns and many trees and forest Mountain with gentle slope Mountain with steep slope			0.75 to 0.95 0.20 to 0.40 0.10 to 0.25 0.30 0.50
Paddy field, water surface Field			0.70 to 0.80 0.10 to 0.30

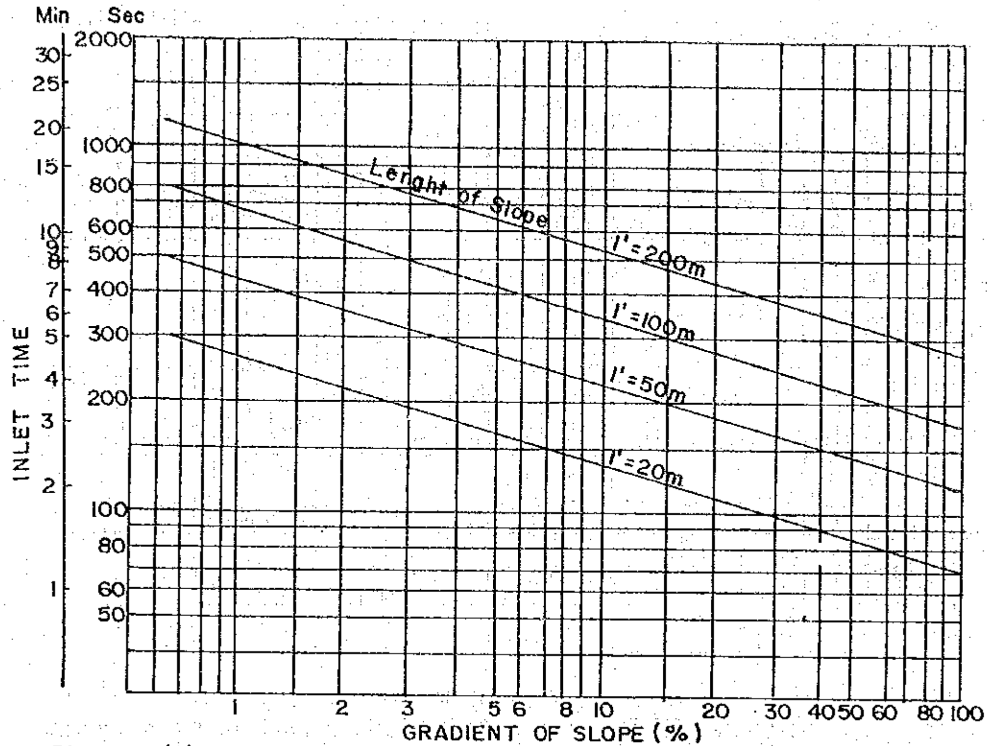


Fig. 7-2 (1) INLET TIME (Smooth surface, Coefficient of roughness) n=0.02

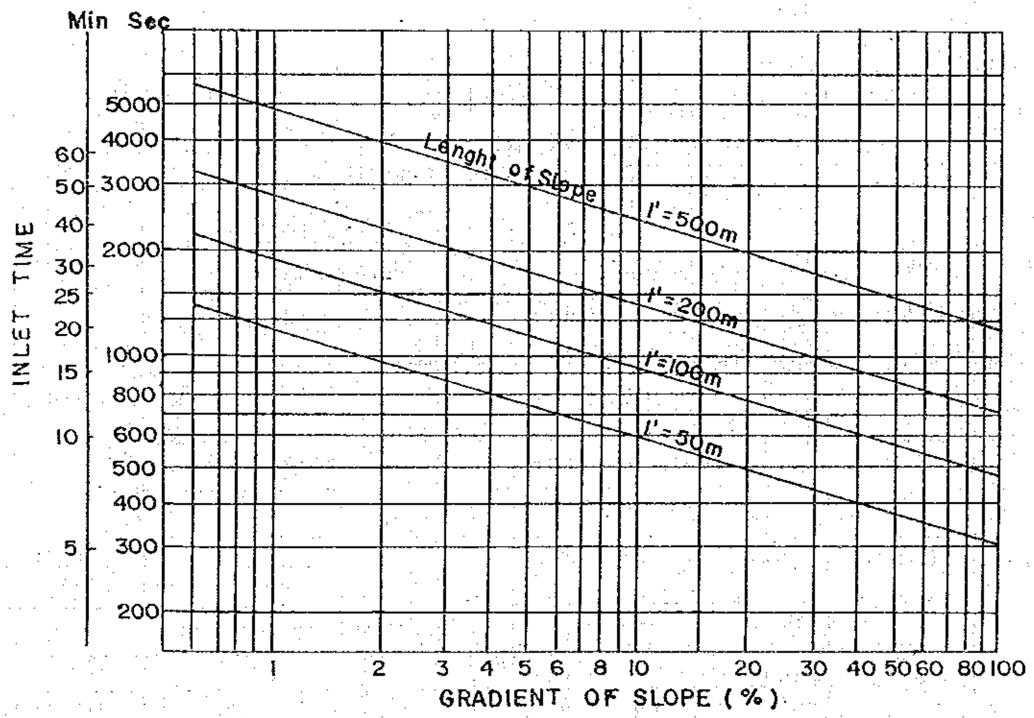


Fig. 7-2 (2) INLET TIME (Bare area with no stone n=0.1)

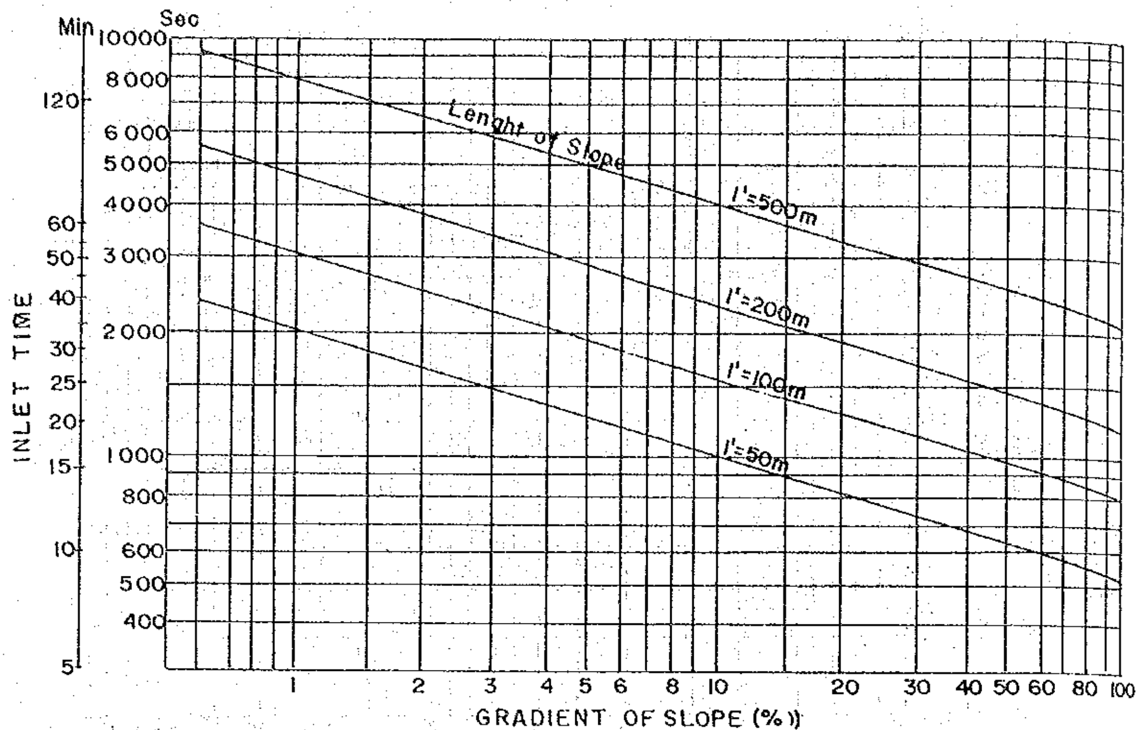


Fig. 7-2 (3) INLET TIME (Area with few grasses, bare area with h = 0.2)

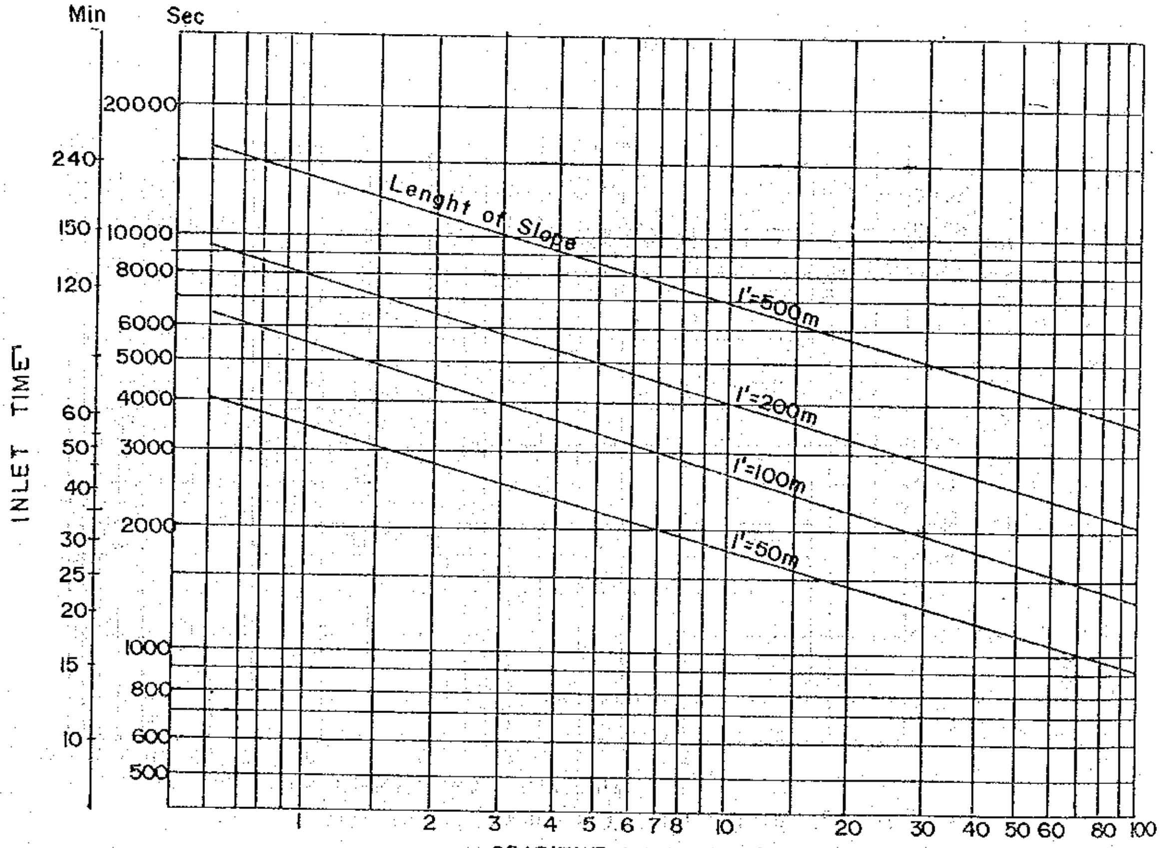


Fig. 7-2 (4) INLET TIME (Ordinary grassland n= 0.4)

7.2.3 RUNNING WATER VELOCITY

Refer to APPENDIX 1; DESIGN EXAMPLE NO. 2; DESIGN OF SIDE DITCH

The running water velocity is calculated using Manning's Formula.

$$V = \frac{1}{n} \cdot R^{2/3} \cdot i^{1/2}$$

Where;

n ; Coefficient of roughness

i ; Hydraulic Gradient

R ; Hydraulic radius $\left(= \frac{A}{P}\right)$

A ; Area of running water

P ; Wetted perimeter

Travel time of water flows in water course to the point under consideration may be calculated using the estimated velocity.

Required cross sectional area of water course (side ditch) is calculated using the following formula.

$$Q = A \cdot V$$

Where;

Q ; Discharge of side ditch

A ; Cross-sectional area of side ditch

V ; Mean velocity of stream

<u>Coefficient of Roughness</u>

Table 7-3 shows the coefficient of roughness generally adopted for different types of drainage.

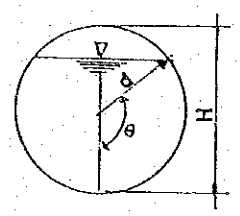
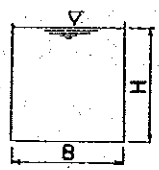
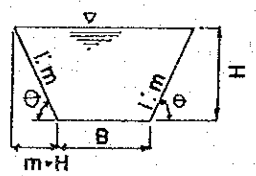
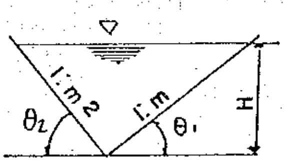
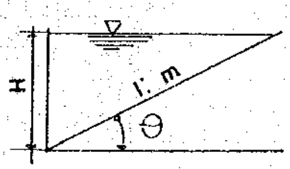
TABLE 7-3 COEFFICIENT OF ROUGHNESS

Type of Drainage		n (Coefficient of Roughness)
Earth and Gravel	Earth	0.02 ~ 0.025
	Sand and Gravel	0.025 ~ 0.04
	Rock	0.025 ~ 0.035
Cast-in-Place	Cement mortar	0.01 ~ 0.013
	Concrete	0.013 ~ 0.018
	Stone pitching	0.015 ~ 0.03
Fabricated	Concrete pipe	0.012 ~ 0.016

Hydraulic Radius of Water Course

Table 7-4 shows a simplified formula in the calculation of the area of running water and hydraulic radius for the different cross-sections.

TABLE 7-4 HYDRAULIC RADIUS OF WATER COURSE

	Cross Section	Area of Running Water	Hydraulic Radius
Circle	 $H = d(1 - \cos \theta)$	$d^2 (\varphi - \frac{1}{2} \sin 2\varphi)$ (d : radian)	$\frac{\varphi}{2} (1 - \frac{\sin 2\varphi}{2\varphi})$ (φ : radian)
Rectangle		$B \cdot H$	$\frac{B \cdot H}{2H + B}$
Trapezoid		$H (B + m.H)$ or $H (B + H \cot \theta)$	$\frac{H (B + m.H)}{B + 2H\sqrt{1 + m^2}}$ $\frac{H (B + H \cot \theta)}{B + 2H \operatorname{cosec} \theta}$
Triangle		$\frac{H^2}{2} (m_1 + m_2)$ or $\frac{H^2}{2} (\cot\theta_1 + \cot\theta_2)$	$\frac{H}{2} \cdot \frac{m_1 + m_2}{\sqrt{1+m_1^2} + \sqrt{1+m_2^2}}$ or $\frac{H}{2} \cdot \frac{\sin(\theta_1 + \theta_2)}{\sin\theta_1 + \sin\theta_2}$
		$\frac{m. H^2}{2}$ or $\frac{H^2 . \cot\theta}{2}$	$\frac{H}{2} \cdot \frac{m}{1 + \sqrt{1+m^2}}$ or $\frac{H}{2} \cdot \frac{\cos \theta}{1 + \sin \theta}$