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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE PUBLIC WORKS DEPARTMENT (JKR) MALAYSIA

THE STUDY ON SLOPE DISASTER MANAGEMENT FOR FEDERAL ROADS IN MALAYSIA

GUIDE III

GUIDE TO EARLY WARNING SYSTEM AND SITE INVESTIGATION

MARCH 2002

NIPPON KOEI CO., LTD.
OYO CORPORATION

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PREFACE

This guide consists of two parts, one is Early Warning System (Guide III-1) and the other is Detailed Investigation for Countermeasure Design (Guide III-2).
Guide III-1 describes the system which detects the sign of slope disaster and warn the road management body or drivers. Instrumentation and monitoring for early warning system and for site investigation are also described in this guide.
Guide III-2 describes method of site investigation for every disaster type.

Early Warning System

To prevent and minimise the road slope disasters, we must evaluate the slope condition exactly, and we must find the factors which trigger the disasters in early stage by daily maintenance. To predict the disaster is important to defend the traffic from the disasters. However, it is difficult at the moment to evaluate the slope condition and emergency by daily maintenance since the objects to be estimated contain various natural factors which are internal factors as well as external factors.
Therefore the monitoring work should be important for prediction of slope disaster and warn to the traffic. This is called Early Warning System.

There may be two type of Early Warning System.
One is Early Warning at High Risk Slope by best use of monitoring systems, second is Early Warning for wide area is mainly by rainfall monitoring. In the mountain area, it is difficult to know which slope is dangerous stage in the heavy raining. Instrumentation and monitoring at each slope cannot correspond to warn the traffic in wide area. Only monitoring of rainfall can correspond to warn wide area.
This guide introduces the Early Warning Systems in Japan as well as the standard criteria to control the traffic.

Following chapters are contained in Guide III-1.
Chapter 1 Introduction of Early Warning System
Chapter 2 Recommendation for Malaysia
Chapter 3 Instrumentation for Early Warning System

Site Investigation

This guideline describes the standard method for investigation and monitoring through instrumentation for each of six classified failure patterns. Depending on the scale of slope failure or the positional relationship between the failure slope and road concerned, it may be recommended to study the feasibility of more appropriate investigation and instrumentation method. It also introduces special or new investigation methods and instrumentations other than standard ones.

Reasonable estimation of the disaster location, scale, and pattern is essential to ensure the appropriate countermeasure. Any countermeasure implemented based on impractical estimation may suffer ineffectiveness or over-design, resulting in wasting of money and time. There are various soil investigation methods that also vary in applicability, simpleness, and costs. These methods are roughly classified into the following five types:

i) Site reconnaissance

ii) Geophysical survey from the surface

iii) Boring investigation (including core sampling, borehole test, sounding)

iv) Borehole logging

v) In-situ test (including sampling in a test pit, adit, and shaft)

Survey as referred to in this guideline includes additionally

vi) understanding of topography through survey and

vii) monitoring through installed instruments.

This guideline covers two stages of slope inspection or investigations to be made during a preliminary stage to design and implementation of the countermeasure as described below,

(1) Preliminary Study (mainly i) and vi)) and

(2) Detailed Study (mainly ii), iii), and vii)) as standard methods.

Following chapters are contained in Guide III-2.

Chapter 4 Introduction of Site Investigation
Chapter 5 Preliminary Study
Chapter 6 Detailed Study
Chapter 7 New Technologies of Investigation

CHAPTER 1 INTRODUCTION OF EARLY WARNING SYSTEM

1.1 Early Warning at High Risk Slope

A threat or a sign that something bad on slope must be known by instrumentation and monitoring on the slope to defend the traffic from disasters.

The instruments shall be installed at slopes are determined based on the expected disaster types.

Table 1.1.1 shows the instruments useful to get the information about disasters

Table 1.1.1 Instruments for Early Warning

Items	Instrument	Notes	Applicable Disaster
Rock Fall Detection	Rock Fall Detector	For direct information of actual fall or failure occurrence.	Rock Fall Rock Mass Failure Debris Flow
Slope Surface Movement	Wire Extensometer Electro- Optical Distance Meter	For early warning based on large displacement exceeding the established standard criteria	Collapse Rock Fall Rock Mass Failure Landslide Embankment Failure
Slope Surface Behaviour	Crack Gauge Surface Tiltmeter	For getting information of accelerated change of the measured items (The standard criteria to be studied and determined for each slope.)	Collapse Rock Fall Rock Mass Failure Landslide Embankment Failure For Road Structure
Subsurface Movement	Borehole Inclinometer Borehole Extensometer	For getting information of accelerated change of the measured items (The standard criteria to be studied and determined for each slope.)	Landslide
Groundwater Level (Pore Pressure)	Water Level Meter Piezometer	For getting information of change of water level or pore pressure (The standard criteria to be studied and determined for each slope.)	Landslide Collapse
Rainfall	Rain Gage	For analysis of relation with other measurement result For traffic control	For all disasters

The details of instruments are in Chapter 3 Instrumentation for Early Warning System in this Guide.

Actual selection instrumentation and location shall be decided by experienced geotechnical engineer to consider

a) Level of risk
b) Level of emergency
c) Importance of the road
d) Distance from the road management office

It is important that all instruments can warn to the road management office as soon as they detect the warning level of any movement or signal through monitoring operator or automatic information system.

The automatic information system could be the part of automatic measurement system. The automatic measurement system processes all monitoring work such as data collection, data storage and data transportation automatically.

Automatic measurement system should be planned taking into account the deformation condition of slope, objective of measurement, measurement items, measurement frequency, layout and quantity of instruments, type of instrument, maintenance of instrument, and site condition. Fig. 1.1.1 shows a typical conceptual drawing of automatic measurement system.

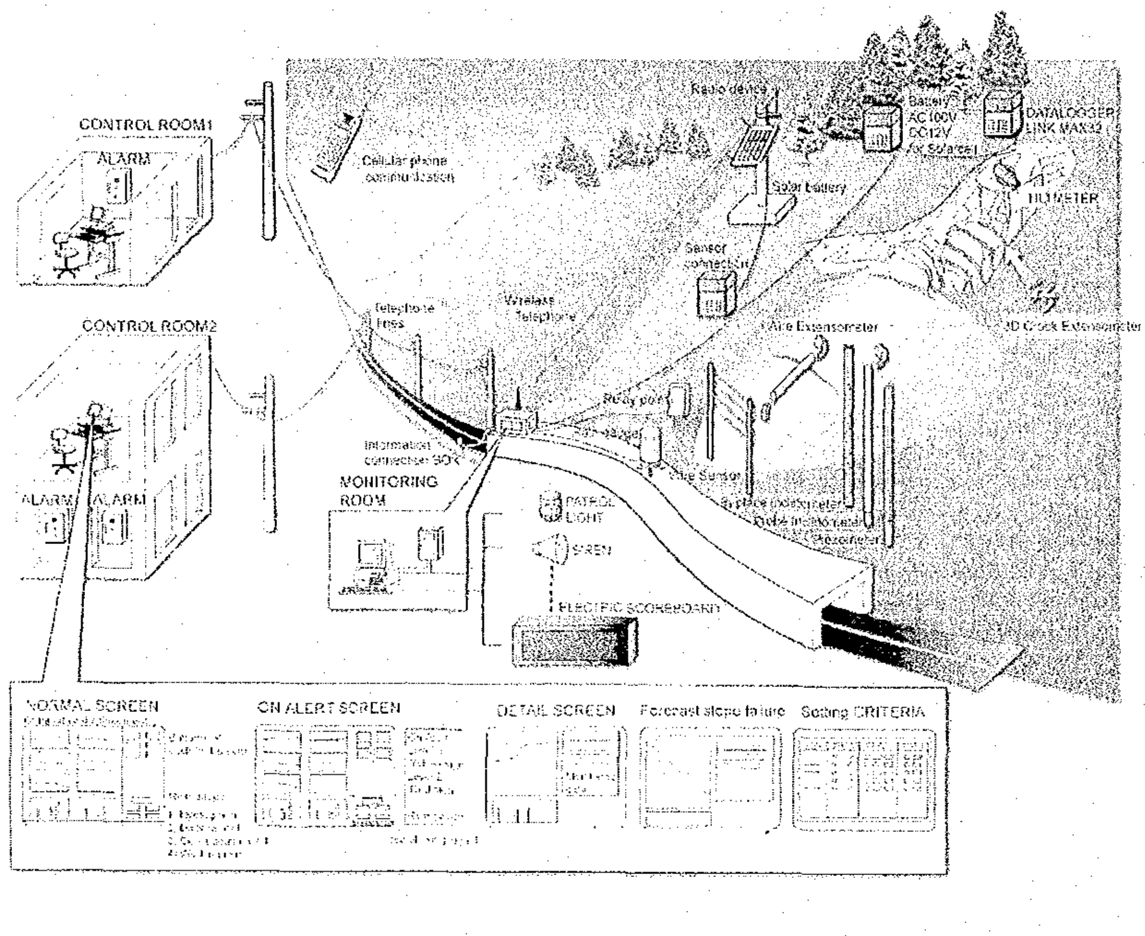


Figure 1.1.1 Typical Conceptual Drawing of Automatic Measurement System

Basically the system consists of a sensor block, data recorder, control block, data processing block, transmission block, alarm unit, surge protector, and power supply system as shown below.

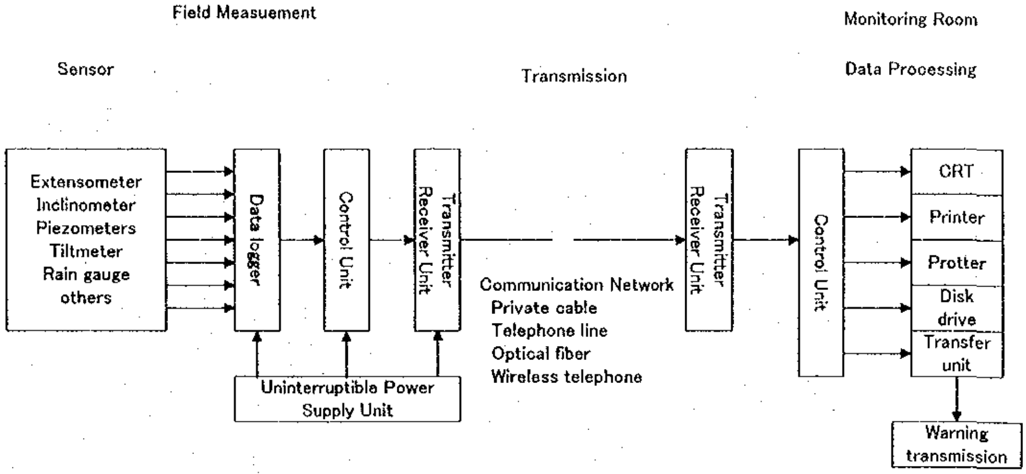


Figure 1.1.2 An typical Conceptual Drawing of Measurement System (Ref. *13) p.187, Fig.7.4.1)

(1) Standard Criteria based on Ground Movement

By the careful analysis of monitoring result, we could know how critical the slope is.

Figure 1.1.3 shows the example of the prediction curve which is based on actual wire extensometer monitoring on landslides in Japan. As shown in the figure, remaining time Tr to the failure is expected by the speed of ground surface movement ε using following formula.

$$\log_{10} Ts = 2.3 - 0.9 \log_{10} \varepsilon$$

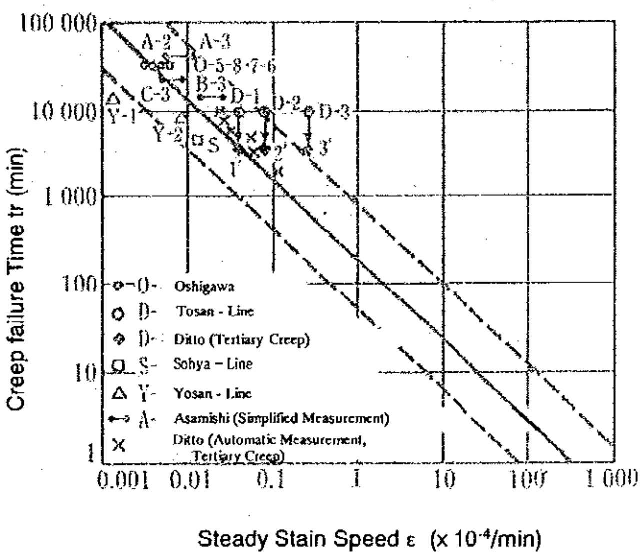


Figure 1.1.3 Time to Slope Failure – Strain Speed (Wire Extensometer)
(Strain : conversion to 10 m long wire)

As a result of the above, the following analytical criteria of wire extensometer has been generated and common in Japan.

Table 1.1.2 Example Standard Criteria of the Wire Extensometer

Criteria	Daily displacement (mm)	Monthly displacement (mm)
Urgent Stage	2×10^{1} or more	5×10^{2} or more
Established Stage	1×10^{0} or more	1×10^{1} or more
Semi-Established Stage	1×10^{-1} or more	2×10^{0} or more
Latent change	2×10^{-2} or more	5×10^{-1} or more

As shown above example, many data were accumulated in the study of slope disasters in Japan. Not only the wire extensometer data but also data of inclinometer, tiltmeter and so on are accumulated and studied in terms of the relation between disasters. Some standard criteria based on the monitoring result has been established in road management bodies or railway companies in Japan.

Table 1.1.3 shows the standard criteria for road disaster created by The Highway Study Committee in Japan. There are four levels of warning based on the monitoring results. Other bodies issued different criteria, but they may not much different from Table 1.1.3.

Table 1.1.3 Standard Criteria (Except Rain Gauge)

Warning Level		Level 1	Level 2	Level 3	Level 4
Action		Site Inspection, Frequent Monitoring	Call a Committee	Preliminary Alert, Emergency Measure	Danger Level, Evacuation
Extensometer Borehole Extensometer Distance Meter	Ground Surface Displacement Velocity	**>10 mm /30days**	**5-50 mm /5days**	**10-100 mm /day**	**>100 mm /day**
Inclinometer	Displacement Velocity at Slip Surface	**>1 mm /10days**	**5-50 mm /5days**	-	-
Tiltmeter	Tilting Velocity	**10-50 seconds /10days**	-	-	-
Rock Fall Detector	Rack Fall Detect	**Detect any rock fall**	-	-	-

The rainfall monitoring is more useful for the wide area. From the economical view, it is not recommendable to install one rain gage at one slope because rainfall data could represent certain area around rain gauge. The rainfall monitoring shall be used for the traffic control in wide area.

The groundwater level is usually very related with rainfall. Theoretically when the ground water level is higher, the slope becomes unstable. It is, however, not usual because the groundwater is depend on geological and topographical condition as well as vegetation. The groundwater level in borehole at which landslide begins to be active is defined as the critical water level. Figure 1.1.4 shows an example comparison between the groundwater level and daily movement. The critical water level is estimated to be around GL-8 m in the figure.

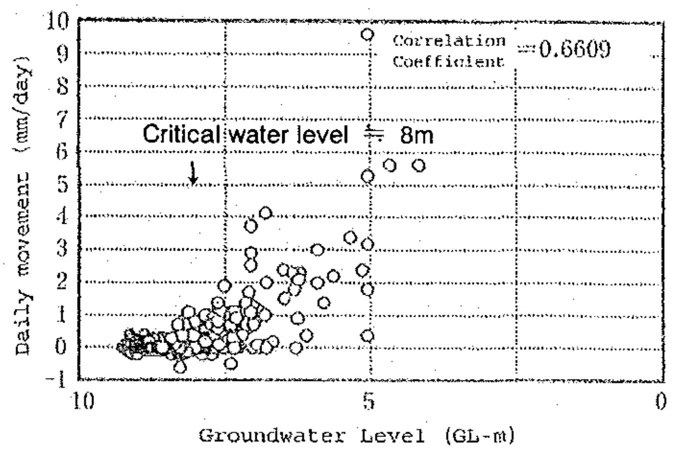


Figure 1.1.4 Typical Comparison between the Groundwater Level and Daily Movement

(Ref. *14) p.330, Fig.2.1.1 (1))

1.2 Early Warning for Wide Area

It is the fact that one of the main factors that could lead the slope disasters is the rainfall. What kind of rainfall may influence the disaster is concerned with the topographic and/or the geological conditions at the respective areas. According to various peculiar conditions, the drizzling rain in long period or the heavy rain in short period, to say nothing of the heavy rain in long period, might be a trigger of the disasters. As to the road disaster management, not only prevention works against the dangerous slopes but the reliable rainfall observation and appropriate measures for the traffic control based on the rainfall data is indispensable.

Rainfall Monitoring should be useful for comprehensive road management such as the traffic control under heavy rain.

The traffic control under heavy rain is based on the experimental fact or statistical knowledge that the number of slope failures increases remarkably when the amount of rainfall exceeds a certain value.

The several methods to evaluate the rain fall in terms of the relation between disasters such as collapse, debris flow have been proposed and applied as follows in Japan.

a) Hourly Rainfall Method
Hourly rainfall can be thought to represent well for the rainfall intensity indicator.
To be a good indicator causing shallow slope failure (generally <1m depth)

b) Accumulated Rainfall Method
Accumulated rainfall (summation of precedent rain without break) reflects better on collapse or landslide than heavy rain of short term.

$R = \Sigma Ri$ (Ri : hourly rainfall at i hours before)
If the rainfall has been stopped for three ours Ri shall be 0.
This is most simple method applicable to urgent evaluation. This method is widely used in road management in mountain area in Japan.
This method is more reliable than Hourly Rainfall Method, however, it has still have some error to predict the disasters.

c) Combined Method of Hourly Rainfall and Accumulated Rainfall
Combined of methods of a) and b) is more reliable than the single application.
This method is adopted by Japan Railway (Figure 1.2.2).

d) Effective Rainfall Method
Effective rainfall is defined as the accumulated rainfall with attenuation by run-off effect of precedent rain. It is explained by following formula.

$R = \Sigma AiRi$
($Ai = 0.5^{1/T}$, T : half life of water level in the ground (depend on geology))

This method is adopted by many road administrator Japan, including expressway and federal road.

e) Water Storage in-Soil Method
Change of water volume in the soil is evaluated using tank model analysis.
Being adopted in special program aerial disaster warning in use of weather forecast radar network.

Effective Rain Fall Method and Combined Method are common in road management and railway management. The followings are example of rainfall evaluation based on two methods.

(1) Effective Rain Fall Method by Road Management Japan
to decide a criteria by this method, the rainfall data and the disaster record of the region in last 15 years shall be obtained. The relation between the rainfall and the disaster has be cleared based on the 15 years data and graphed as shown on Figure below. The exampled shown on Figure shows that the disasters were increased in 80 – 130 mm effective rainfall. The 80 mm of effective rainfall could be decided as criteria rainfall by this result.

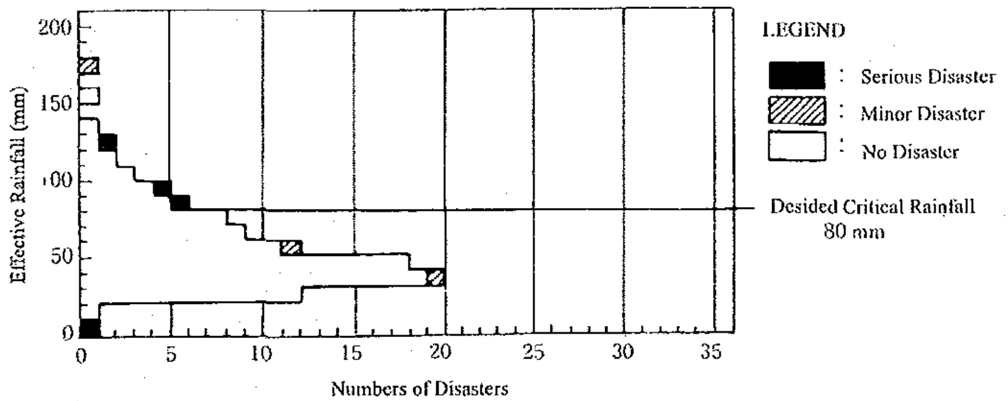


Figure 1.2.1 Effective Rainfall with Disasters Last 15 years (Ministry of Construction, Japan)

(2) Combined Method of Hourly Rainfall and Accumulated Rainfall

Japan Railway (JR) is using the following graph to control train system. Figure 1.2.2 shows that the example of train control based on rainfall by Japan Railways. It is based on accumulated rainfall and hourly rainfall.

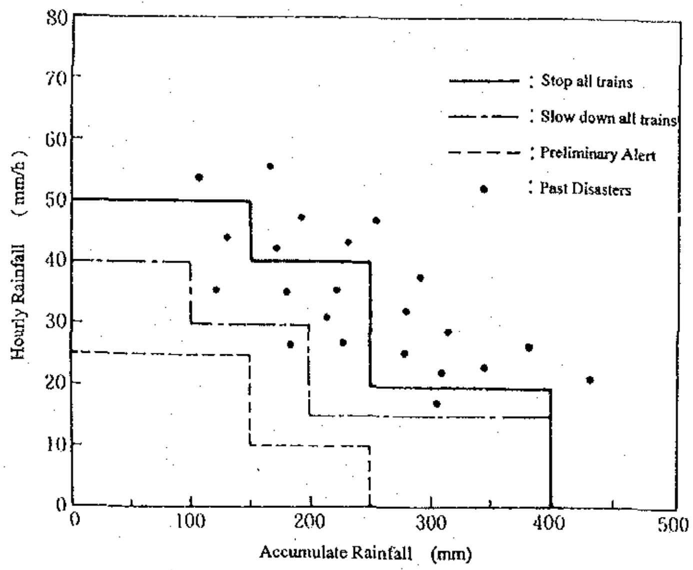


Figure 1.2.2 Train Control Based on Rainfall by Japan Railways

Japan Highway Corporation (JH) is using the following graph to control traffic. Figure 1.2.3 shows that the example of train control based on rainfall by JH. It is based on accumulated rainfall and hourly rainfall. The shadowed area in the graph is to be considered as critical stage for the highway.

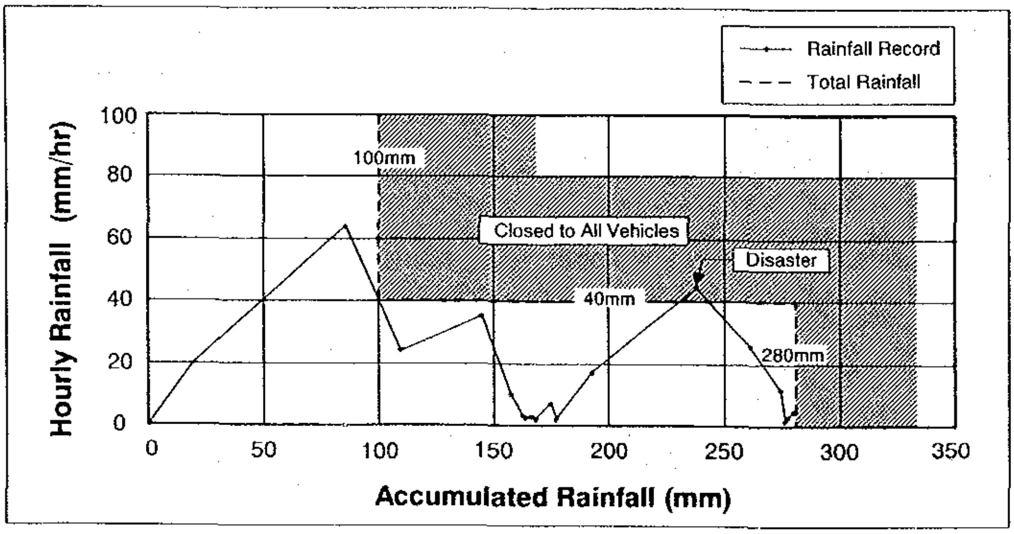


Figure 1.2.3 Train Control Base on Rainfall by Japan Highway Corporation

CHAPTER 2 RECOMMENDATION FOR MALAYSIA

2.1 Early Warning at High Risk Slope

(1) Instrumentation

For the purpose of road maintenance, following action should be required to decide the slope to be monitored.

1) Pick up high risk slopes by Slope Inspection

2) Select the slope in the high risk slopes to be monitored based on critical stage, road importance

3) Decide monitoring method, automatic monitoring or manual monitoring. If the road is very important or the access is difficult, the automatic monitoring is recommendable.

4) Decide instruments. Table 1.1.1 might be good guide to decide, however, actual selection of instrumentation shall be done by experienced engineer.

The measures shall be taken against the high risk slopes which are selected by slope inspection as soon as possible. However, the measure work could not be done on all high risk slope so soon. Early Warning System which makes best use of monitoring systems shall be installed at the slopes to defend the traffic from disasters until the completion of measure work.

(2) Criteria

Rainfall, geology and vegetation in Malaysia are different from them in Japan. It is not sure that the standard criteria can be applied in Malaysia. It is recommendable to accumulate the monitoring result and study the ground movement at slope disaster like Figure 1.1.3.

Until accumulate the data, Table 1.1.3 could be applied as the criteria in Malaysia.

2.2 Early Warning for Malaysia

(1) Rain Gauge Installation

Malaysia has rainfall monitoring system already in DID (Irrigation and Drainage Department) and MMS (Malaysia Meteorological Service). It obviously is not enough to manage the federal roads.

Exposed major problems and recommended improvements of the rainfall observation in Malaysia are summarized in the following table.

Table 2.2.1 Problems and Recommended Improvement of Rainfall Observation

No.	*Problems*		***Recommended improvement***
1	Reliability of the data:	The observed data involve a lot of deficiencies caused by troubled equipment in most of the existing stations.	Regular maintenance of the observation equipment Establishment of the suitable observation system/organization
2	Uneven distribution of the stations:	Present distribution of the stations is concentrated mostly in the flat area because of a matter of the O&M.	• Comprehensive examination of appropriate arrangement of the stations • Practical use of the radar-rain gauge data (wide area data)
3	Interval of the observed data:	Available interval of the data is limited to daily basis at present, except for some major city areas.	• Hourly data observation by automatic rain gauge equipment • Practical use of the radar-rain gauge data (short interval and instant data)

General standard for an arrangement of the rainfall observation in Japan is that one station covers at least an area of 50 km^2. Currently, the average area covered by one station is an area of 17 km^2, and many observation stations with the radar technology have been installed to cover throughout the country. The data obtained from the fixed point and the radar observation are complemented each other and analysed effectively. It contributes to reliability of the data, supply of the data at short intervals and in an instant. Furthermore, the additional observation stations have been installed suitably for the dangerous areas in accordance with the importance of the traffic situations.

Considering the present situation in Malaysia, an average area covered by one station in the whole country is an area of 250 km^2. Some radar-rain gauge stations have been installed already in the Peninsular and the Borneo, however the areas covered by those stations are limited and the number of the stations is still in shortage. Moreover, distribution of the stations is concentrated in urban area, of which the altitude is low and where it is easy to operate and maintain the stations as compared with the one at the mountainous areas, and a lot of deficient data have been involved during the observed periods. As summarized in Table 2.2.1 as well, further improvements of the rainfall observation both in quantity and quality are necessary in Malaysia.

Being discussed in 1) Observed rainfall in the Study, it is very difficult to catch the rainfall trends/characteristics in mountainous area, especially in such tropical regions as Malaysia. From the point of view of road disaster management, to arrange observation stations at the specified areas with respect to the circumstances would be realistic for the present in Malaysia rather than an arrangement of the stations based on the fixed standard. On that occasion, we have to take the economic (occasionally environmental) influence caused by the disaster and the budget for meteorological observation into consideration. Simultaneously, with regard to the road disaster management, how the traffic control can be conducted effectively might be one of the key issues. As for the effective traffic control, there are two important prerequisites to be considered. One is a settlement of the dangerous rainfall index, and the other is the timely and suitable measures according to the index. In order to examine the both items, the observation performed on daily basis would be insufficient to provide effective information. Consequently, the observation of the hourly rainfall is highly required.

In addition, the observation by automatic rain gauge instruments with the data logger is appeared to be reasonable and recommended for the fixed point observation due to consideration of reliability of the data, the necessity of the hourly rainfall data and the cost of installation/O&M including the equipment cost.

Table 2.2.2 Installed Rain Gauge Stations along Main Roads

No.	state	nos of stn MMS	DID	total	area (km2)	nos of stn per 1 km2	50 km2	km2/ per station	length of fed. road (km)	nos of stn per 1 km	10 km	km/per station
1	Federal Territory (KL)	3	14	17	243	0.07	3.50	14	0	—	—	—
2	Federal Territory (Labuan)	1	0	1	92	0.01	0.54	92	124	0.01	0.08	124
3	Johor	22	122	144	18,986	0.01	0.38	132	2,653	0.05	0.54	18
4	Kedah	17	65	82	9,426	0.01	0.43	115	705	0.12	1.16	9
5	Kelantan	23	64	87	14,920	0.01	0.29	171	829	0.10	1.05	10
6	Malacca	7	20	27	1,651	0.02	0.82	61	249	0.11	1.09	9
7	Negeri Sembinan	14	47	61	6,643	0.01	0.46	109	1,575	0.04	0.39	26
8	Pahang	52	136	188	35,965	0.01	0.26	191	3,689	0.05	0.51	20
9	Penang	7	25	32	1,030	0.03	1.55	32	166	0.19	1.93	5
10	Perak	31	108	139	21,005	0.01	0.33	151	1,658	0.08	0.84	12
11	Perlis	4	14	18	795	0.02	1.13	44	124	0.14	1.45	7
12	Sabah	46	77	123	73,620	0.00	0.08	599	1,368	0.09	0.90	11
13	Sarawak	11	183	194	124,449	0.00	0.08	641	1,492	0.13	1.30	8
14	Selangor	27	88	115	7,955	0.01	0.72	69	456	0.25	2.52	4
15	Terengganu	11	64	75	12,955	0.01	0.29	173	995	0.08	0.75	13
		276	1,027	1,303	329,735	0.00	0.20			0.08	0.81	12

(2) Criteria

Empirically we know that the risk of slope disaster increase in heavy rain in Malaysia.

The value of rainfall criteria for Early Warning shall be finalized in accordance with various conditions of each federal road section as follows, because the warning shall be wide area and effect to various people.

a) Rainfall characteristics of the region
b) Slope failure history of the region (connected with geology and other conditions)
c) Traffic Volume of the road section
d) Social, economical importance in the region
e) Age of the slopes after construction (In general road slope newly constructed within five years tends to show higher probability of causing failure.)

As the first step of Early Waning, the criteria in Malaysia could follow the one of Japan. The method JR and JH adopts shown in Figures 1.2.2 and 1.2.3 are not complicated and could be applicable In Malaysia. However, the rainfall pattern in Malaysia may be very different from it in Japan. It is strongly recommended to accumulate the rainfall data and study the relation between the rainfall and disasters. The criteria should be improved based on it.

Tentatively this guide recommend for Malaysia Road Management to adopts JH criteria to control traffic in heavy rain.

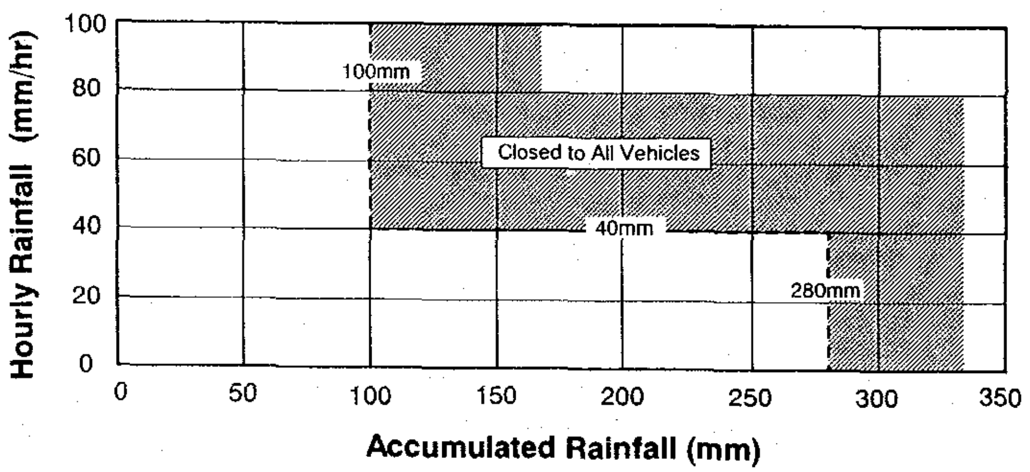


Figure 2.2.1 Recommended Criteria for Traffic Control

CHAPTER 3 INSTRUMENTATION FOR EARLY WARNING SYSTEM

In this chapter, the standard instrumentation in Early Warning System and Site Investigation is introduced. Specific principle and procedure of each method are described in BS and technical documents. This chapter describes mainly considerations for implementation.

For the measurement system, selection and design of each component should be made with due consideration of the following evaluation items.

Table 3.1 Evaluation Standard of the Measurement System (Ref. *13) p.186, Table 7.4.1)

Evaluation Item	Standard
Adaptability	Free setting of measurement interval
	Time-series indication of measurement values
	Compatibility with power supply
	Matching of accuracies between measurement equipment and system
Reliability	Function to protect each equipment against indirect lightning stroke
	Backup function in case of power failure
Convenience	Addition of sensor and local station as required by the situation while keeping the present state of power supply and data transmission equipment
	Rapid transmission of measurement result
Weather resistance	Compatibility with particularity, such as a tropical area, etc.
	Superior waterproof and moisture resistance
	Normal operation under expected temperature conditions
Maintainability	Less inspection frequency
	Short-term inspection
Economy	Inexpensive system

The instruments introduced in this guide are listed in Table 3.2. As shown in Table 3.2, there are various kinds of instruments. Suitable one should be selected by experienced engineer based on the site condition or management condition.

Table 3.2 Instruments for Early Warning System

Type	Name of Instrument	Chapter
Surface Fluctuation	Wire Extensometer	Chapter 3.1
	Tiltmeter (Water Tube Type)	
	Tiltmeter (Electric Type)	
	Site Survey	
	GPS	
	Strain Gauge	
	Crack Gauge (Manual)	
	Crack Gauge (Automatic)	
	Rock Fall Detector	
	Slope Collapse Detector	
	Embankment Collapse Detector	
Subsurface Fluctuation	Inclinometer	Chapter 3.2
	Pipe Strain Gauge	
	Multipoint Borehole Extensometer	
	In-place Inclinometer	
	Acoustic Emission	
Groundwater Fluctuation	Water Standpipe	Chapter 3.3
	Piezometer	
Rainfall	Rainfall Gauge	Chapter 3.4
Other New Method	Three-Dimensional Shear Displacementmeter	Chapter 3.5
	Fibre-optic Sensor	

3.1 Measurement of Surface Fluctuation

3.1.1 Wire Extesometer

The wire extensometer is used mainly to understand the movement of landslide activities. If landslide becomes active, with cracks appearing in the ground surface, the wire extensometer is installed and observed to determine development of crack and movement of landslide soil mass.

As shown in Figure 3.1.1, piles are provided on both ends of the area concerned. The instrument is provided to one of them while the invar wire (nickel-copper wire with low coefficient of thermal expansion) is spread from the other one. This wire crosses over the area concerned and is connected to the instrument. The invar wire on the pile side is fixed while that on the instrument side is connected to the wire wound on a drum. The drum of extensometer has the recording form, on which a recording pen that moves parallel to the drum rotation axis plots the time-displacement graph.

The actual accuracy is about 1 mm, so that it is difficult to detect any latent landslide activity. Besides, this instrument is almost insensitive to the movement in a direction nearly normal to the elongation direction. When the instrument has to be installed on the side of landslide, it is necessary to bring the invar wire as near as possible to the landslide movement direction.

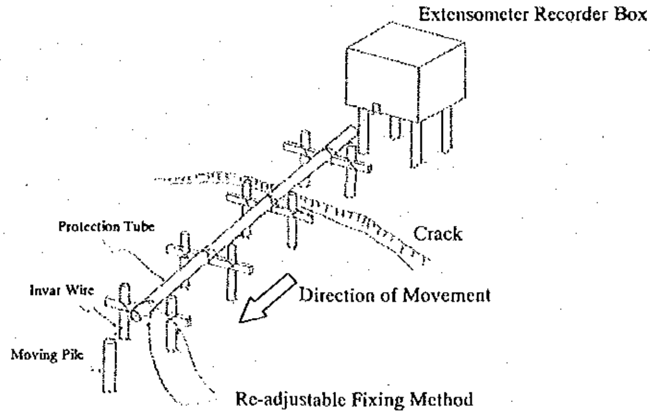


Figure 3.1.1 Graphical Installation Diagram of Wire Extensometer

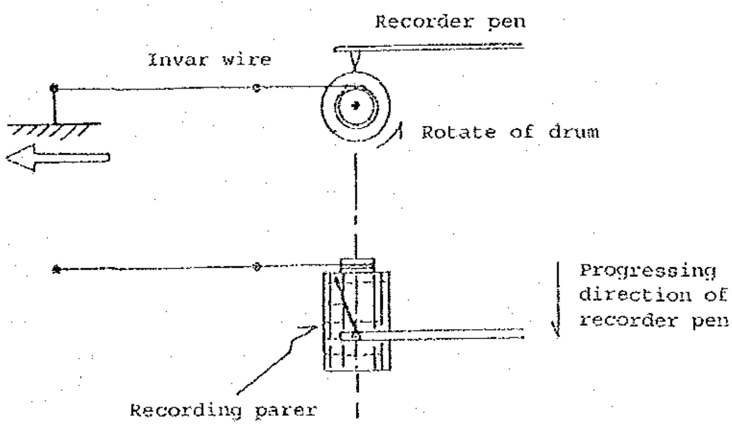


Figure 3.1.2 Diagram Explaining the Principle of Wire Extensometer

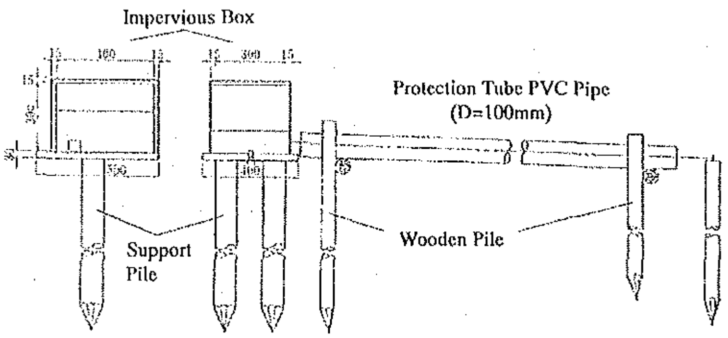


Figure 3.1.3 Typical Construction Diagram of Box Housing the Wire Extensometer

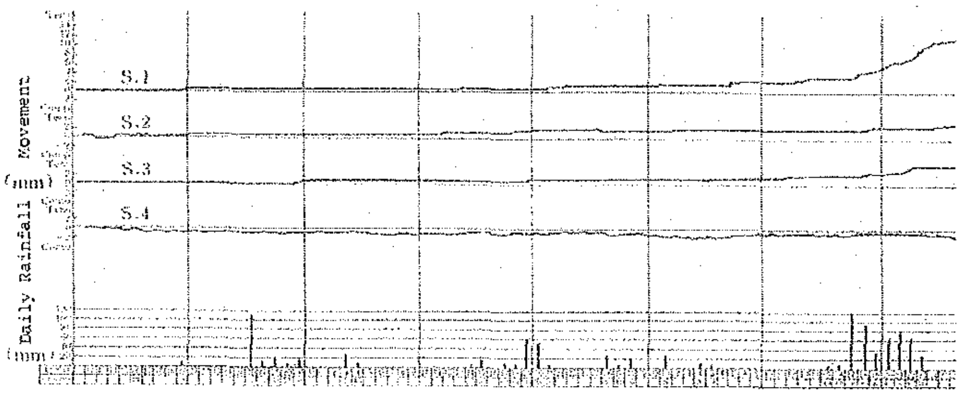


Figure 3.1.4 Result of Measurement with an Installed Extensometer

(1) Installation method

i) The direction to install the wire extensometer should agree with the movement direction of landslide as much as possible. As shown in (a) of Figure 3.1.5, this instrument is generally installed on both sides of a primary scarp. A shifting pile should not be provided in a location with high settlement.

ii) Figure 3.1.5, (b) shows observation of the relative movement of blocked landslide soil mass on both sides of crack in the landslide area. Installation of instruments consecutively as shown in (c) enables observation of the absolute movement of the landslide as a whole, difference in movement of blocked soil mass, and time lag of movement among blocks.

iii) Figure 3.1.5, (b) shows determination of the movement vector when the movement direction is not known.

iv) As the invar wire is readily bent, a levelling string is provided between two points. Checking should be made whether the gradient is too steep, the height of support pile of invar wire protective tube is unstable, or exuberance of vegetation in the neighbourhood presents hindrance to observation. The distance between two points is 10 m, maximum 15 m.

v) The invar wire protective tube is used to prevent recording of abnormal values through shielding from direct sunshine, wind, plants and animals, and other influences. Normally, about 100 mm dia. PVC pipe is used. After installation of the pipe, the levelling line should be replaced by the invar wire.

vi) The borehole extensometer shown in Figure 3.1.5 is used to observe the movement on the slide surface position by fixing the end of invar wire to the bedrock in the bottom of borehole.

vii) The extensometer could be used for monitor the rock mass failure as shown in Figure 3.1.6.

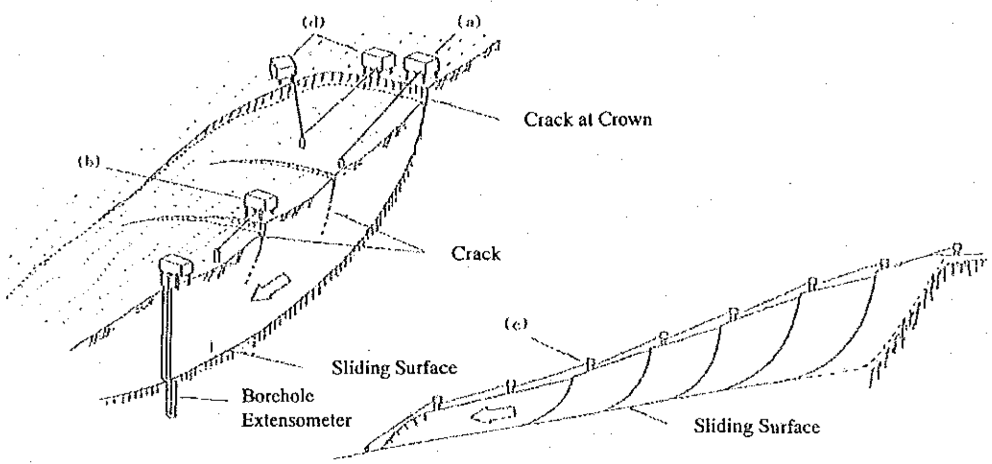


Figure 3.1.5 Typical Installation of Wire Extensometer (Ref. *14) p.112 - 115, Fig.2.1.1(1)-(5))

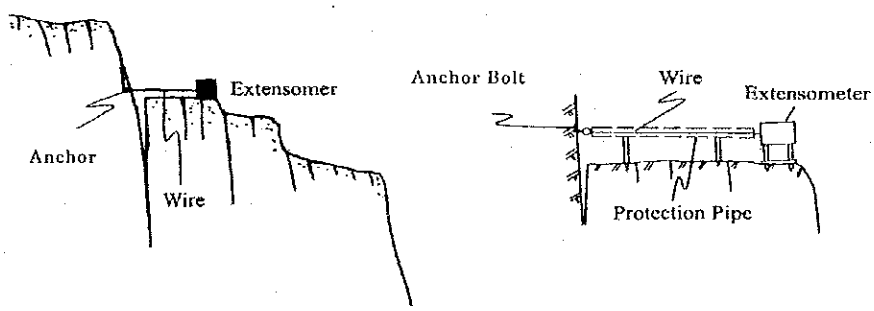


Figure 3.1.6 Wire Extensometer Monitoring on Rock Mass Failure

(2) Measurement, maintenance, and inspection

i) At start of recording, the recording pen is set at that time point and the date/time of start, the name of location, and other necessary data are entered in the recording paper.

ii) When the invar wire protective tube is bent contacting the invar wire, the daily expansion/contraction change may be recorded according to deformation of the protective tube. In this case, the tube should be corrected to keep a space from the invar wire.

iii) When any sudden elongation or discontinuous noise of expansion/contraction is recorded, pull-out and dislodgement of the tube, contact of twig with the invar wire after storm, and other causes may be considered. The area around the invar wire should be checked, and the tube should be repaired and surrounding trees removed.

iv) In case of loss of record, defective recording pen, over-stroke or metal fatigue cutting of invar wire, battery down of the clock, etc. may be considered. Regular inspection/maintenance should be made at least once a month.

(3) Data filing and judgment

i) Data from observation is filed in the form of the time-movement curve, with the data, daily rainfall, and groundwater level around the observation point included.

ii) Determination is made on landslide condition, such as the movement of landslide soil mass, movement velocity, mutual relationship between landslide blocks, and movement direction, from the time-movement curve.

iii) Enquiry is made into the relationship between the rainfall, groundwater level, etc. and the movement condition to review the landslide mechanism.

iv) When the movement is accelerated, with imminent possibility of landslide, the collapse time is predicted.

3.1.2 Tiltmeter

The tiltmeter is used mainly to determine inclination change of the ground surface. Representative sensors used in this inclinometer are of a water tube, servo type accelerometer, operational transformer, and strain gauge type. The water tube type is used for manual measurement. Others are electric and used for automatic observation.

The foundation bed for tiltmeter should be firm with foundation piles driven, so as to avoid various noises caused by change in the surface layer due to drying, wetting, and frost heave as well as settlement of surface soil under the weight of observation personnel and wild life. (Figure.3.1.8)

It should be noted that the tiltmeter is extremely sensitive to landslide with large change amount, exceeding the observation range too early.

In order to judge the change of inclination, observation results are filed in the form of the cumulative inclination changes by observation direction, cumulative inclination change – direction diagram, daily inclination change diagram, and daily inclination change – direction diagram. It is difficult to determine the scale of disaster and the pattern of change only from the observation results of tiltmeter. Results from other investigations should also be taken into account to achieve overall judgment.

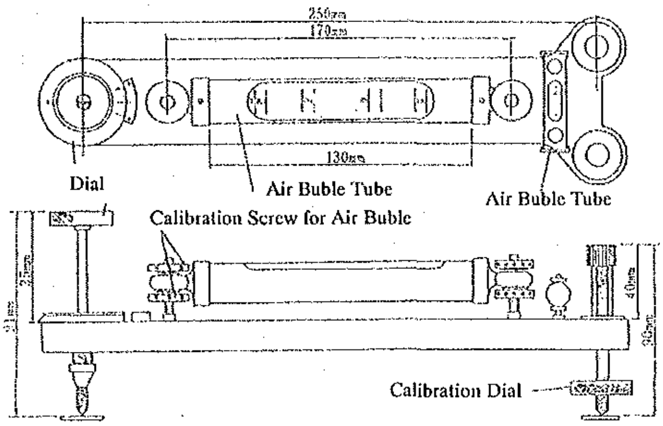
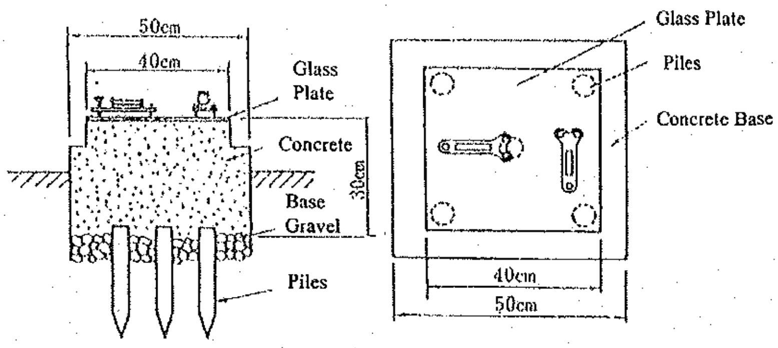


Figure 3.1.7 Water Tube Tiltmeter (Ref. *[14] p.120, Fig.2.1.2 (1))



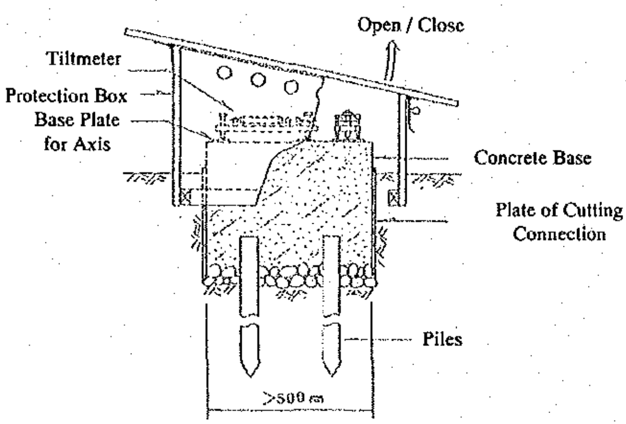


Figure 3.1.8 Typical Installation of Water Tube Tiltmeter (Ref. *14) p.125 - 126, Fig.2.1.2 (4), (5))

Electric type tiltmeter is common for monitor the surface fluctuation. Its installation method is almost same as manual type tiltmeter. The typical electric type tiltmeter is shown in Figure 3.1. 9.

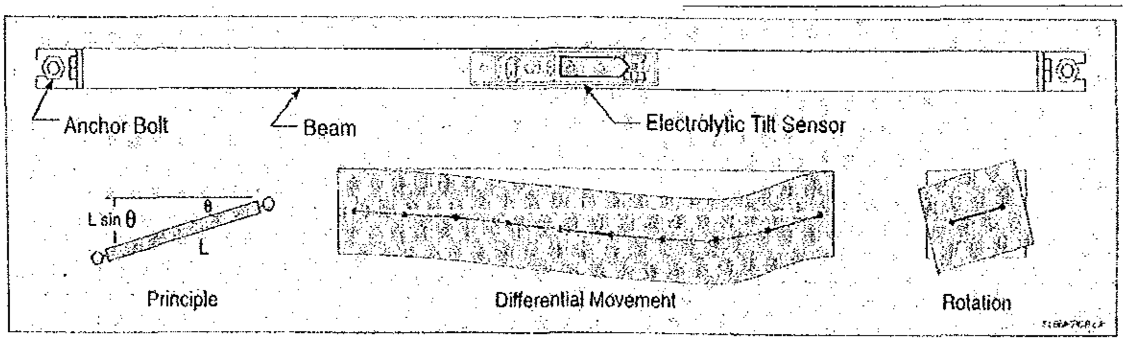


Figure 3.1.9 Electric Type Tilt Meter

3.1.3 Measurement of the change amount by survey

Fixed-point observation is made on the slope using survey instruments such as a total station, etc. This method enables determination of the change range and change rate.

For marking to fix points, it is essential to secure reflective prisms firmly. Recently, the total station enabling measurement without using dedicated reflective prism has been developed, and attempt is made to apply this station for observation of the slope of steep cliff.

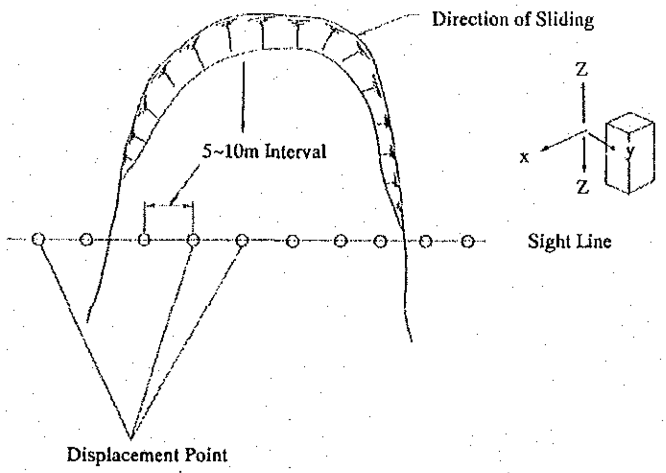


Figure 3.1.10 Sight Survey Outline View (Ref. *8) p.119 Fig.2-27)

3.1.4 GPS (Global Positioning System)

This is a radiolocation system using satellite. This method uses 24 satellites arranged along the orbit 20000 km from the earth and can be classified in types according to the ratio utilization method and installation/observation methods of receivers. The static type that is said to be the least in error is used for the landslide area.

Applicability to observation of the slope is limited because of the necessity of over-view, precision machinery, and expensive receiver (30,000 RM or more). The equipment cost is in the rapid downward trend in these days, and the utility value will increase in the future if the accuracy of simplified measurement is enhanced through improvement of the software.

Figure 3.1.11 shows a typical example of the slope displacement monitoring system using GPS. This is called a real-time kinematic type, including multiple GPS receiving points (measurement points) and one GPS receiver (reference point) provided at a point considered immobile. Observation data from these points is collected in a computer via a network, determining and displaying in real time relative three-dimensional coordinates (base line vector) between each measurement point and the reference point.

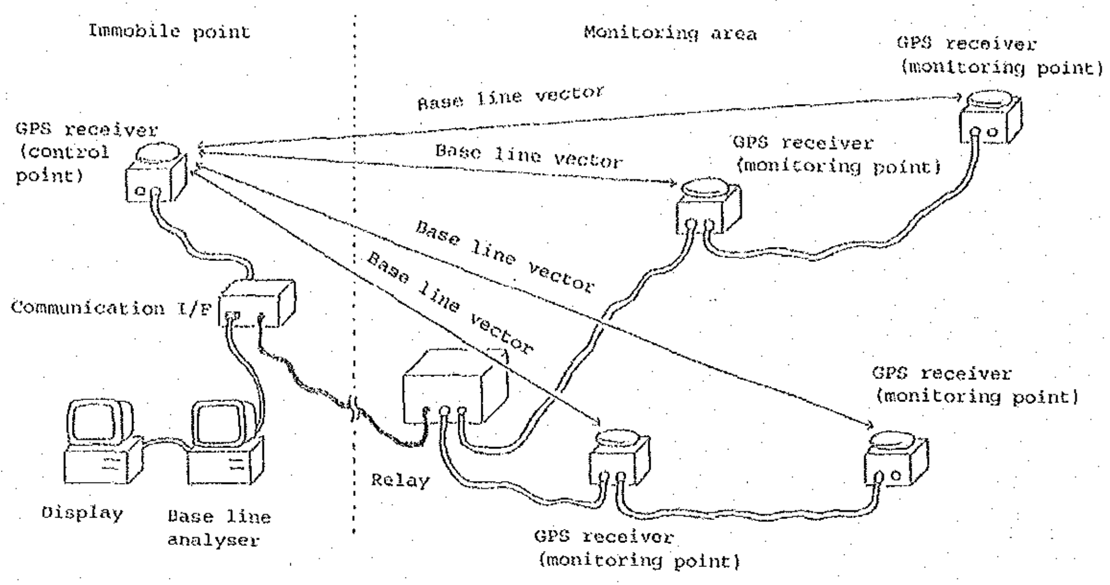


Figure 3.1.11 Typical GPS Displacement Monitoring System (Ref. *12) p.47, Fig.2.4.10)

3.1.5 Strain Gauge

Strain Gauge is commonly applied to the monitoring of structural strain in building construction or civil engineering work. Strain Gauge can be applied to the monitoring of strain on rock or measure structures such as retaining wall.

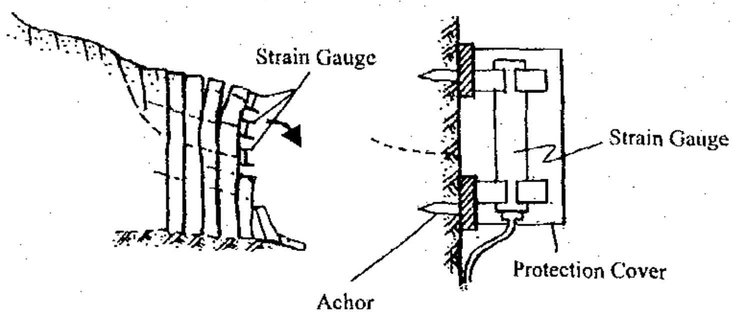


Figure 3.1.12 Example of Strain Gauge Installation on Rock Cliff

3.1.6 Crack Gauge

Crack Gauge can monitor the opening speed of crack on rock or concrete structure. Various type of crack gauge are developed as shown in Figures 3.1.13 and 3.1.14. Figure 3.1.13 shows simple measurement of crack. Figure 3.1.14 shows automatic type.

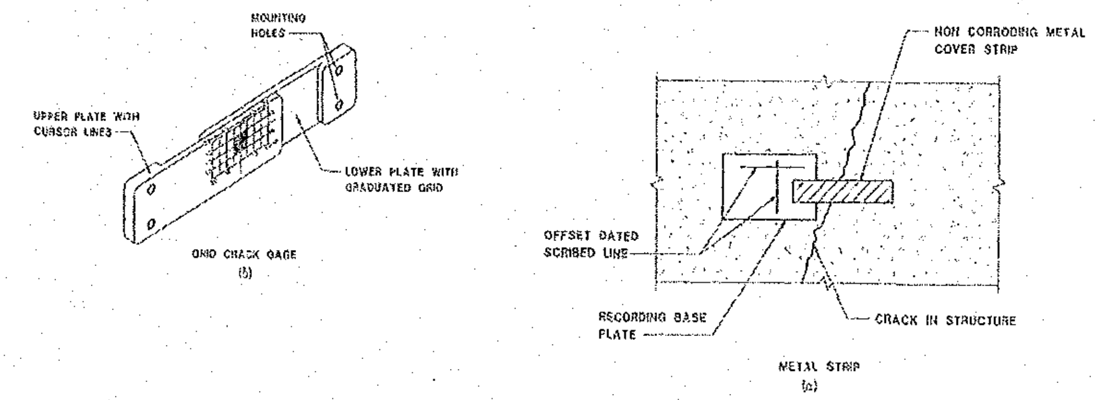


Figure 3.1.13 Manual Crack Gauge (a) Grid Crack Gauge, (b) Metal Strip

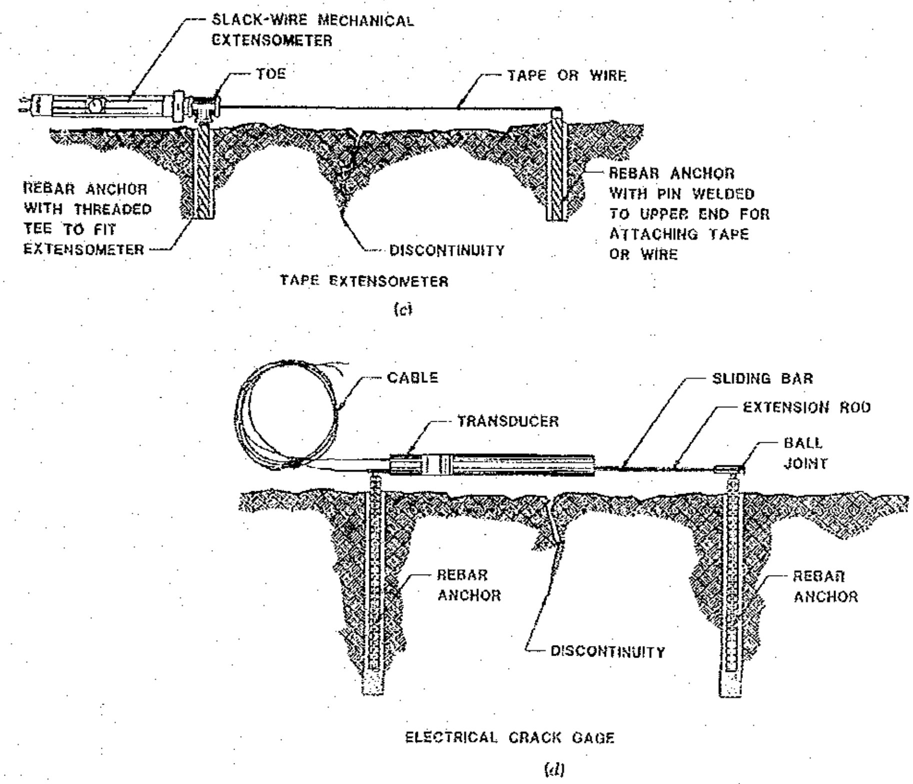


Figure 3.1.14 Automatic Crack Gauge
(a) Tape Extensometer, (d) Electric Crack Gage

3.1.7 Rock Fall Detector

Various types of rock fall detector were developed. Three types of detector are common in railway in Japan as shown in Figures 3.1.15 to 3.1.17.

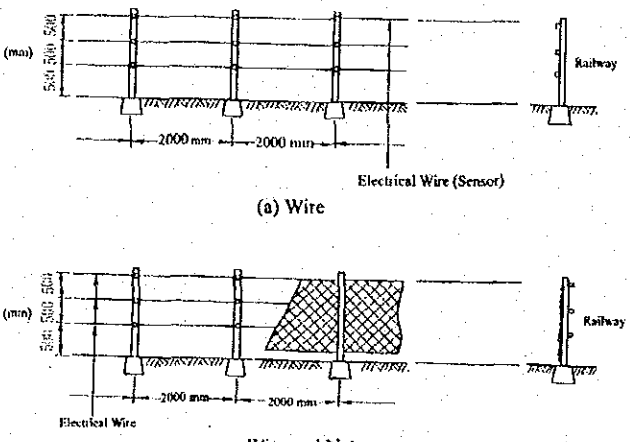


Figure 3.1.15 Example of Rock Fall Detector (Japan Railway)

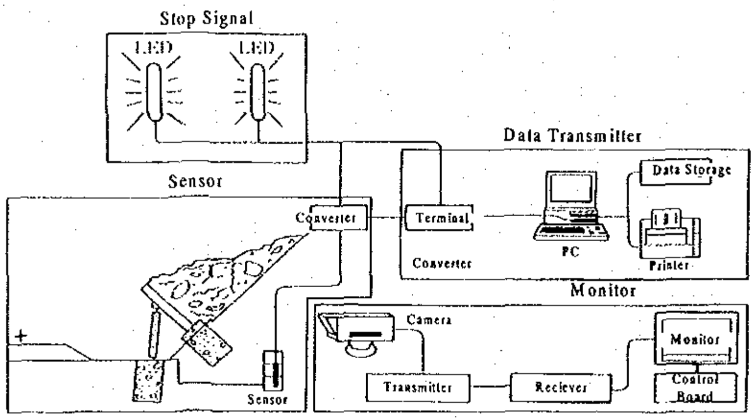


Figure 3.1.16 Example of Slope Collapse Detector (Japan Railway)

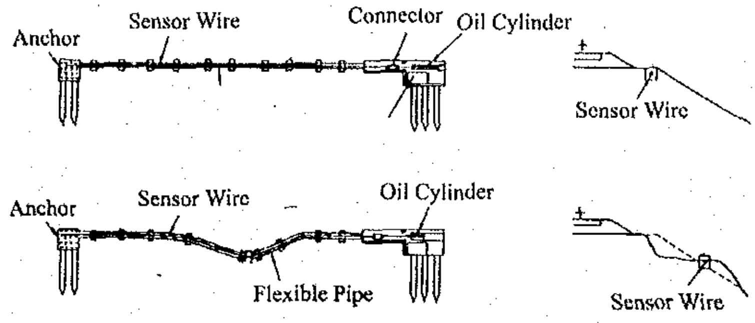


Figure 3.1.17 Example of Embankment Collapse Detector

3.2 Measurements of Subsurface Fluctuations

3.2.1 Inclinometer

Two types of borehole inclinometer are available; insertion and stationary types. This section describes the probe inclinometer (insertion type) as a standard monitoring instrument. The in-place inclinometer (stationary type) is dealt with in Section 3.2.4.

In the probe inclinometer, a dedicated guide pipe is inserted and fixed in a borehole and its inclination angle is measured continuously by inserting a probe with built-in sensor in the pipe. In this way, this type of inclinometer is used to determine the slide surface location and the displacement of slide soil mass.

As shown in Figure 3.2.2, the cumulative deflection diagram of guide pipe is prepared for the horizontal displacement per 50 cm of the probe length. Then, from the secular change after installation of the guide pipe, the slide surface location, landslide movement and movement velocity are estimated.

The probe inclinometer can keep measurement as long as the guide pipe remains normal.

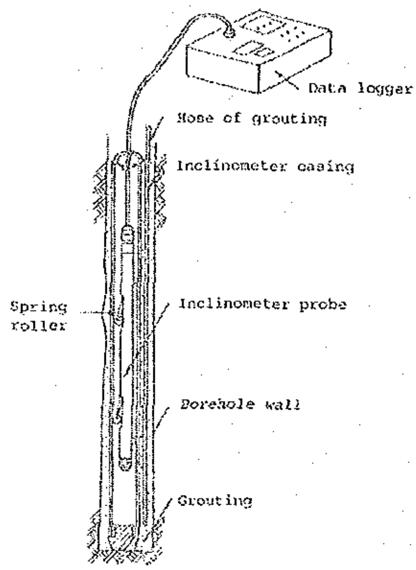
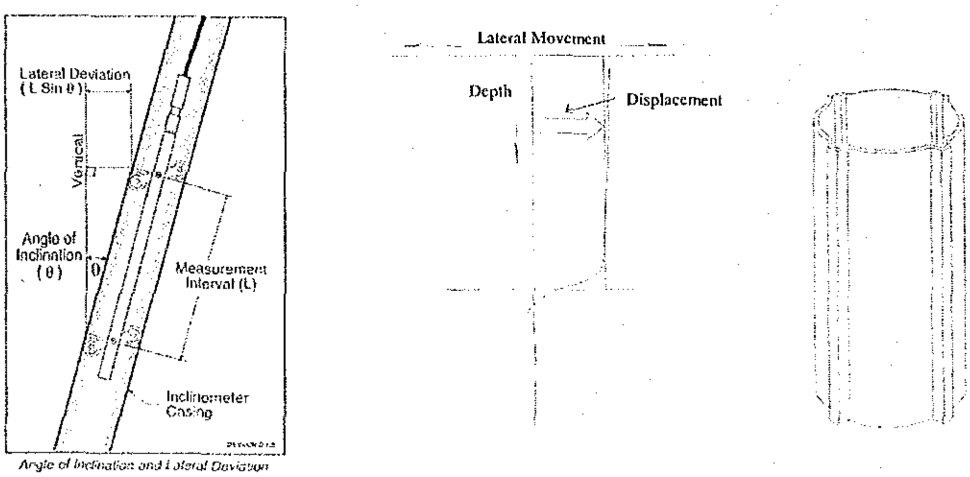


Figure 3.2.4 Graphical Measuring Diagram of the Probe Inclinometer (Ref. *8) p.123, Fig.2.31)



(a) (b) (c)

Figure 3.2.2 (a) Measurement Principle, (b) Deflection Diagram, and (c) Guide Pipe, of the Probe Inclinometer. (Ref. *14) p.154, Fig.2.1.5 (1)-(3))

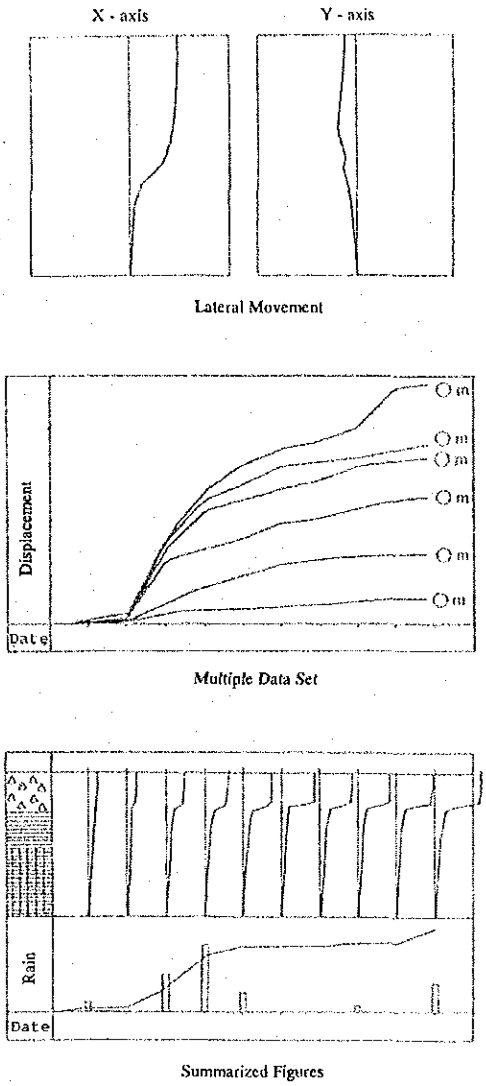


Figure 3.2.3 Typical Analytical Diagram of Measurement Result of the Probe Inclinometer (Ref. *14) p.161, Fig.2.1.5 (9))

(1) Installation method

i) The borehole should penetrate sufficiently to the bed rock below the slide surface.

ii) It is essential to drill the borehole vertically and straight with minimum bend. Setting the guide pipe straight can minimize the measurement error and measurement noise that occur when repeated setting in the same position with high accuracy is difficult.

iii) When the guide pipe is installed, the direction of measurement axis should agree with the movement direction of landslide. No twisting should be applied to the pipe in an attempt to adjust the guide pipe setting direction during grouting. During insertion of the guide pipe, do not force insertion while resisting against the buoyant force. Instead, before grouting, the lower end of guide pipe should be fixed to the bed rock. A plan should work out that allows the pipe to extend upward in the straight condition under the buoyant force of grout.

iv) Grouting of the gap between the borehole and guide pipe thoroughly using cement paste. The grout hose should be inserted, together with the guide pipe, to the lower end of borehole, and grouting should be made from the bottom side so that excavation slurry and slime are discharged to the outside. Insufficient grouting causes unstable guide pipe, resulting in measurement noise.

v) On the ground surface, the guide pipe head should be protected from artificial damage or damage by wild life with a protective tube or underground basin after placement of base concrete.

(2) Measurement, maintenance, and inspection

i) Measurement should be started at least in one week or ten days after grouting, that is, after lowering of grout.

ii) The probe length is more than 50 cm, so that progressive bending of hole may make passage of the probe impossible. While the landslide movement is considerable (exceeding 5 to 10 cm), a dummy probe is first lowered into the hole to prevent jamming.

iii) For measurement, the probe, cable, and logger are connected, with the probe lowered along the guide groove to the hole bottom. Then, the power supply is turned ON and the probe is left as it is for 20 to 30 minutes. This is necessary to prevent temperature drift of measured values from occurring due to temperature change of the probe during measurement because temperature difference exists between above and under the ground surface.

iv) Each of depth marks marked on the cable is set to the zero mark at the hole mouth each time measurement is made. At each mark, the measurement at the deepest point is made in the similar manner. When the current measurement value differs excessively from the previous one, checking should be made to see if there is any water in the connector or if shock has been applied to the probe.

v) The probe is lifted every 50 cm exactly, and measurement is made at each depth by setting the depth mark to the zero mark. When data is obtained in this manner up to the ground surface, the probe direction is inverted and the probe inserted to the hole bottom. When the reading of measurement instrument becomes stable, measurement is made.

vi) The same probe should be used for all measurements. Should the previous probe be changed because of failure, the measurement result should be reviewed carefully. Subsequently, the changed probe should be used continuously.

vii) The sensor in the probe is highly sensitive and susceptible to vibration and shock. During transport, the sensor must be housed in a protective case and handled as if it is made from glass.

viii) The probe and instrument should be checked and serviced two to four times a year to secure the desired accuracy.

ix) The cable connector should always be kept clean and dry. Deteriorated connector packing causes faulty insulation.

x) The cable should be handled with care to prevent bend or twist. Since the cable may be elongated more or less after a long-time use, the length should be verified once a year.

(3) Filing of data and judgment

i) From the observation data, the measurement record and calculation, displacement distribution map with X and Y axes for each date, secure displacement map, and contrast diagram should be prepared. The contrast map should include the date, daily rainfall, and groundwater level around the observation point. If necessary, the vector diagram indicating the displacement direction at specific depths should be prepared to determine the landslide movement.

ii) The slide surface position is determined, taking into account the deflection and displacement, from the displacement distribution map.

iii) The landslide activity time is determined from secular change of the deflection.

iv) The vector distribution map by deflection direction is checked to see if there is any abnormal twist of the pipe and there is any deviation in the deflection direction by depth.

v) The depth at which the deflection direction changes should not be easily identified as the slide surface. Judgment should be made after overall consideration on the relationship between the boring core, various site investigation results, rainfall, and groundwater level and the movement condition.

3.2.2 Pipe Strain Gauge

The pipe strain gauge determines deflection of the pipe fixed in the borehole under deformation of the ground by measuring a strain gauge adhered to the pipe.

The materials used as inexpensive and the construction is simple. This method is useful in detecting the slide surface of landslide if the gauge is thoroughly and carefully calibrated and installed with care.

Figure 3.2.5 shows the construction of the pipe strain gauge and Figure 3.2.6 shows the deflection and strain distribution of pipe because of landslide.

Installation should be made with care not to damage the waterproof portion of gauge and the lead wire. Measures such as double coating of lead wire to prevent wire breakage, etc. are essential when the gap between the pipe and borehole is to be filled by grouting or with sand. Filling with sand requires particular attention because inadequate filling may cause noise in data.

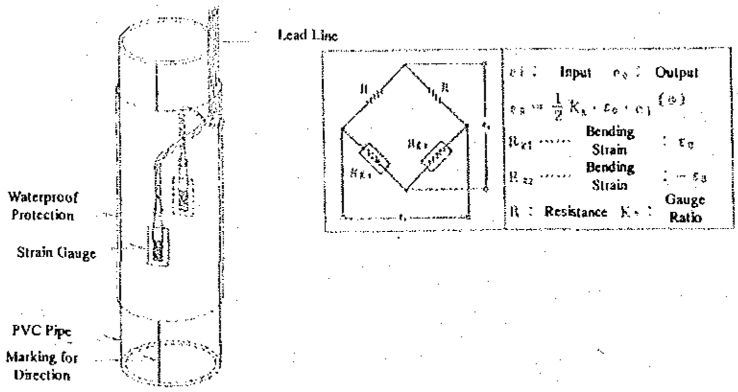


Figure 3.2.5 Construction of the Pipe Strain Gauge (Ref. *14) p.136, Fig.2.1.3 (1))

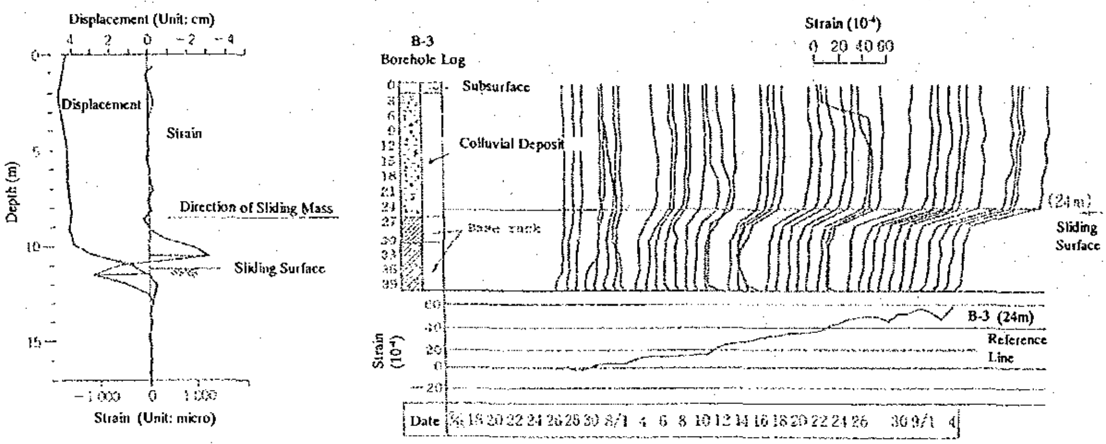


Figure 3.2.6 Pipe Deflection and Strain due to Landslide (Ref. *14) p.137, Fig.2.1.3 (2))

3.2.3 Multipoint Borehole Extensometer

The multipoint extensometer determines the behaviour of landslide soil mass through direct measurement of the wire extension. This wire is fixed at each depth below the ground surface and directed to the aboveground point. This instrument enables determination of the slide surface and the movement on the slide surface.

This instrument is suitable for landslide with large movement. The construction is simple and robust. However, installation of the instrument in the borehole is rather complicated, requiring carefulness and time.

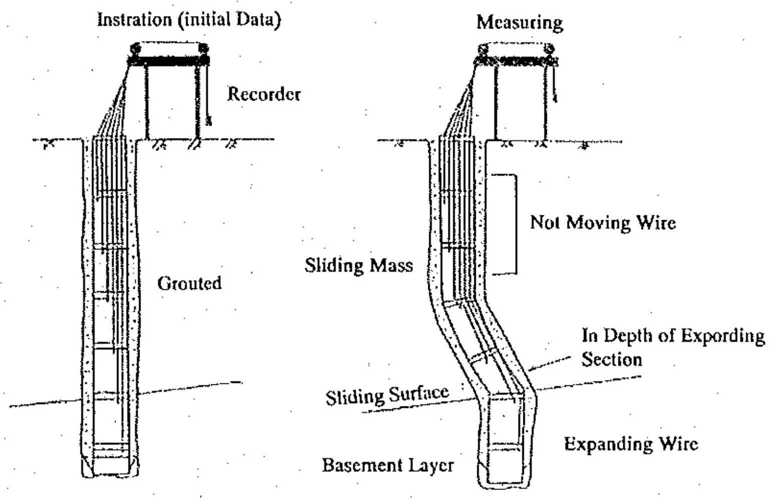


Figure 3.2.7 Concept of Borehole Extensometer

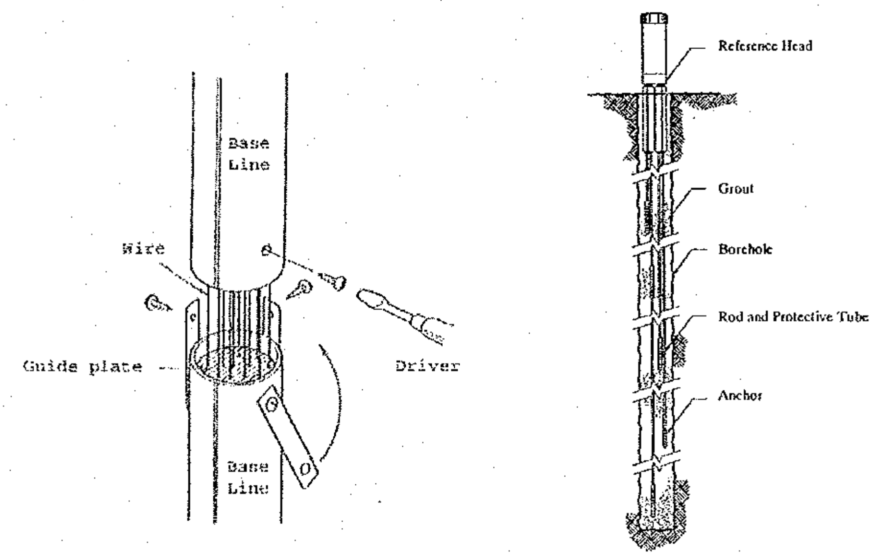


Figure 3.2.8 Detailed Connection Diagram of Multipoint Borehole Extensometer
(Ref. *14) p.170 - 172, Fig.2.1.7 (1), (3) *19) p.602, Fig.8.6)

3.2.4 In-Place Inclinometer

Conventionally, the in-place inclinometer has been used to observe the change condition around the slide surface when the location around the slide surface is roughly confirmed. Recently, a high-performance inexpensive inclinometer has been put into practical application. In certain cases, multiple inclinometers may be arranged in one location for confirmation of the slide surface.

When compared with the insertion type, the stationary type is advantageous in that the difficulty of repeated setting with high accuracy can be eliminated and that it can be combined with automatic/remote measurement and alarm.

Because the cable has to be passed through the guide pipe or PVC pipe, the number of sensors that can be installed per hole is maximum 12 to 16 for the guide pipe type and 24 to 28 for the PVC pipe fixed type. At least one of sensors to be installed should be placed in the bedrock.

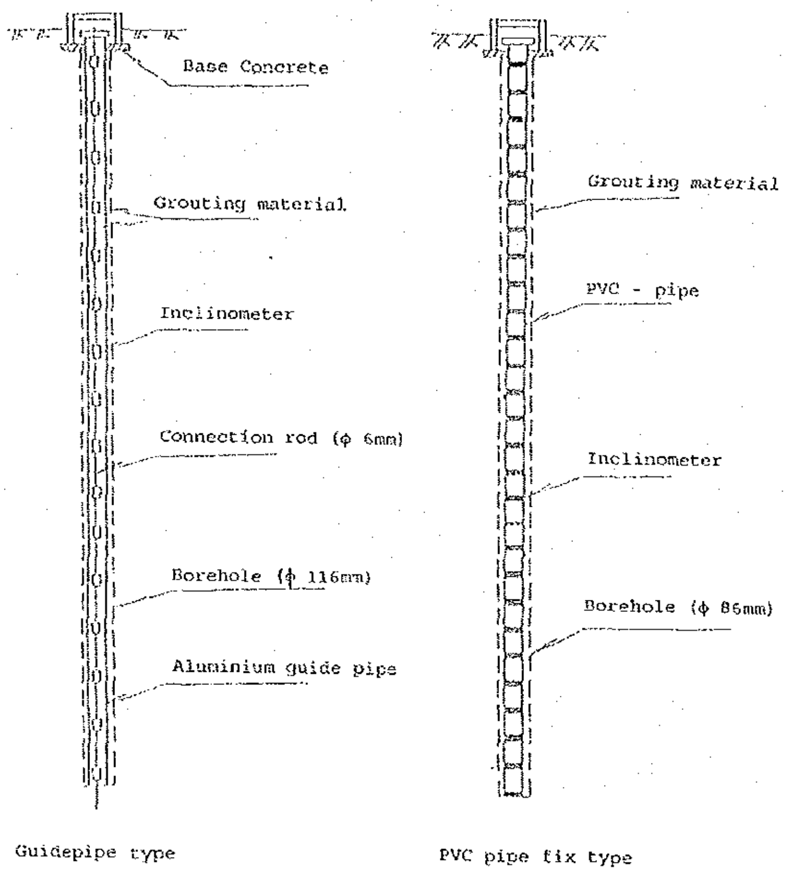


Figure 3.2.9 Typical Installation of the In-Place Inclinometer (Ref. *14) p.148, Fig.2.1.4 (1))

3.2.5 AE (Acoustic Emission) method

In the case of rock mass slope, strain up to a point of collapse is small and it is difficult for conventional displacement measurement to detect any precursory phenomena. The AE (Acoustic Emission) method is based on the fact that failure is already under way on an extremely small level even before an object develops visible fracture. This method is intended to use the AE wave released when the strain energy is released during extremely small failure for prediction of failure of the rock mass.

Since AE measurement amplifies considerably an extremely weak AE wave generated in the course of progress of failure, due attention should be paid to the types of sensor and measurement instruments and the installation methods.

Figure 3.2.10 shows a typical observation of the rock mass slope according to the AE method. However, there are not much examples of applying this method to monitoring of the stability of rock mass. To promote more positive application in the actual field, there are many subjects to overcome, such as accumulation of field measurement data, review for more rational evaluation methods, etc.

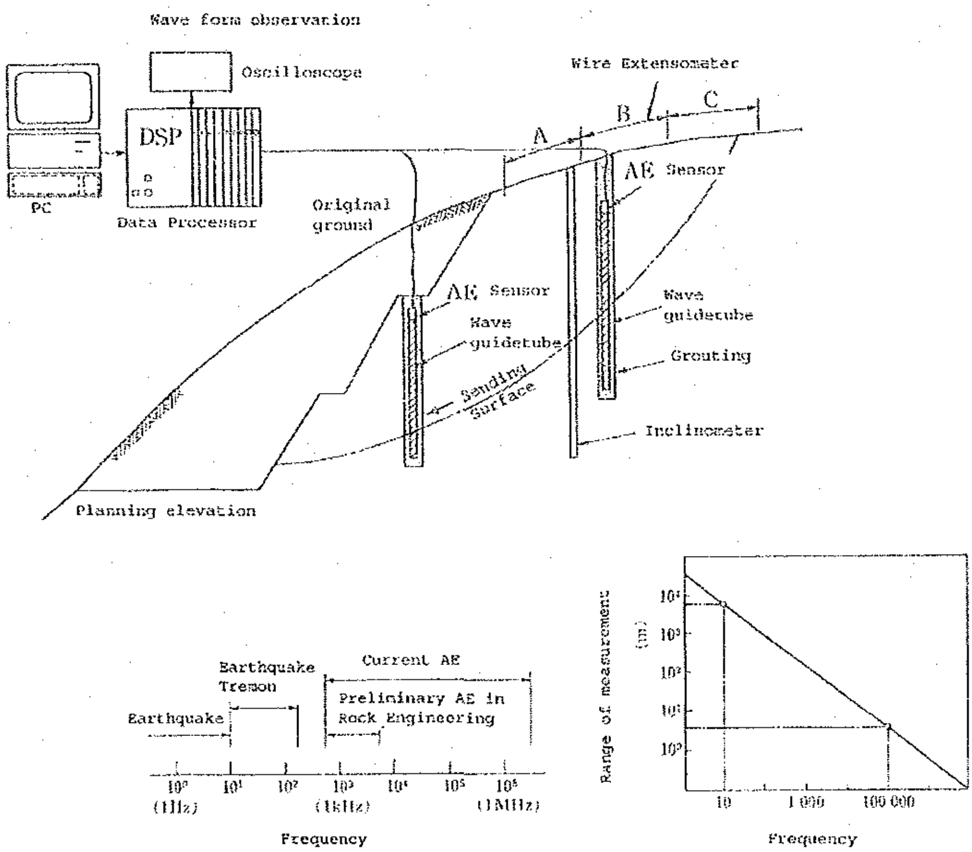


Figure 3.2.10 Outline of AE Measurement on the Slope (Ref. *13) p.266, Fig.9.2.5)

3.3 Measurements of Groundwater Fluctuations (Piezometer and Water Standpipe)

Groundwater in landslide is in the form of either unconfined groundwater continuing from the ground surface and confined groundwater intervened in impervious layer. Groundwater data necessary for analysis is the pore water pressure on the slide surface.

The geological and hydraulic structure is assumed from the site investigation result, narrowing down to the groundwater zone related to landslide. Then, the water standpipe or piezometer is provided at the position and depth appropriate for confirmation of the groundwater potential distribution in the expected slide surface.

The pore water pressure in the slide surface is the sum of the uplift by groundwater and the excess pore water pressure. In the case of the piezometer, the installation depth is difficult to determine while the slide surface is not yet identified, installation itself is difficult when the slide surface is deeper, and measurement is impossible for certain landslide movement. Because of these reasons, the hydrostatic pressure measured with the water standpipe may often be used instead of the power water pressure.

The water standpipe and piezometer are available in various types depending on the measurement principle and the sensor and recording method. The instrument market is progressive, with development competition in terms of the functionality, long-term reliability, and costs. Therefore, instrument selection should be made according to the objective of investigation and applicability in the field. For example, simple measurement with auger boring is enough for groundwater observation hole near the ground surface. It is essential to have a sense to develop a plan appropriate to the objective.

For the model having a water pressure sensor, it is necessary to select the sensor with appropriate measurement range and sensitivity while considering the expected change range of water level.

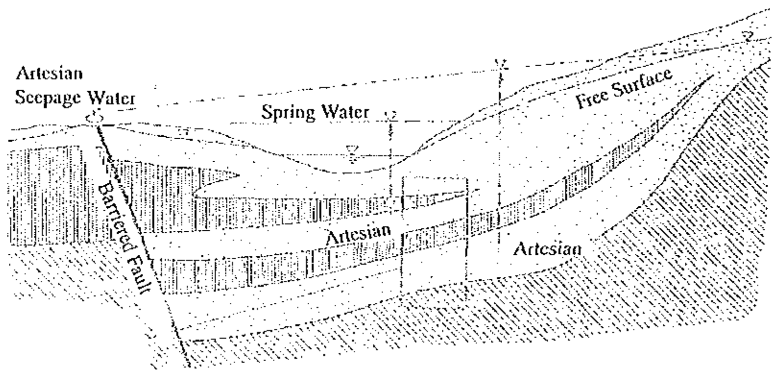
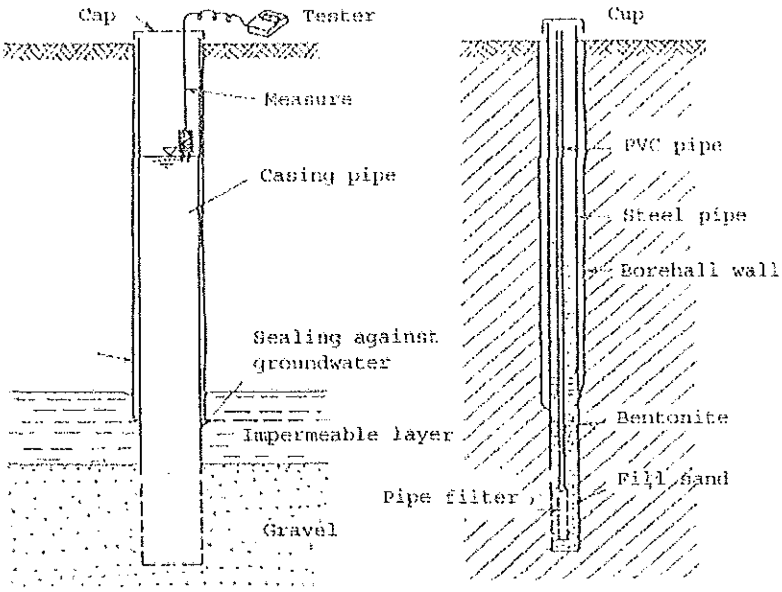
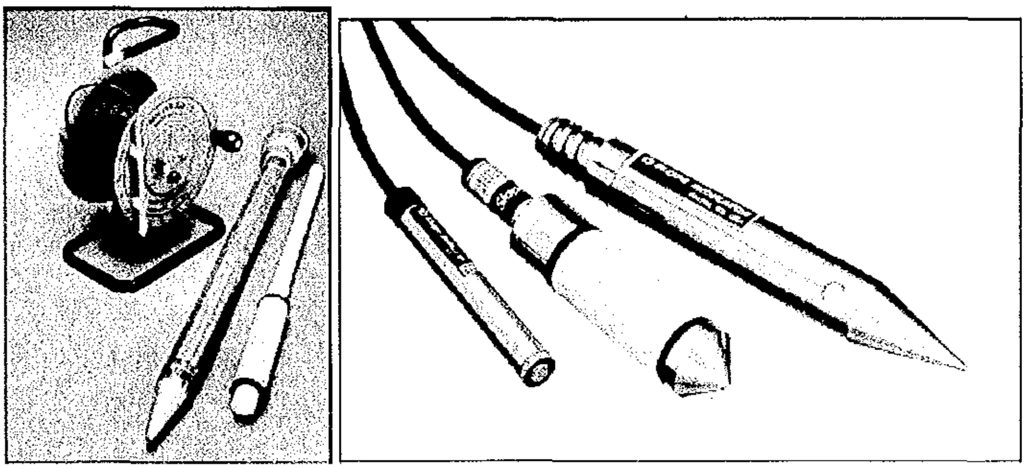


Figure 3.3.1 Typical Groundwater Patterns(Ref. *14) p.190, Fig.2.3.1)



(a)Casing pipe method (b)Improved Casagrande method

Figure 3.3.2 Typical Piezometer (Ref. *14) p.193, Fig.2.3.1 (3)-(4))



(a) Water Level Indicator and Filter Tips. (b)Typical Piezometer Sensors

Figure 3.3.3 Typical Instruments of Groundwater Investigation (Ref. *14) p.198, Fig.2.3.2 (1))

(1) Installation method

i) The instrument is installed in a vertical borehole drilled to the slide surface. The depth to the groundwater zone concerned is identified from observation of boring core and other samples and through electric logging.

ii) When the instrument is installed, it is essential to isolate completely groundwater to be measured from other groundwater. The installation method varies more or less depending on whether a standpipe type or a hydraulic type is used. What is common to these types is to perform sealing positively so that the groundwater pressure of the ground concerned can be measured correctly.

iii) The stand pipe type consists of screening of only the hole protection pipe portion facing the groundwater zone portion. No hole is drilled in other portion. The gap between the borehole wall and hole protection pipe is filled with sand for the screening section. At top and bottom ends of the section, sealing is made with bentonite balls or pellet. The section without holes is grouted.

iv) In the case of the hydraulic piezometer, de-aired water is well infiltrated into the porous filter of sensor to purge air from the filter. While the instrument is inserted in the borehole, it must be kept fully immersed in water.

v) After installation, checking should be made to confirm correct installation.

vi) The standpipe, cable, and recording unit on the ground surface should be protected from artificial damage or damage by wild life with a protective tube or underground basin after placement of base concrete.

Installing Piezometer in Borehole

Pneumatic, VWP, and VS piezometers

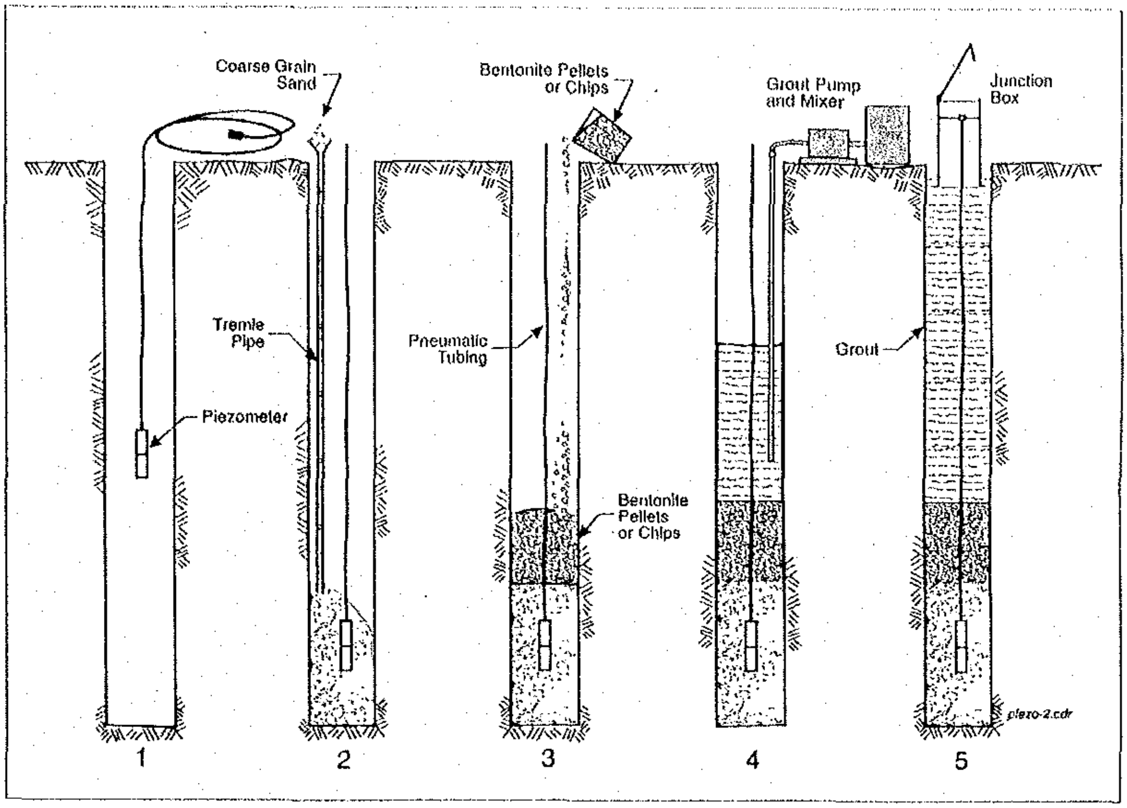


Figure 3.3.4 Piezometer Installation Procedures

(2) Measurement, maintenance, and inspection

i) Measurement and maintenance is made according to the method appropriate to each instrument. If the instrument has an electric circuitry, maintenance and inspection to confirm waterproof is necessary. Checking should be made for damage or clogging of the pipe and breakage of the signal cable. Zero adjustment should also be made.

ii) Judgment on whether the measurement result indicates the abnormal value or failure of sensor, such as cutting of the connection pipe due to landslide, malfunction due to electric trouble, mixing of air bubbles at installation, should be made with due consideration of the water level gauge reading and rainfall condition in the neighbourhood.

(3) Filing of data and judgment

i) Observation data is filed in the form of the time-groundwater level curve or time-pore water pressure curve.

ii) The water level at start and stop of landslide, maximum and minimum levels, and constant water level are filed and compared with the rainfall and ground change, reviewing the relationship between the water level and landslide.

3.4 Observation of Rainfall

In order for disaster preventive control of the road slope, the standard approach for observation of rainfall with the rainfall gauge, etc. should be developed. As a rule, self-registering observation is made.

3.4.1 Arrangement and provision of observatories

(1) Arrangement

The road concerned is divided into sections indicating approximately even rainfall condition, and one rainfall observatory is provided in each section. When such division is difficult, the district including the road concerned is divided into sections, each having the approximate area of 50 km^2, and one observatory is provided in each of these sections.

(2) Selection of the location

The location of provision to be selected on the map should be as follows:

i) Location where the wind direction and velocity do not show any singular values because of narrow topography
ii) Location without excessive exposure to or shield from wind, and other singular rainfall condition

(3) Determination of the location

The location should as a rule comply with the following conditions:

i) Open land with an approximately 10 m wide or more square, with limited localized change of air flow
ii) No possibility of inundation
iii) Convenient for observation and patrol inspection
iv) No attack from wild lives, etc.

3.4.2 Equipment

(1) Instrument

Instruments for observation of rainfall should comply with the authorization rules.

i) Inlet
The standard diameter of inlet of rainfall gauge is 20 cm, and the inlet should be provided horizontally.

ii) Sign
The sign describing the location ID, name of installer, year/month/day of installation, latitude, longitude, altitude, and name of observation personnel

should be provided near the installed instrument, with the fence provided around the location.

iii) Register

When an observatory is provided or observation is contracted to the existing observatory, the personnel to perform rainfall survey should prepare the register of rainfall observatories and attached location map. The register should describe the location of observatories and data of facility construction.

3.4.3 Observation

(1) Observation personnel

For observation, the agency to perform survey of rainfall should select the eligible personnel complying with the following conditions and contract the survey to those personnel:

i) Personnel who can be engaged in observation at given times continuously over a long period.
ii) Personnel who have the knowledge necessary for handling of self-registering instrument when the observatory is equipped with self-registering instrument

(2) Directions for observation and observation personnel

The agency in charge of rainfall observation should develop directions for observation and observation personnel and deliver them to those performing observation.

Directives concerning observation should contain the following matters:

i) Objective and meaning of observation
ii) How to use observation facilities
iii) How to handle observation instruments
iv) Cautions for implementation of observation
v) Standard for ad-hoc observation
vi) Other necessary matters
vii) Directives for observation personnel should contain the following matters:
viii) How to handle observation record and to report the observation results
ix) Procedure for newly-appointment, resignation, or delegation of observation personnel
x) Storage and turn-over of properties
xi) Other necessary matters

(3) Patrol check

In order to confirm that observation is implemented without fail, patrol is made among observatories in the specified timing, checking the operation condition of instruments. Periodical inspection at least once a month and overall inspection at least once a year should be made on observation instruments and facilities.

(4) Observation with self-registering rainfall gauge

During observation with the self-registering rainfall gauge, either the self-registering media is replaced or record reading is made.

3.4.4 Filing of data

(1) Filing of data

Rainfall data is filed according to the specified form.

(2) Job assignment

Job assignment should be established beforehand among persons concerned to ensure smooth data filing operation.

(3) Verification

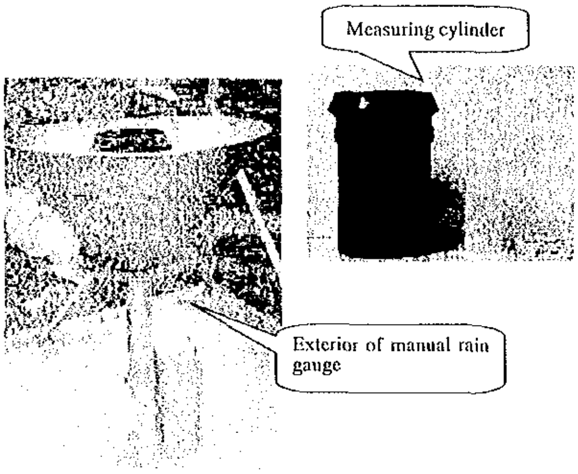
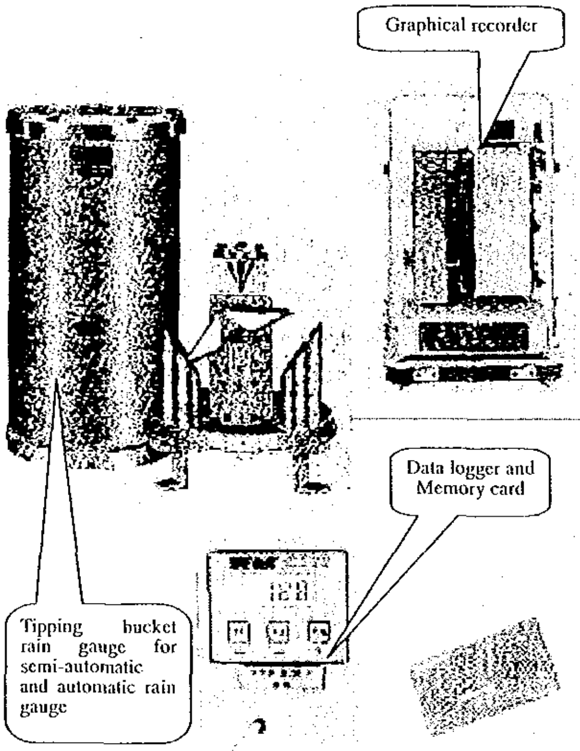
Prior to publication of data, thorough verification should be made in each stage of filing, ensuring appropriateness of numerical values to be published. Any ambiguities should be checked if found after verification. Any detected error should be corrected according to the specified procedure.

(4) Storage

Self-registered record should be stored without fail.

Table 3.4.1 shows rain gauge instruments commonly used in Malaysia.

Table 3.4.1 Installed Types of Rain Gauge Instruments

No.	Type		Remarks
1	Manual rain gauge		Rainfall are observed and recorded manually.
2	Semi-automatic rain gauge		Rainfall are Observed automatically and recorded using graphical recorder.
3	Automatic rain gauge		Rainfall are observed automatically and recorded using data acquisition unit (data logger etc.).

3.5 Other New Method

3.5.1 Three-dimensional shear displacement meter

This is designed to observe three-dimensional change of the slope. Meters are arranged consecutively in the slope to establish the change range and to determine the three-dimensional behaviour.

As shown in Figure 3.5.1, the hinged end with an operational transformer is provided to one end of steel pipe for observation of horizontal and vertical displacement of pipe. The distance between instruments is measured with an extensometer provided in the lower portion of the main body. Synthesizing these data and connection with neighbouring instruments allow determination of the change condition of the line provided.

This method is suitable for fluctuating slope change where the movement range is not definite, enabling automatic observation.

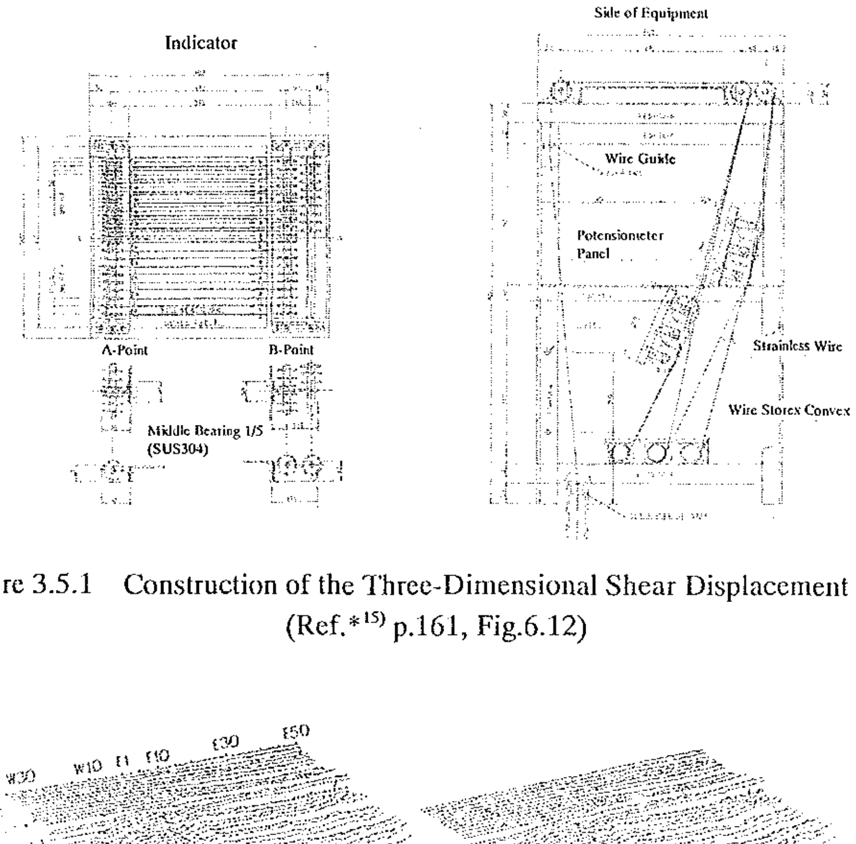


Figure 3.5.1 Construction of the Three-Dimensional Shear Displacement Meter (Ref.*[15] p.161, Fig.6.12)

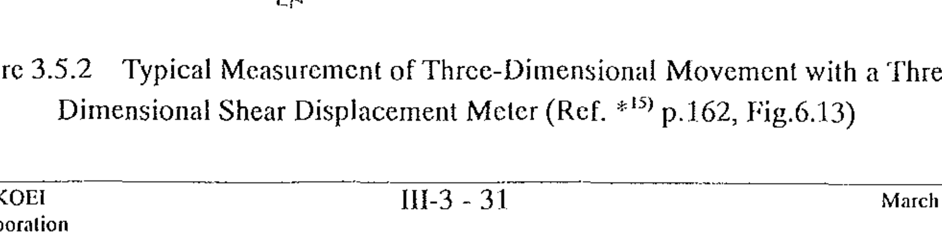


Figure 3.5.2 Typical Measurement of Three-Dimensional Movement with a Three-Dimensional Shear Displacement Meter (Ref. *[15] p.162, Fig.6.13)

3.5.2 Fibre-optic sensor

In the case of fibre-optic sensor, the sensor itself functions also as a transmission unit, ensuring features appropriate to observation of the road slope, such easy measurement over a wide area, real-time measurement, superior durability, and high resistance against lightening. Initially, the fibre-optic as a sensor utilizes the nature in which the transmission loss occurs when it is bent, mainly detecting deformation of the slope and identification of the location. Recently, studies are active to apply strain measurement technology with fibre-optic using Brillouin scattered light or Bragg grid to monitoring.

The use as a sensor covering the wire area is mainly for continuous monitoring of slope along the road or area dynamic observation of large landslide. The sensor may also be used for localized monitoring such as measurement in boreholes and countermeasure control. It is expected that the fibre-optic superior in durability enable longer time measurement than existing sensors.

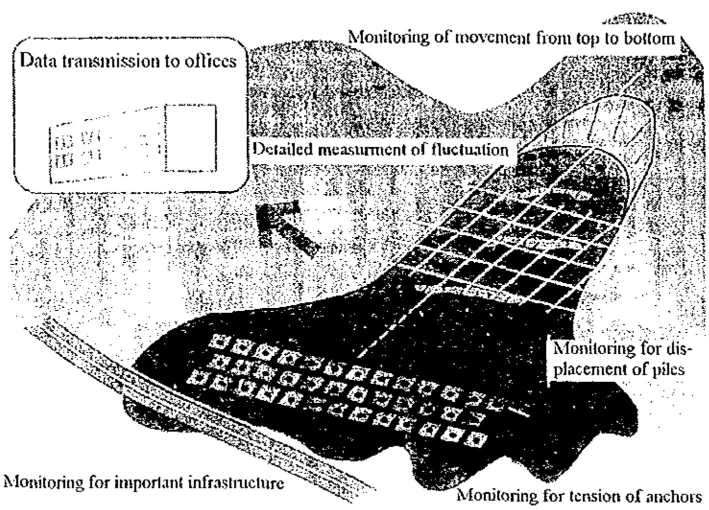


Figure 3.5.3 Image of Measurement of Landslide with Fibre-Optic (Ref. *17) p.24, Fig.1)

III-2 DETAILED INVESTIGATION FOR COUNTERMEASURE DESIGN

CHAPTER 4 INTRODUCTION OF SITE INVESTIGATION

This guideline describes the standard method for investigation and monitoring through instrumentation for each of six classified failure patterns. Depending on the scale of slope failure or the positional relationship between the failure slope and road concerned, it may be recommended to study the feasibility of more appropriate investigation and instrumentation method. Refer to Chapter 7 that introduces special or new investigation methods and instrumentations other than standard ones.

Reasonable estimation of the disaster location, scale, and pattern is essential to ensure the appropriate countermeasure. Any countermeasure implemented based on impractical estimation may suffer ineffectiveness or over-design, resulting in wasting of money and time. There are various soil investigation methods that also vary in applicability, simpleness, and costs. These methods are roughly classified into the following five types:

i) Site reconnaissance

ii) Geophysical survey from the surface

iii) Boring investigation (including core sampling, borehole test, sounding)

iv) Borehole logging

v) In-situ test (including sampling in a test pit, adit, and shaft)

Survey as referred to in this guideline includes additionally

vi) understanding of topography through survey and

vii) monitoring through installed instruments.

This guideline covers two stages of slope inspection or investigations to be made during a preliminary stage to design and implementation of the countermeasure as described below,

(1) Preliminary Study (mainly i) and vi)) and

(2) Detailed Study (mainly ii), iii), and vii)) as standard methods.

Figure 4.1 shows general flow of site investigation and designing of countermeasure. In Preliminary Survey, the location, scale and pattern of the disaster shall be estimate. The necessary site investigation, instrumentation and monitoring shall also be reviewed in Preliminary Stage. Using new information thus determined, the initial estimation is confirmed and corrected, followed by Detailed Stage if necessary. In Detailed Stage, subsurface investigation such as boring, seismic survey could be adopted. Such repetition is the basic process.

In the course of a series of procedure as above described, selection of the investigation method and establishment of the investigation plan are made, taking into account generally the objectives, scale of failure, geological conditions, surface and topographic conditions, access to the site, overall countermeasure policy, restriction in terms of budget and time, etc. Engineers concerned are expected to draw flexible and appropriate judgments concerning the urgency and safety, since conditions of actual sites vary widely,

Subsequent chapters describe the standard investigation method (procedure and investigation items) for each type of disasters while the method that is currently specific is described in Chapter 7. Details of Instrumentation and monitoring are described in III-1.

Table 4.1 Outline of Site Investigation

Type of Disasters	Preliminary Study	Detailed Study
Collapse (CL)	Mainly Preliminary Study only	To confirm depth of highly weathered zone or lose layer covers slope
Rock Fall (RF)	Mainly Preliminary Study only	If necessary, to confirm number and size of loose rocks.
Rock Mass Failure (RM)	Mainly Preliminary Study only	If necessary, to confirm width and opening speed of crack
Landslide (LS)	Preliminary Study is made to estimate the scale and mechanism of landslide, followed by establishment of the necessary investigation and monitoring plan.	To confirm depth, volume, speed of landslide for designing of the countermeasure
Debris Flow (DF)	Mainly Preliminary Study only. Check if there is any drawing around the road concerned.	If necessary, to confirm thickness of sediments and gradient along stream.
Embankment (EB)	Mainly Preliminary Study only. Check if there is any data and record during construction.	If the embankment is critical stage, detailed study is made for designing of the countermeasure.

Table 4.2 Outline of Preliminary Study and Detailed Study

Item	Item	Description	Application
Preliminary Study	Interpretation of topography	Interpretation of wide area around the slope concerned. Large-scale topographic map and stereoscopic aerial photos	Implemented always
	Collection of existing data	Past disaster history, boring log, geological map, groundwater	
	Site reconnaissance	In-depth survey of the slope concerned and its surrounding area Range from the ridge to channel in certain cases	
	Simplified measurement	Simplified measurement with marking and batten plate	
	Survey	Made when no existing survey drawings exist or are available	
Detailed Study	Geophysical survey	Seismic refraction survey, resistivity imaging method, etc. Applicability and profile line length are reviewed with reference to the transverse direction.	Implemented if judged necessary as a result of detailed survey
	Boring investigation	Basically, all-core boring is made, including sampling. Survey to be made to a point below the estimated slide surface, collapse surface, and bed rock.	
	Sounding	Dynamic probing, Swedish sounding, etc.	
	Borehole logging	Borehole television, electrical method, PS logging, etc. depending on geological condition	
	In-situ test	Standard penetration and borehole horizontal loading tests in boreholes depending on geological condition, including sampling in test pit, adit, and shaft	
	Laboratory test	Rock and soil tests to be made as required	
	Instrumentation and Monitoring	Measurement of ground surface slide movement (ground surface extensometer), measurement of borehole movement (probe-inclinometer), groundwater survey (piezometer, Casagrande type), precipitation survey (rain gauge), periodical ground Site reconnaissance	

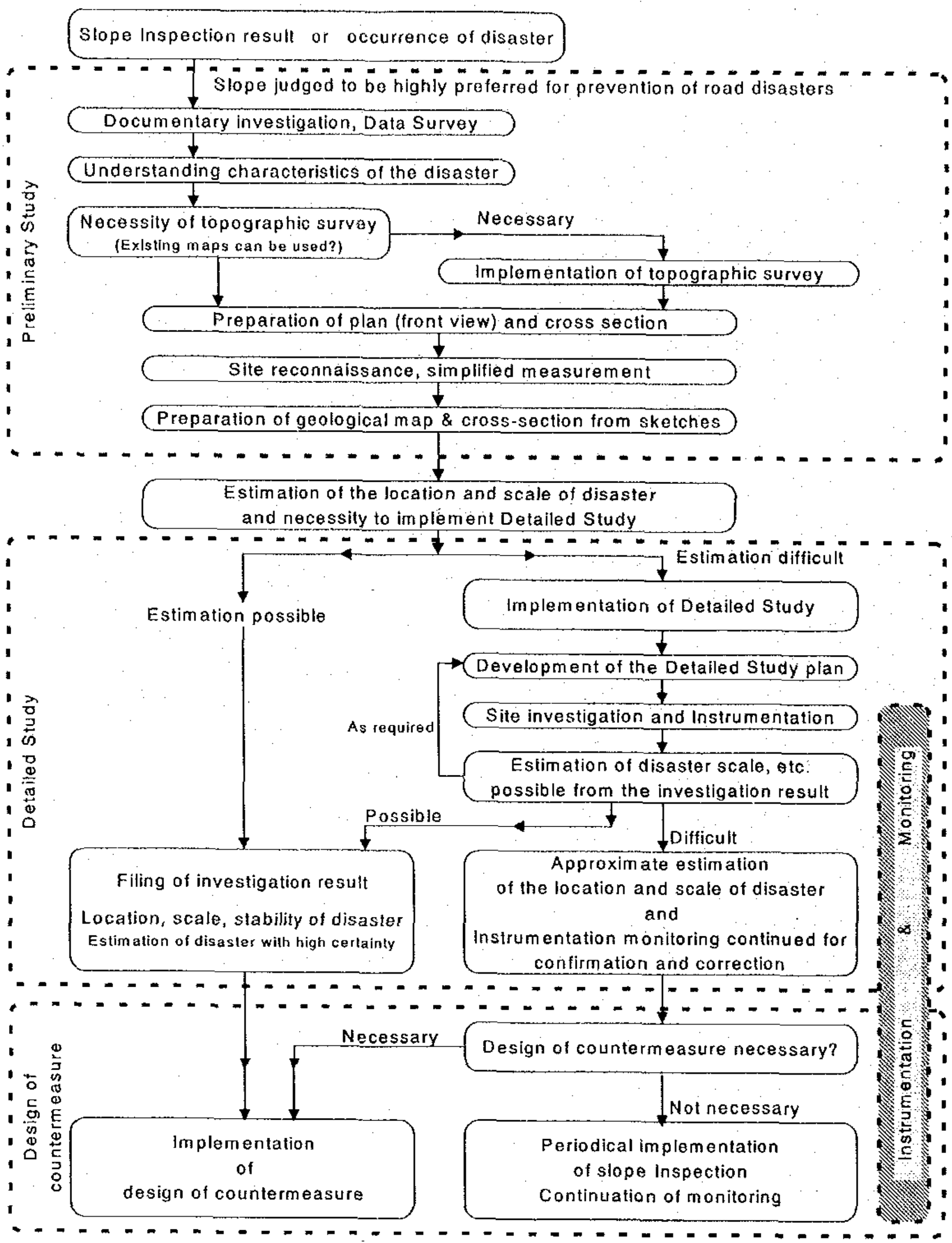
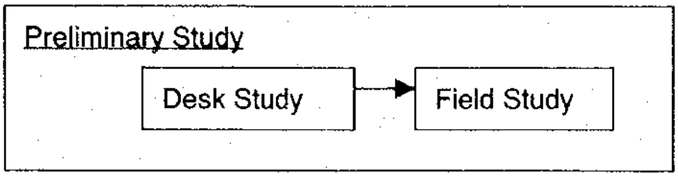


Figure 4.1 Flow of Investigation for Design of Countermeasure
(Five types excluding debris flow)

CHAPTER 5 PRELIMINARY STUDY

The information such as topography, geology, slope condition which is collected by Slope Inspection Work and may be in SIMS (Slope Information Management System) should be applied to the planning of the site investigation.

Prior to the detailed study, mainly preliminary desk study and field study are required during the preliminary study.



This investigation should produce the following information:

(1) History of disasters. Understanding of prime factors and inducements such as volume of disaster, scale and route of rock fall.

(2) Understanding of the present state. Estimated location (range) and scale (collapse depth, volume of loose rock mass), pattern, stability, location of the existing countermeasure, presence of structures, relationship between the road and slope, etc..

(3) Acquisition of ground characteristic values (ground constant) necessary for countermeasure design.

(4) Effectiveness of existing countermeasure in case of collapse and its effects on the road.

(5) Extraction of essential monitoring, simplified measurement, and instrument locations.

As far as the preliminary study has been done well, the detailed study could be omitted for many case except landslide. Therefore the preliminary study is important to reduce the study cost.

5.1 Desk Study

First of all after selection of the slopes by SIMS, the basic data of the slope should be collected and studied.

The data which collected in the slope inspection and stored in SIMS must be studied in detail. Especially the sketch, site photos and Form D should be useful to understand the slope condition. Aerial photos should be useful for study landslide and debris flow because it is difficult to see the whole view of landslide and debris flow at the site.

The large scale of the topographic map and cross section are necessary for the field study to decide the location of the items of the detailed study. In the desk study, the area and scale of survey shall be decided. The scale of map and cross section shall be 1:100 to 1:500.

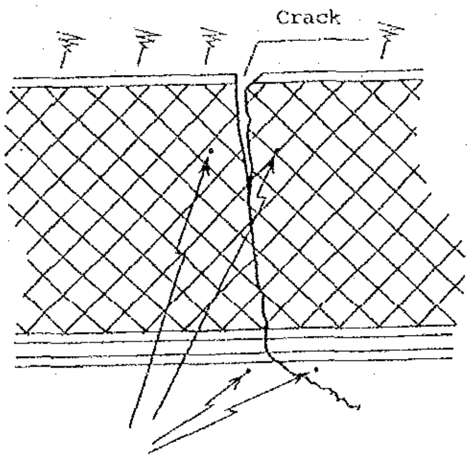
5.2 Field Study

Field Study shall be done in order to confirm the slope condition and to consider the detailed site investigation.

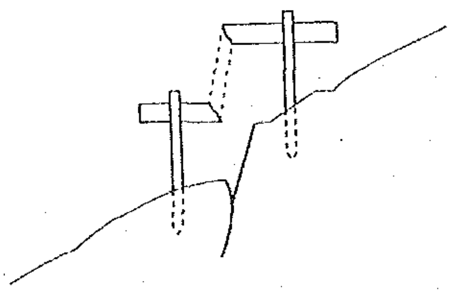
Site reconnaissance consists fundamentally of visual and careful confirmation of any deformation of the ground surface in addition to geological, topographical, vegetative, and hydraulic condition by engineering geologists or geotechnical engineers with the information such as sketch and photos which printed out from SIMS.

Stereoscopic vision of photos taken from the opposite bank and measurement survey using simplified instruments (measure, pole, hand level, altimeter, laser range and angle measuring instrument) may also be useful.

When there is any deformation that may indicate possible collapse, simplified measurements are made. They include the measurement of a distance between marked pins and nails provided on both sides of fracture and step, observation of mortar provided to repair fracture for any deformation, etc as shown on Figure 5.2.1.



Crack measurement example with nail and pins



Opening fracture development measurement example with finishing stake

Figure 5.2.1 Example of Simplified Measurement (Ref. *6) p.86 Fig.5.3.2)

Following items shall be investigated, estimated and examined at the site. Also the site reconnaissance results shall be entered in plan and cross-sectional views of the scale of about 1/100～1/500.

1) The geology and its structure of the slope. Observation is made while paying attention to the hardness of geology, separation surface, weathering, and looseness of rock mass. With attention paid to discontinuity of joint, etc., and its type, direction, spacing, continuity, and nature, determination is made on whether the ground is excavated or dip slope.

2) Microtopography on the slope. Slope height, slope length, gradient, position of the knick line, small steps, presence of open cracks or faulting, etc.

3) Presence of seepage location, water-holding condition of surface soil, vegetation, etc and drainage facilities.

4) Range and depth of unstable matter through the site reconnaissance by surface deformation with fracture and elevation, faulting and cave-in, distribution of grooved topography, etc.

5) Mechanism of the disaster.

6) Existing countermeasure condition. Fracture and squeezing, peeling and deterioration of concrete, cut and corrosion of net, rope, and wire, loosened anchor.

7) Positional relationship between the disaster and road. The pattern is estimated on the basis of overall evaluation on the location, scale, pattern, and failure route of the phenomena possibly affecting the road as well as effectiveness of existing countermeasures.

8) Any other anomaly or deformation surrounding area.

5.3 Determination of Detailed Study

Based on the site reconnaissance, plan of the detailed study shall be determined.

Boring investigation is effective for clarification of the geology and geological structure. Boreholes can also be used as survey holes for observation of groundwater and as dynamic observation hole to estimate the collapse depth. On the other hand, geophysical survey proves effective for investigation of the degree of weathering and looseness of rock mass and, when used together with boring investigation, enables understanding of the sectional structure of unstable slope. In any case, transfer or temporary set up of the machinery in the site of steep slope with possibility to collapse is mostly not easy. Therefore, the Phase 2 Study plan must be developed taking into account the applicability of investigation methods to the site concerned and investigation costs.

As described above, the necessity to implement Detailed Study should be determined after thorough review of above factors.