８－９　斜面モニタリングのための講習会

８－９．斜面モニタリングのために講習会

８－９－１　講習会参加者名簿

所属		名前	役職
1	DOR	Mr. Deepak K. C	Senior Divisional Engineer
2		Mr. Bijendra Bade Shrestha	Senior Divisional Engineer
3		Mr. Naresh Shakya	Senior Divisional Engineer
4		Dr. Bishwo Ranjan Shahi	Senior Divisional Engineer
5		Mr.Anata Prasad Paudel	Engineer
6		Mr. Shiva Prasad Nepal	Engineer
7		Mr. Narayan Prasad Nihure	Engineer
8		Mr. Chandra Kumar Subedi	Engineer
9		Mr. Badri Prasad Shama	Engineer
10		Mr. Rajesh Kumar Das	Engineer
11		Mr. Madhusudan Acharya	Engineer
12		Mr. Madan Kumar Shrestha	Engineer
13		Mr. Shyam Kharel	Engineer
14		Mr. Ghanashyam Gautam	Engineer
15		Mr. Michinori. Hanko	JICA Adviser to DOR
16	DOR	Mr. B. S. Rana	Project Manager
17	Sindhuli Road	Mr. S. R. Adhikari	Senior Engineer
18	Project	Mr. Govinda Wagle	Engineer
19	MOPPW	Mr. Narayan Prasad Bhandan	Engineer
20	DWIDP	Mr. Kato	Team Leader
21		Mr. Roshan Shakya	Japanese Interpreter
22		Dr. Ramesh Man Tuladhar	Hydro- geologist
23		Mr. Hemanta K. Jha	Senior Divisional Engineer
24		Mr. Ajit K. Chaudhary	Project Manager
25		Mr. Shamukesh C. Amatya	Hydro- geologist
26		Mr. Saroj Pandit	Project Manager
27		Mr. Adadhesh C. Jha	Senior Divisional Engineer
28		Mr. Sanjaya Pradhan	Engineer
29	EOJ	Mr. Makoto Yoashino	First Secretary
30		Mr. Kailash Pradhan	Senior Program Manager
31	JICA Nepal Office	Mr. Yusuke Tsumori	Assist. Reside. Representative
32	調査団	Mr. Fumio Nakamura	Nippon Koei

８－９－２　講習会プログラム

SEMINAR ON LANDSLIDE INVESTIGATION FOR SINDHULI ROAD
17-19 September, 2008

SEMINAR PROGRAMME

→ Day 1, 17 Sept 2008 (Hotel Everest)

Time	No.	Topic
09.30 – 09.45		Arrival of participants . Distribution of Seminar materials
09.45- 10.15		Introduction of Participant by themselves (self introduction)
10.15 – 10.20		Welcome to participant *Mr. Y. Tsumori, ARR, JICA NEPAL*
10 20 – 10.25		Project Briefing and purpose of the Seminar *Mr. S.R. adhikari, Sindhuli Road*
10.25 – 10.30		Opening of Seminar and Message from the chief Guest . **Mr. Yoshino, First secretary, EOJ**
10.30 – 12.30	1	Landslide and their Investigation , *Mr. Nakumura/BD Study Team/Sec-3*
Lunch Break		
13.00 – 14.00	2	Landslide Investigation of Mulkot (Sindhuli Road Sec-III) *Mr. Nakumura/BD Study Team/Sec-3*
14.00 – 15.00	3	Landslide Investigation Equipment *Mr. Nakumura/BD Study Team/Sec-3 and Mr. Kameda*
Tea Break		
15.20 – 16.30	4	Landslide Investigation Equipment and Measurement Methods *Mr. Nakumura/BD Study Team/Sec-3 and Mr. Kameda*

→ **Day 2, 18 Sept. 2008** Site visit, Sindhuli road Sec III (MULKOT)

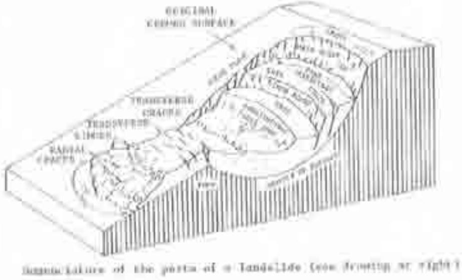
Time	No.	Topic
06.00		**Departure from Kathmandu, Babarmahal, DOR Gate** (distribution of Light Snacks to each Participant)
10:00		View of Landscape of Landslide Area from river side *Mr. Nakumura and Kameda*
Lunch Break at Mulkot Local Restaurant		
11.00 – 14.00	5	Exhibition of measuring equipment (ground strain- meter, ground water level in well, bubble tiltmeter) and inspection of moving pile/peg. *Mr. Nakumura and Kameda*
14.00 – 15. 00		Interaction and Discussion about Mulkot landslide *Mr. Nakumura and Kameda*
15.00		Leaving Mulkot for Kathmandu

→ **Day 3, 19 Sept., 2008** (Hotel Everest)

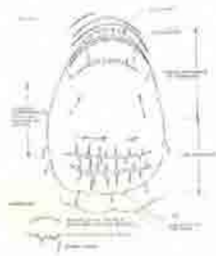
Time	No.	Topic
09.30 – 12 .00	6	Plotting of Landslide (Strain meter, bubble tilt meter) *Mr. Nakumura and Kameda*
Lunch Break		
12.30 – 16.00	7	Discussion on Different nature of Landslide *Mr. Nakumura*
16.00 – 16.30	8	Conclusion, discussion and feedback,
16.30 – onwards		End of Seminar

Landslide

Nomenclature of the part of a landslide



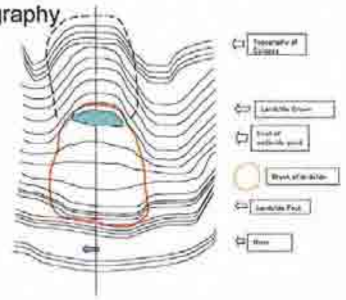
Cracks, bulges, scarp and spring



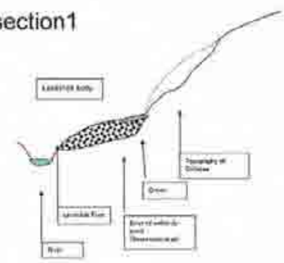
Type of landslide

Type1:General landslide type

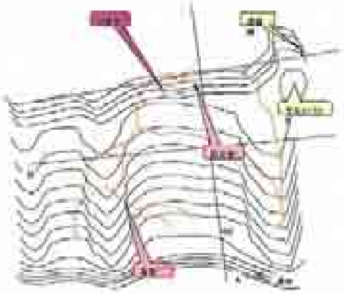
- Topography



- Cross section1



Landslide of tertiary rock



Cross section

Tertiary landslide by earthquake [Imokawa in Niigata pref.]

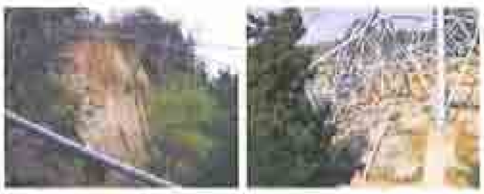
Landslide phenomena of mountain

left: crown, right: depression zone
[Nagano pref. in Japan]

Left: tension crack, Right: upheaval area

Tertiary landslide

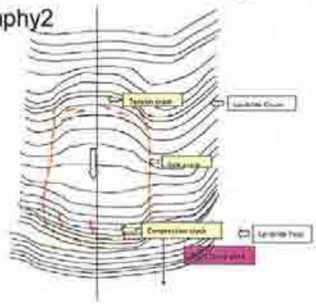
Left: crown ,
Right; destroy a steel tower (a pylon)



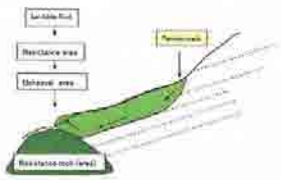
Landslide plane (in sand stone)

Type2:End of uplift type

- Topography2



- Cross section 2

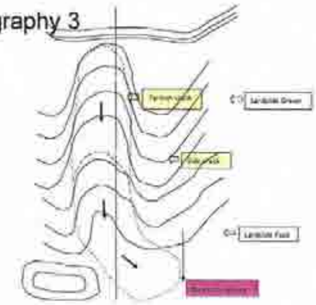


Phenomenon of upheaval section (1)

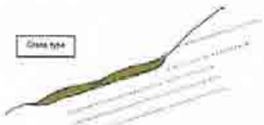
Phenomenon of upheaval section(2)

Type3:Landslide of clay type

- Topography 3



- Cross section 3

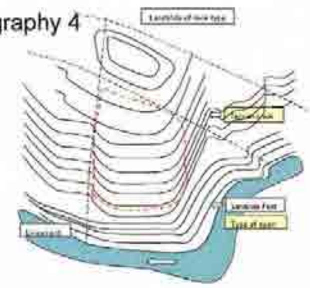


Landslide of clay (embankment)

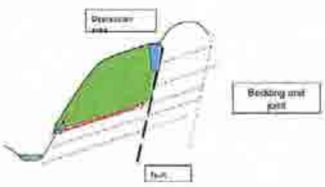
Landslide of clay (embankment)

Type4:Landslide of rock

- Topography 4



- Cross section

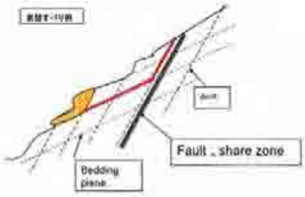


Large-scale landslide (Tertiary rock) June 2008

4

Type of rock landslide

- Cross section



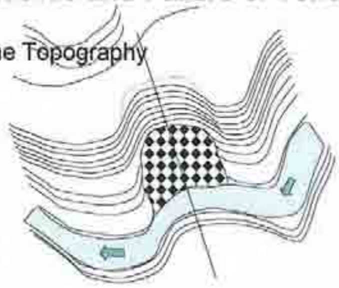
Rock landslide on bedding plan

Destroy the bridge by landslide (Rock landslide on joints)

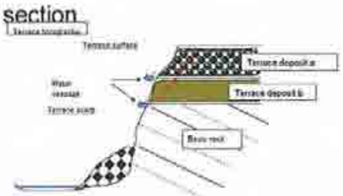
Creep phenomenon of rocks [Ishikawa pref.]

Landslide and Failure of Terrace.

- Plane Topography



- Cross section

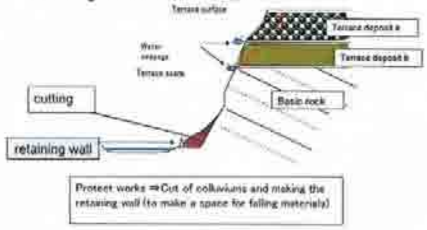


Landslide,Failure of Terrace.

- Photo

Planning of prevention works

- Cutting and retaining wall

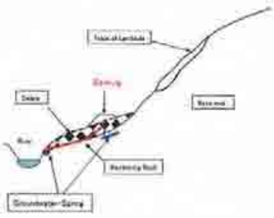


Landslide of Road

Landslide of embankment and cutting

Landslide of road (embankment)

- Banking



Landslide of embankment in Ethiopia

- B地区は土捨て場の盛土に起因した地すべり
- C地区は道路盛土部のすべりで降雨が原因

Phenomenon of landslide




6

Phenomenon of depression (1)

【地すべり頭部の盛土部陥没帯】

【陥没帯現象】

A process of Depression zone

Phenomenon in landslide end

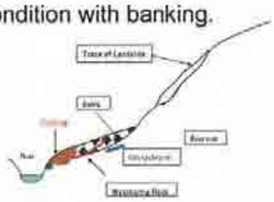
Upheaval phenomenon in landslide end

Failure phenomena in landslide end

Embankment area

Landslide of road cutting.

- Same condition with banking.



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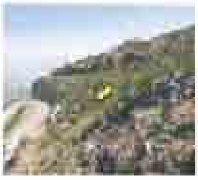
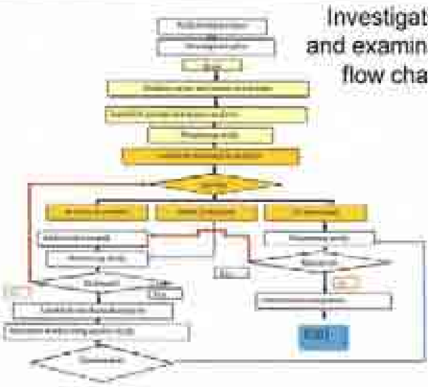
Landslide of road cutting.



Investigation of landslide



Investigation and examination flow chart

Field reconnaissance

- In order to recognize activities of landslide, and to make plans of surveys and emergency measures, field reconnaissance, with which the mechanism of landslide initiation and movement can be estimated, is required.

Field reconnaissance (I)

1) Estimation of the extent of landslide.
2) Survey on geology (structure).
3) Survey on geomorphology
4) Survey on distribution of groundwater.
5) Estimation of the movement type.

Field reconnaissance (II)

6) Estimation of the cause of landslide.
7) Prediction of movement in future.
8) Estimation of potential damage due to landslide activities and its area.
9) Examination of possible emergency measures.

Field reconnaissance (Ⅲ)

1) General geomorphology and geology of the area should be understood first, by observing from a high place in the opposite side slope of the landslide area

2)Point of field reconnaissance

- At the block of landslide, main cracks and their continuation, Constitution material forming slope, spring locations, water level of wells and its change, geometric distribution of valleys,
- Erosion of the toe by streams, main's activities (excavation, embankment, land use, management of surface water, water supply for irrigation or domestic usage),
- Age of cracks, producing state of clay at the toe, states of secondary landslides at the toe and sides,
- and topography and geology of the area surrounding the landslide, should be observed carefully.

Tools for field reconnaissance

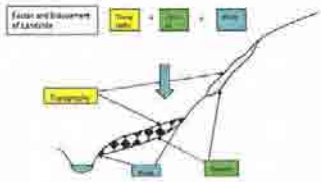
- Topographic maps,
- a clinometer,
- a camera,
- a hammer,
- a folding ruler,
- a binoculars

Planning Investigations

1)Classification of landslide shape based on geology and topography
2)Estimation of the landslide activity area
3)Estimation of sliding thickness
4)Estimation of moving blocks and their movement types from micro-topography and micro-phenomena of land surface (cracks, etc.)
5)Estimation of the moving direction of each blocks
6)Estimation of groundwater distribution
7)Estimation of planes of weakness in geologic structure

Survey of Factor and Inducement ⇒ Detailed Survey of Site

- Grasp of Factor and Inducement from an Experience.



Flow of Landslide Survey.

Detail survey of site.

- Grasp a wide area topography by topographic map and aerial photograph.
- Assume the landslide past history
- Grasp the landslide phenomenon by survey⇒ Make a map of crack distribution.
- Assume the landslide area and blocks.

STA17 Failure of Rock

Sta17+ Loosed rock around Joint.

STA18 Failure of Weathering Rock

Panorama of area

Phenomenon

Loosed Weathering Rock

Crack of Weathering Rock

Weathering of metamorphic rock

11

Mulkot landslide

Picture of around the Mulkot

Geographical features around Mulkot district

Geographical features around Mulkot (the left bank of a river)

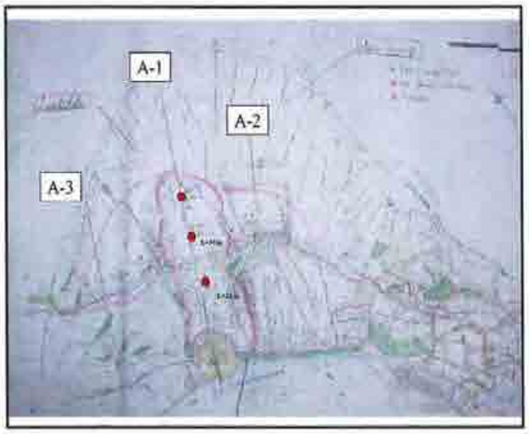
Mulkot landslide

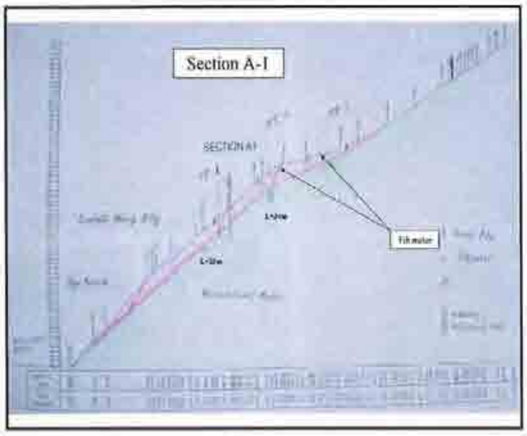
Collapse of landslide foot

1

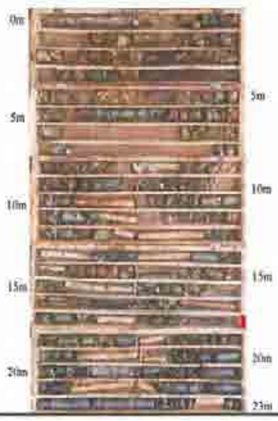
Collapse of landslide foot(2)

Materials of collapse surface

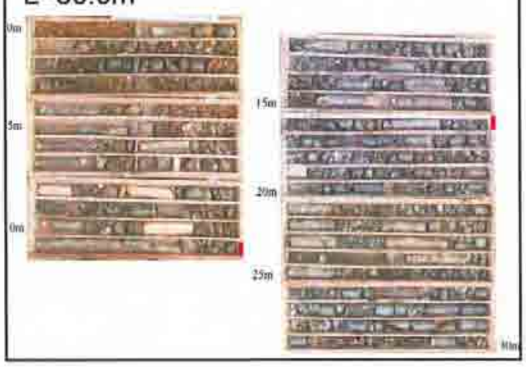


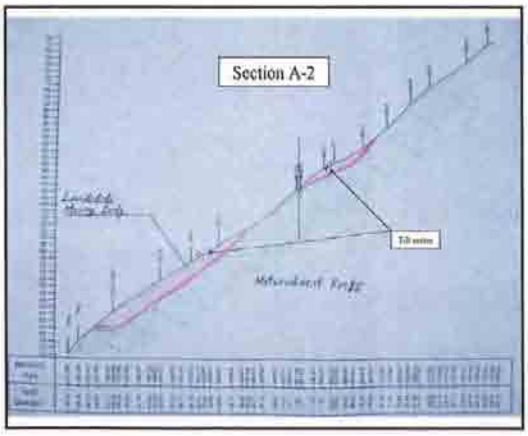


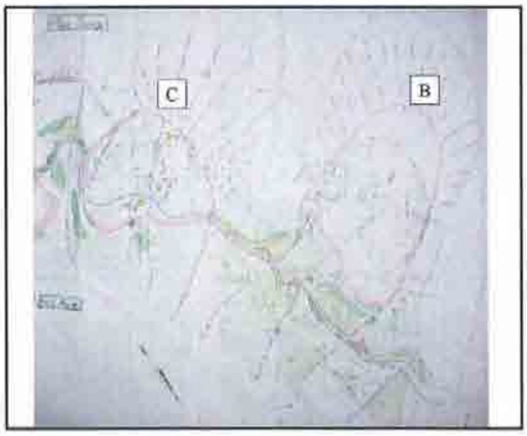
BV-1
L=23.0m

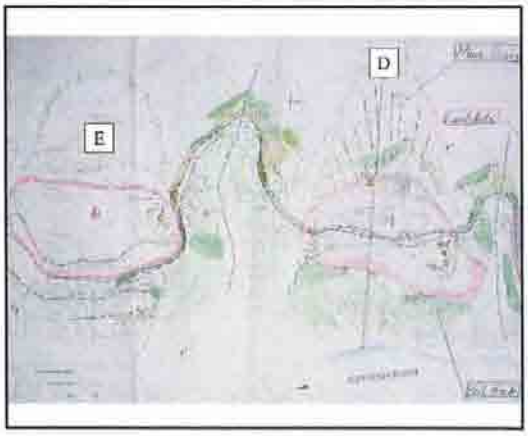


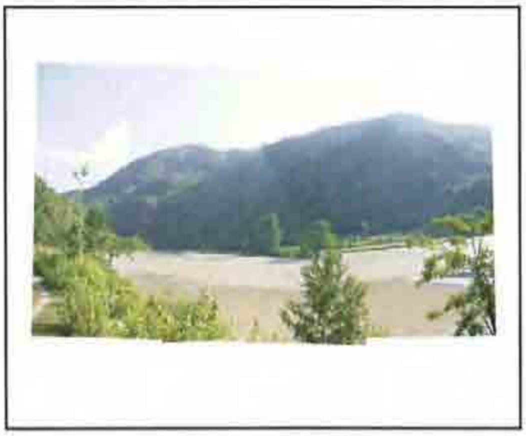
BV-2
L=30.0m

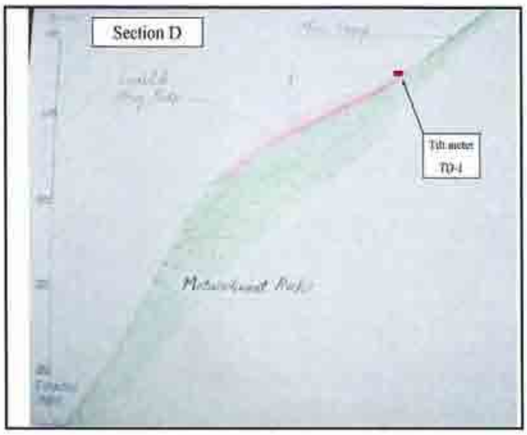












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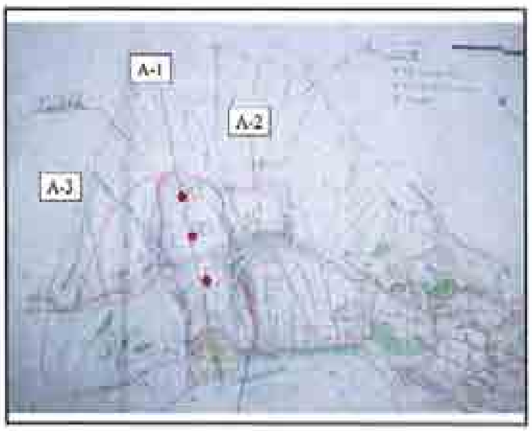
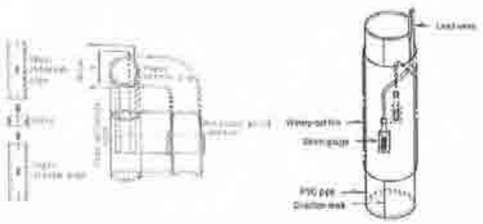
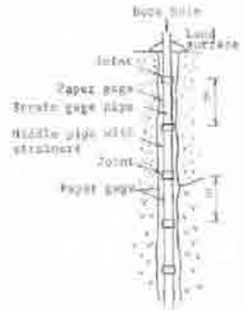


4

Monitoring instrument in Landslide

1. PVC Strain meter





PVC Strain meter

Setting the PVC Strain meter

Insert the PVC Strain gauge in the Boring hole.

2. How to Monitoring

PVC Strain Gauge

STEP1 Monitoring Start.

STEP2 Open the cover of Protection Box.

STEP3 Take out the Strain gauge terminal

STEP4 Clean the terminal with cloth.

STEP5 Connect the terminal to the strain meter among same colors

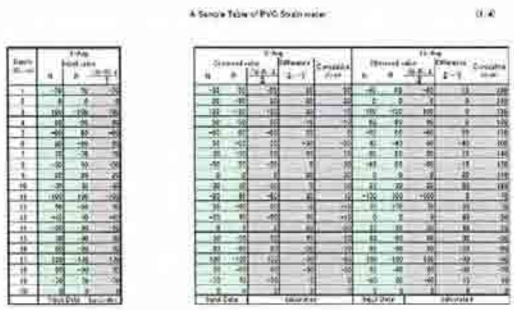
STEP6 At first, measure the value of normal position (N)

STEP7 Second measure the value of reverse position (R). And repeat every depth gauges.

STEP8 Close the cover of Protection Box.

3 How to Arrangement of the data

Strain meter



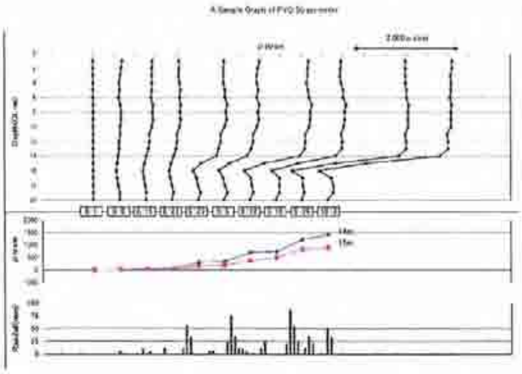
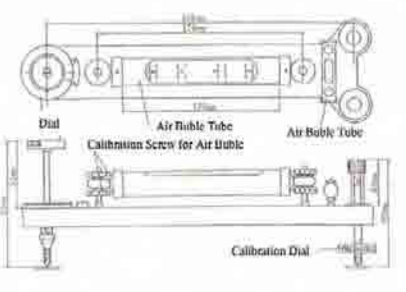


Table 3-1 Criterion of pipe strain gage

Danger degree of activity	Daily activity amount	Accumulative activity amount	Accumulative tendency to some direction	Movement type	Quality of activity
A	over 10 /day	over 5*10 /month	Greatly remarkable	Accumulative activity	Activity movement
B	over 10 /day	over 10 /month	remarkable	Accumulative activity	Slowly movement
C	under10 /day	over10 /month	existed	*Accumulative *Intermittent *Recurring	Necessity of continuous measurement
D	over 10 /day	over 10 /month	No existed	*Intermittent *Recurring	Local slope activity (or relating landslide activity)

4. Tilt Meter



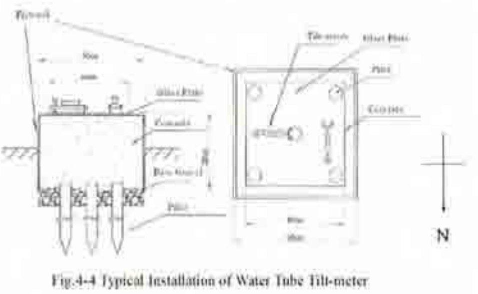


Fig.4-4 Typical Installation of Water Tube Tilt-meter

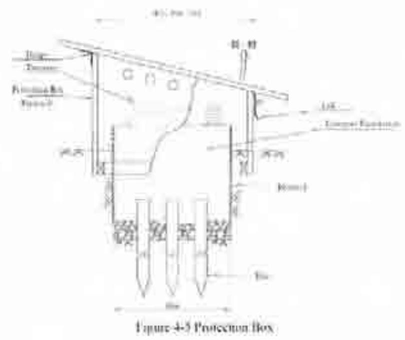


Figure 4-5 Protection Box

Base of tilt meter

Base of tilt meter

5. How to Monitoring

Tilt Meter

STEP1 Monitoring Start

STEP2 Open the cover of Protection Box.

STEP3 Remove the Sunshine, such as an umbrella.

STEP4 Before touching the Tiltmeter Check the shape of air bubble, and enter this data in an Monitoring form.

STEP5 Check the tick mark of dial, and enter the value in an Monitoring form.

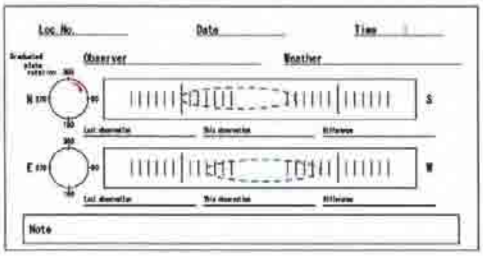
STEP6 Center the air bubble with rotating the dial, and enter the value in an Monitoring form.

STEP7 Adjust the dial (main and sub) for main and sub bubble which will be center.

STEP8 Observation N-S and E-W. And close the cover of Protection Box.

6. How to Arrangement of the data

Tilt meter



Tiltmeter observation form

Loc.No. ______ Date ______ Time ______

Graduated plate rotation ______ Observer ______ Weather ______

N | S — Last observation | This observation | Difference

E | W — Last observation | This observation | Difference

Note

A Sample Table of Tilt meter

Date	Number of Plat 1	Tilt in N-S direction X: measurement 2	Second 3=2×12	Tilt in E-W direction Y: measurement 4	Second 5=4×12	Maximum tilt 6=√(3²+5²)	Direction of tilt	N-S cumulative tilt (X)	E-W cumulative tilt (Y)	Daily tilt
1-Aug	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8-Aug	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15-Aug	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22-Aug	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29-Aug	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5-Sep	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12-Sep	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19-Sep	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26-Sep	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3-Oct	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

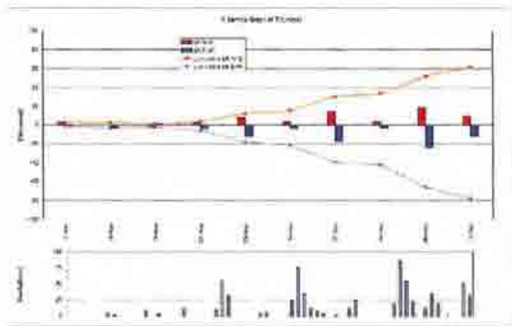


Table 4-6 Criterion for tilt

Danger degree of activity	Daily activity amount	Accumulative activity amount	Accumulative tendency to some direction	Movement type	Quality of activity
A	over 5 sec /day	over 100 sec /month	Greatly remarkable	existed	Activity movement
B	1-5 sec / day	30-100 sec / month	remarkable	existed	Slowly movement
C	Less1 sec / day	Less 30 sec / month	existed	existed	Necessity of continuous measurement
D	If any over 5 sec/day	Nonexisted	Nonexisted	Nonexisted	Local slope activity or relating landslide activity

Table4-5 Relation between positive and negative and direction of dip

Sign of movement of N-S direction	−	−	+	+
Sign of movement of E-W direction	−	+	−	+
Tilt direction	N○°E	N○°W	S○°E	S○°W

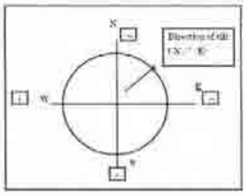
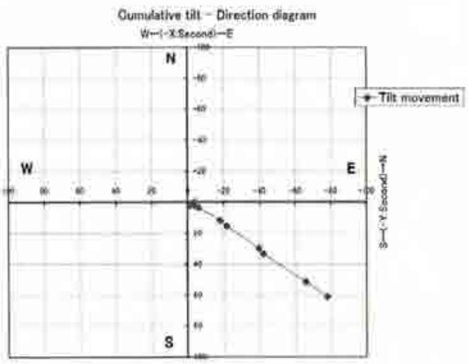
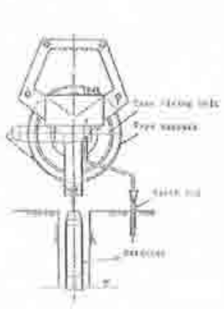


Fig. 4-6 Mea of direction of dip



7. Groundwater meter



8. How to Monitoring

Groundwater meter

STEP1 Monitoring Start

STEP2 Open the cover of Protection Box.

STEP3 Instrument of measuring Groundwater level

STEP4 Insert the sensor into the PVC pipe

STEP5 Drop the sensor. When the sensor touch with Groundwater, sound a buzzer.

STEP6 Measure the depth

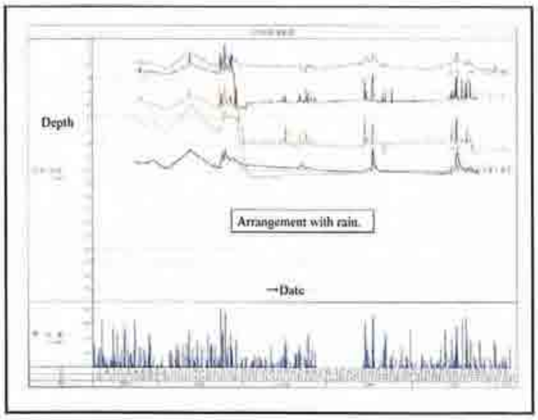
STEP7 Subtract the height of ground

STEP8 Close the cover of Protection Box.

9. How to Arrangement of the data

Groundwater meter

6



10. Rain gauge

STEP1 Monitoring Start

STEP2 Open the cover of box.

STEP3 Remove the old sheet

STEP4 Set the new sheet

STEP5 Slide a handle, and pen contact with sheet.

STEP6 Close the cover of box.

STEP1 Rain gauge

STEP2 Take the cover off a gauge

STEP3 Vessel catch the rain of 0.5mm

STEP4 Count the number of times that vessel moved by 0.5mm rain

11. Extensometer

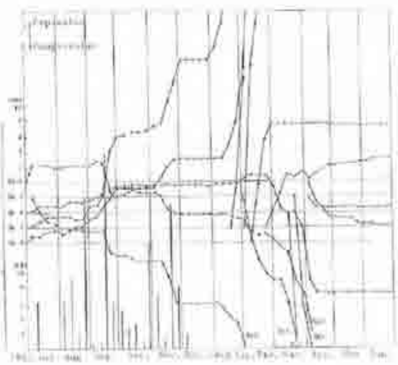
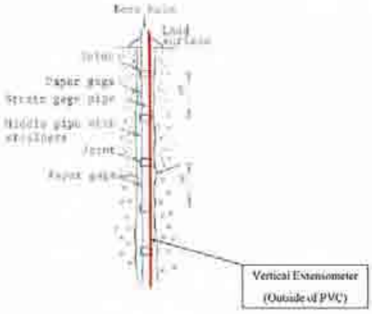


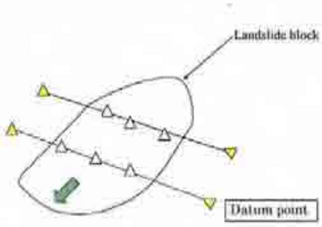
Table4-2 Criterion of extensometer

Danger degree of activity	Daily activity amount	Accumulative activity amount	Accumulative tendency to some direction	Movement type	Quality of activity
A	over 1mm/day	over 10mm/month	Greatly remarkable	Tension movement	Activity movement
B	0.1-1mm/day	2-10mm/month	remarkable	Tension movement or continuous movement	Slowly movement
C	0.02-0.1mm/day	0.5-2mm/month	existed	Tension or compression movement	Necessity of continuous measurement
D	If any over 0.1mm	No noticed	No existed	No regulation	Local slope activity unrelating landslide activity

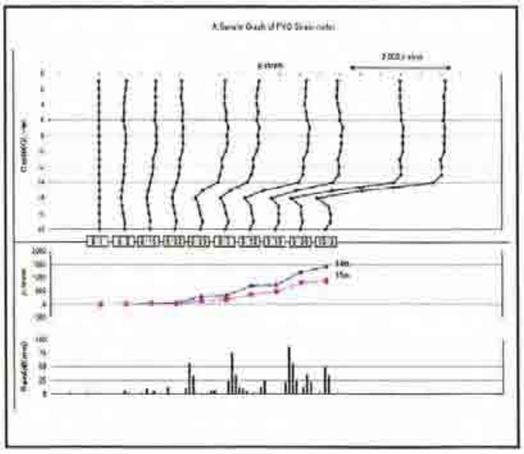
12. Vertical Extensometer

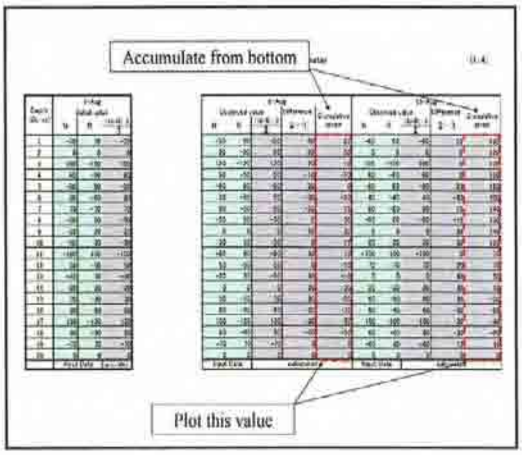


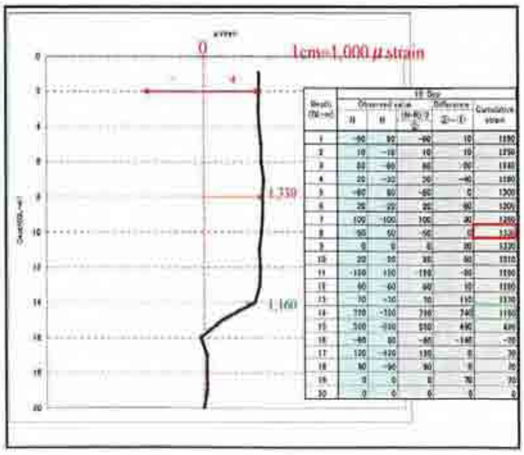
13. Survey pile

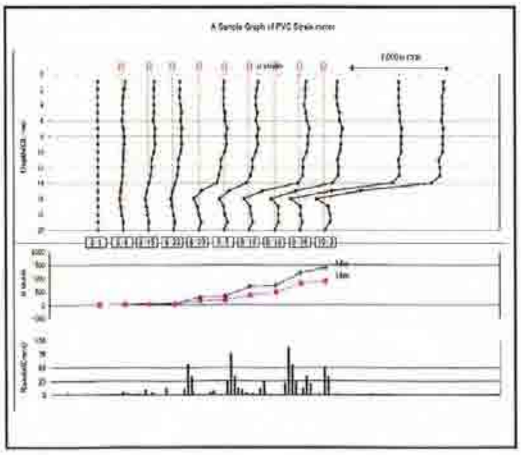


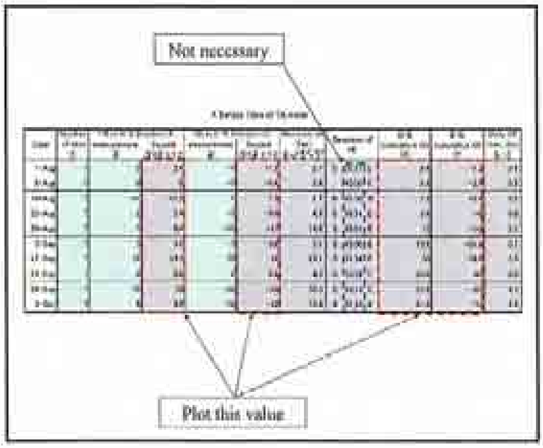
Measurement of survey piles by a transit

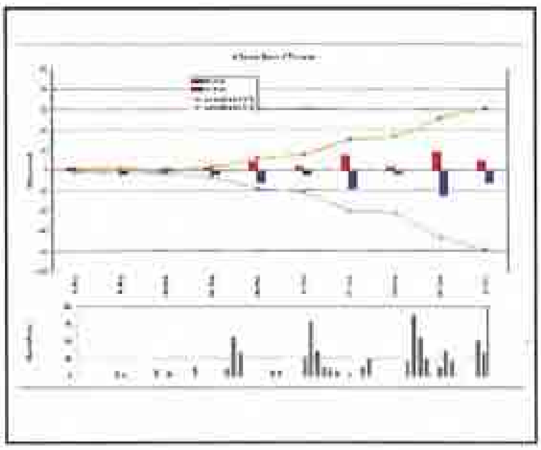

A Sample Graph of PVC Strain meter

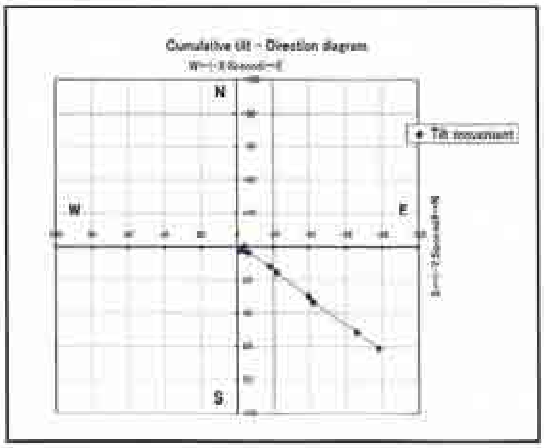

Accumulate from bottom
Plot this value


0
1cm=1,000 μ strain
1,330
1,160


A Sample Graph of PVC Strain meter


Not necessary
Plot this value




Cumulative tilt - Direction diagram
N
W
E
S
Tilt movement

８－９－４　配布資料

A GUIDE　OF
LANDSLIDE INVESTIGATION
FOR
SINDHULI ROAD

September 2008

JICA Study Team

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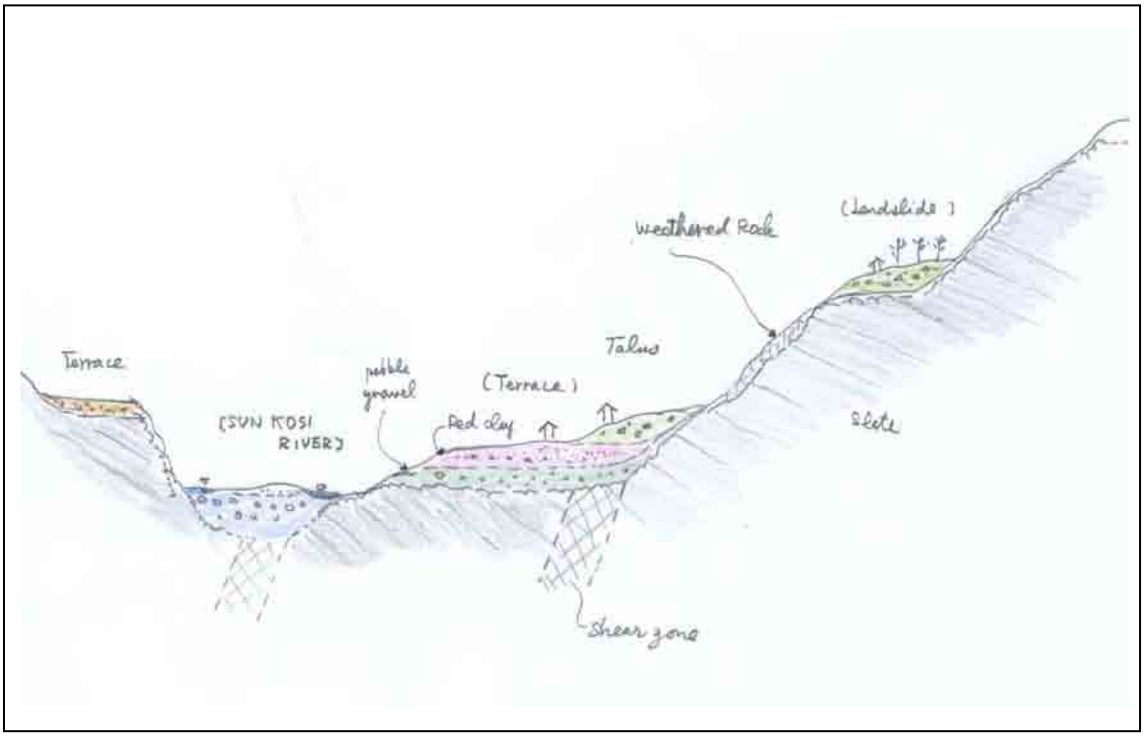
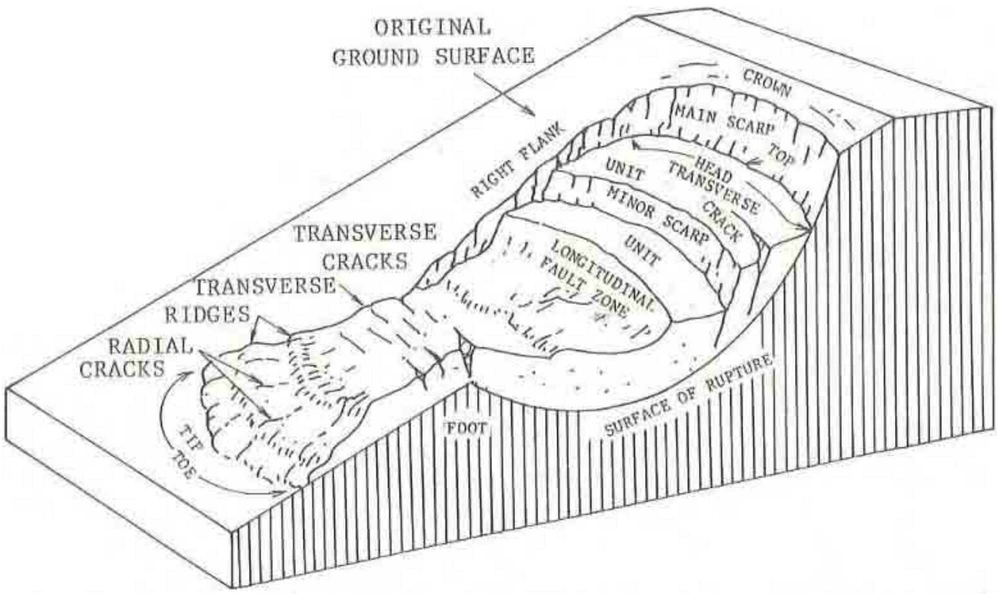


Figure of topographic characteristics around SUN-KOSHI River

1. Topography of landslide

Landslide morphology is surface expression of the present or the past occurred landslides in the area. Figure 1-1 shows the standard model of the landslide morphology. Figure 1-2 shows topographic anomalies, which are commonly observed in the area of landslide.



Nomenclature of the parts of a landslide (see drawing at right)

MAIN SCARP - A steep surface on the undisturbed ground around the periphery of the slide, caused by movement of slide material away from the undisturbed ground.
The projection of the scarp surface under the disturbed material becomes the surface of rupture.

MINOR SCARP - A steep surface on the disturbed material produced by differential movements within the sliding mass.

HEAD - The upper parts of the slide material along the contact between the disturbed material and the main scarp.

TOP - The highest point of contact between the disturbed material and the main scarp.

FOOT - The line of intersection (sometimes buried) between the lower part of the surface of rupture and the original ground surface.

TOE - The margin of disturbed material mast distant from the main scarp.

TIP - The point on the toe most distant from the top of the slide.

FLANK - The side of the landslide.

CROWN - The material that is still in place, practically undisturbed, and adjacent to the highest parts of the main scarp.

ORIGINAL GROUND SURFACE - The slope that existed before the movement which is being considered took place. If this is the surface of an older landslide, that fact should be stated.

LEFT AND RIGHT - Compass directions are preferable in describing a slide, but if right and left are used they refer to the slide as viewer from the crown.

Fig. 1-1 Standard model of landslide morphology

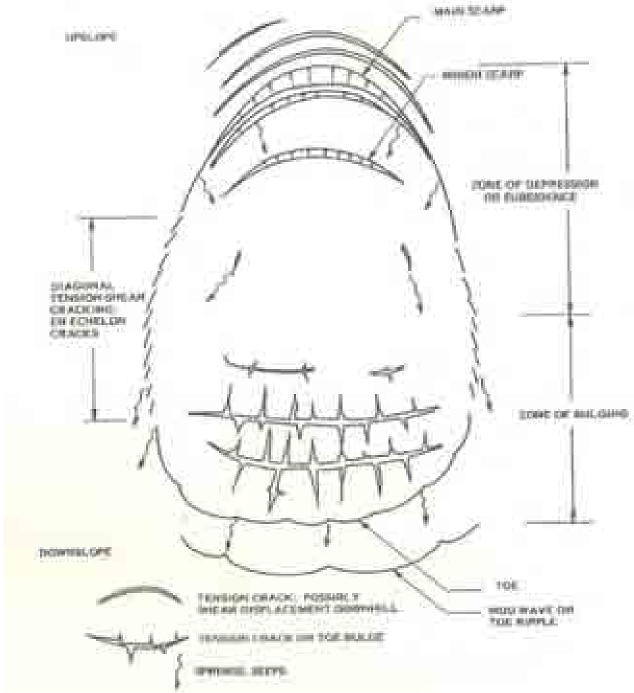


Fig. 1-2 Cracks, bulges, scarp and spring

【Various topography of landslide】

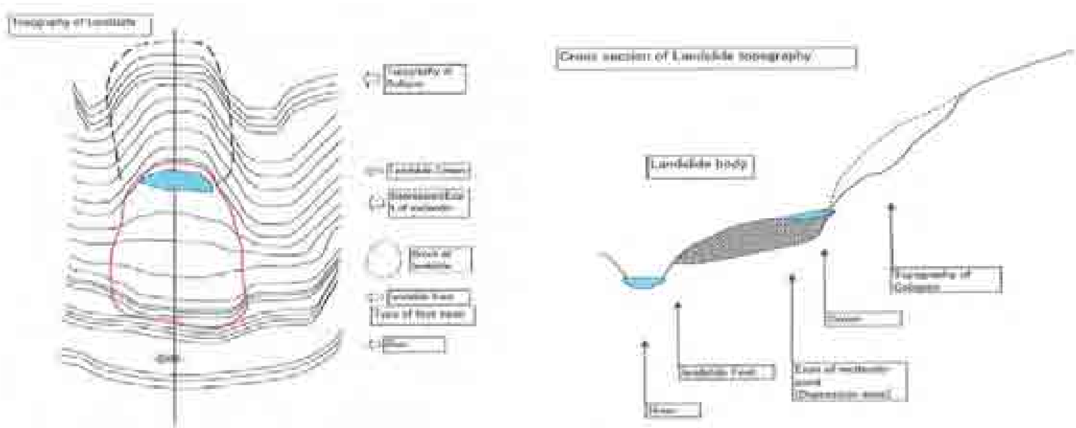


Fig.1-3　Various topography of landslide (debris type)

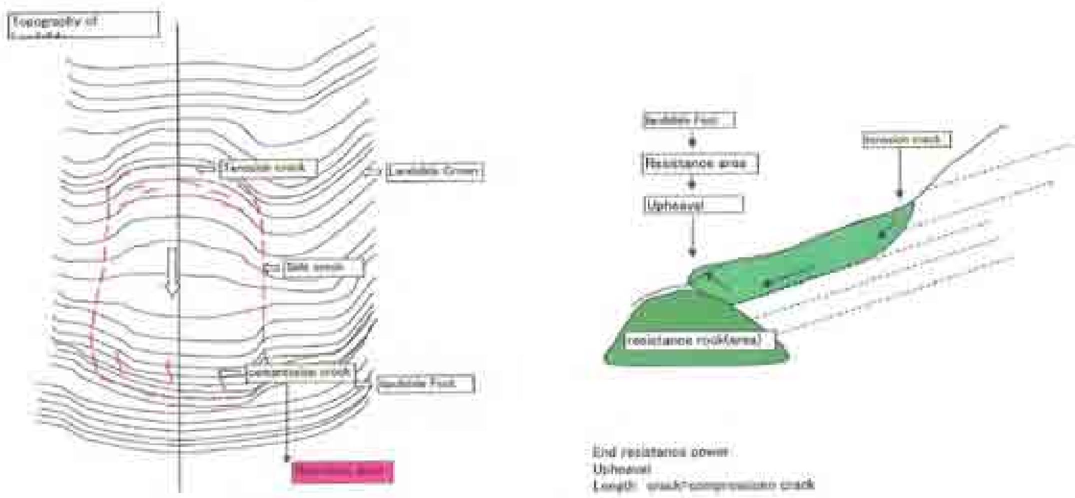


Fig.1-4　Various topography of landslide (upheaval type)

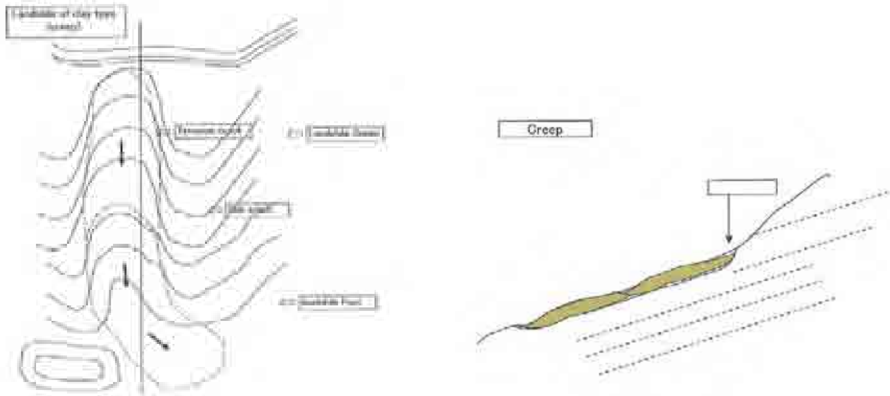


Fig.1-5　Various topography of landslide (creep type)

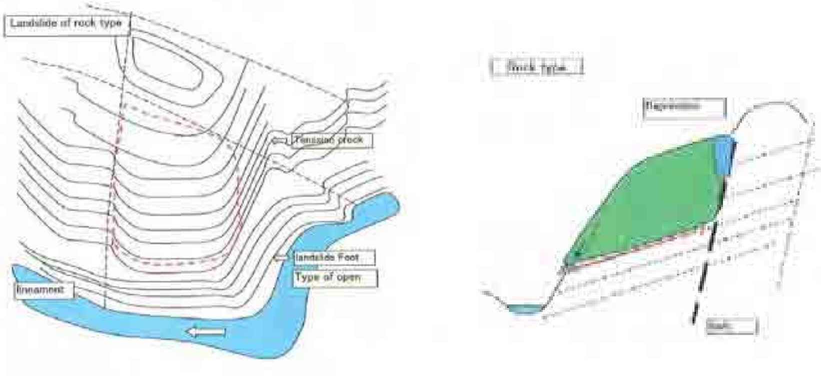


Fig.1-6　Various topography of landslide (rock type)

2. Field Investigation

2.1Planning Investigations

Because causes of landslide activities originate in underground, the mechanisms of landslide initiation can rarely be recognized only from micro-phenomena appearing on the land surface.

Therefore, detailed investigations are planned, and success of protecting works depends on these investigations. The investigation should be planned carefully, otherwise all the results of investigation would become useless.

Many researches in landslide have been progressed recently, and many methods and apparatus for investigation have been invented and applied. Among those, suitable methods and apparatus should be selected for each investigation of landslide. Too much or too less accurate apparatus and unsuitable methods not only waste money and labor, but also delay the decision to take suitable measures for protection.

The most important information for planning investigations is the results of field reconnaissance. Together with literature records and researches on topographic maps, the results of field reconnaissance are used to estimate the mechanisms of landslide. The procedure of this estimation has been mentioned before, and it is summarized briefly below.

- i) Classification of landslide shape based on geology and topography
- ii) Estimation of the landslide activity area
- iii) Estimation of sliding thickness
- iv) Estimation of moving blocks and their movement types from micro-topography and micro-phenomena of land surface (cracks, etc.)
- v) Estimation of the moving direction of each blocks
- vi) Estimation of groundwater distribution
- vii) Estimation of planes of weakness in geologic structure

The mechanism of landslide can be estimated by examining these provisions listed above, and it is the purpose of investigations to confirm this estimation.

(1)Area of Investigation

The area of an investigation is controlled by the size of the project and by the extent of the topographic and geologic features that are to be involved in the landslide activity. At sites where there is potential for movement that has not yet developed, the area that must be investigated cannot be easily defined in advance. The extent of the investigation can be better defined once a landslide has occurred. However, in either case, the area studied must be considerably larger than that comprising the suspected activity or known movement for two reasons: (a) The landslide or potential landslide must be referenced to the stable area surrounding it, and (b) most landslides enlarge with passage of time (moreover, many landslides are much larger than first suspected from the obvious overt indications of activity). As a crude rule of thumb, the area studied should be two to three times wider and longer than the area suspected. In some mountainous areas, it is necessary to investigate to the top of the slope or to some major change in lithology or slope angle. The lateral area must encompass sources of groundwater and geologic structures that are aligned with the area of instability.

The depth of the investigation is even more difficult to define in advance. Borings or other direct techniques should extend deep enough to identify those materials that have not been subject to past movement, but that could be involved in future movement, and the underlying formations that are likely to remain stable. The boring depth is sometimes revised hourly as field operations proceed. When instrumentation of a landslide yields data on the present depth of activity, planned depths are sometimes found to be insufficient and increases are necessary. The specifications should be flexible enough to allow additional depth of investigation when the data obtained suggest deeper movements. Longitudinal cross sections should be drawn through the center of the slide and depict possible toe bulges and uphill scarps; circular or elliptical failure surfaces sketched through these limits can suggest the maximum depth of movement. Continuous thick hard strata within the slope can limit the depth. However at least one boring should extend far below the suspected depth of shear; sometimes deep slow movements are masked by the greater activity at shallower depths. For a second estimate, the depth of movement below the ground surface at the center of the slide is seldom greater than the width of the zone of surface motion.

(2)Time Span

Since most landslides are influenced by climatic changes, a minimum period for investigation should include one seasonal cycle of weather – 1 year in most parts of the world. However, because long-term climatic cycles that occur every 11 or 22 years are superimposed on the yearly changes, a landslide investigation could be necessary for more than 2 decades. Such a long investigation is almost impossible, however, because of the need to draw conclusions and take corrective action. Investigations made during a period in which the climatic conditions are less severe than the maximum will prove too optimistic, and those made during a period of bad climate may appear too pessimistic. The worst climatic conditions that develop during the life of the project control the risk to engineering construction. Experience has indicated that many false conclusions have been reached regarding the causes of landslides and the effectiveness of corrective measures because worsened climatic changes were not considered by the engineers and geologists concerned.

(3)Stages of Investigation

An investigation of landslides is a continuing process but, from the practical point of view, may be divided into four stages.

① The first stage is a preliminary investigation or reconnaissance in which a general overall view of the problem area is gained. The work begins with a review of the published geology in the area and accounts of past land instability. The field study is largely visual and the interpretation is highly subjective. The results of this preliminary evaluation are used as a guide in planning the more intensive, specific investigation during which the major part of the quantitative data are obtained.

② The second stage, which is more intensive and detailed, includes boring, sampling, trenching, and other specific techniques designed to obtain the data needed to satisfy the objectives outlined in the above checklist. Because of climatic changes, the intensive investigation is preferably undertaken during the season that is least favorable for stability. For example, borings to determine the minimum soil strength or groundwater studies to determine maximum water pressures should be made during periods of snowmelt or following heavy rainfall. A similar investigation made during the driest and hottest period of the year could give completely misleading data.

③ The third stage is interactive. As new data are obtained, they will point to the need for additional data from specific locations. The investigative plan must provide for additional work that was not a part of the initial scope. Experience indicates that the additional work stemming from information obtained during the planned study will range from 30 to 50 percent more than that which was originally considered adequate for the intensive investigation.

④ The fourth stage involves continuing surveillance of any area where activity is suspected or where corrective action has been taken. The surveillance period is indeterminate but should extend through at least one cycle of annual climatic change and, to be most meaningful, should be longer term to include the worst climatic conditions. For example, corrective work may be done during a number of consecutively dry years, and the area may not be subjected to its worst climatic test until 4 or 5 years later (assuming an 11-year cycle of climatic change). If the climatic changes occur in a 22-year cycle, the period of observation required could be correspondingly much longer. Rarely do those who finance such long-term surveillance have the wisdom and foresight to continue the data gathering, because the period required extends beyond the tenure of most public officials or private managers. However, public and professional interests are best served if surveillance is maintained long enough for the occurrence of the full range of environmental conditions that can reasonably be expected; otherwise, the extent of continuing risk may never be adequately defined.

(4)Small-middle scale landslides

Landslides which are 50 – 200 m wide and 50 – 100 m long, are usually 10 -20 m thick, and they are very common.

Rough investigations are not generally done on these landslides, and detailed investigation can be done immediately after the field reconnaissance, except some cases listed below. On these small landslides, as field reconnaissance usually can be done into detailed point, and sliding block number is a few comparing with large, th partition of a landslide into movement blocks can be done by surveying micro-topography and sliding phenomena.

a. Rough investigations

(Ⅰ) In the cases listed below, rough investigations are required.

When clear faults and shattered zones are observed, and when their distribution should necessarily be clarified:

Faults or shattered zones sometimes affect the movement of a landslide with forming dividing planes or conduits of groundwater. A shattered zone is usually 2 -10 m wide, and groundwater sometimes overflows from a vertical bore hole nearby. A fault can cause a landslide, because it raises pore water pressure in an aquifer with cutting off effects. Finding these structural lines, however, are often very difficult. Occasionally, these are found at the time of detailed survey, and rough investigation is performed later again in some cases.

(Ⅱ) When there is a clear difference in mass stiffness between a moving (sliding) mass and bed rock or between different bed rocks:

For example, when the difference in stiffness is respectively very large as between porous colluvium and hard Mesozoic or Paleozoic strata (seismic wave velocity 1.00

km/sec and 3.50 km/sec respectively), seismic prospecting will be useful to determine the point of boring for detailed survey, and it helps to reduce the number of boring. However, when the seismic velocity of the bed rock is about 2 km/sec as in the case of a landslide in Neogene mud stone or tuff, seismic prospecting becomes less useful.

Seismic prospecting is also mainly used when intrusion of andesite into Tertiary strata is expected, or when porphyrite is distributed in the area.

(Ⅲ) When existence of clear aquifers is expected in and near the area of landslide: Electric prospecting is used for detecting water distribution when ponds and swamps are observed in the uphill or in the head area of a landslide.

b. Detailed investigations

(I) Drawing up of 1/500 – 1/1000 topographic maps

Topographic maps with 2 m contour interval should be made on the area of landslide including its uphill area. Scale of the map is chosen as shown in Table 2-1.

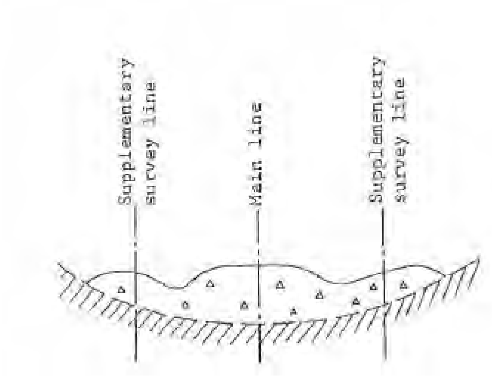
Table. 2-1

Width of landslide	Scale
less than 100 m	larger than 1/500
100 – 200 m	1/500
more than 200 m	whole area 1/1000 area of active landslide 1/500

(II) Setting of survey lines

Survey lines should be set at the time of field reconnaissance when an extent of the landslide, the partition into moving blocks and the direction of movement are estimated. However, results of rough investigation should also be used to set the lines. Survey lines consist of main lines and supplementary lines.

The main line is set parallel to the direction of movement at the center of the main moving block. Stability analyses will be done along this line, and a foundation to take measures will be decided on the basis of data obtained along this line. Therefore, the main survey lines should be set very carefully.



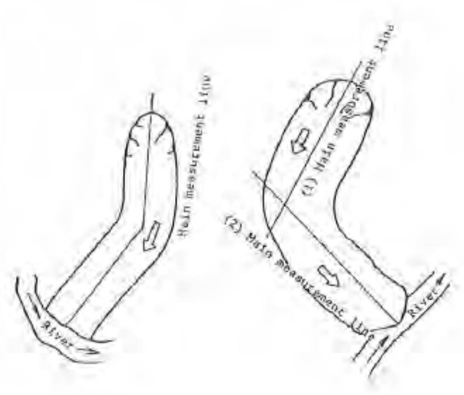


Fig. 2-1 Position of a main survey line in a cross section of landslide

Fig. 2-2 Position of main survey lines

Because a landslide is regarded as balance phenomena of a soil mass, the main survey line should not be settled on a trough but on a ridge (Figure 2-1). When a landslide has a curved sliding, the main survey line may curve. However, two separated main survey lines may be set, when the curvature is too large (Figure 2-2).

A main survey line should be continuous line from the uphill area outside of the moving block to the stable land at the toe. A straight line should be used, because it is convenient for analyses in future. When there are more than two moving blocks, multiple main survey lines can be set (Figure 2-3).

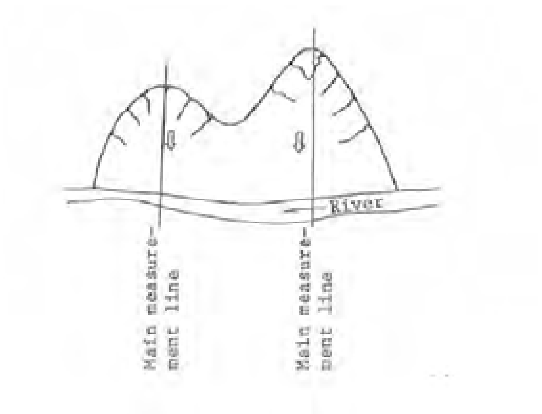


Fig. 2-3 Main survey lines on two moving blocks

Supplementary lines are set on both sides of a main survey line with a interval less than 50 m. These lines are set parallel to the main survey line or along the center of a small slide block adjacent to the main block. Supplementary lines are also set to draw a topographic map of bed rock surface in the area. The stability analysis may be done along the supplementary line at the center of a small sliding block (Figure 2-4).

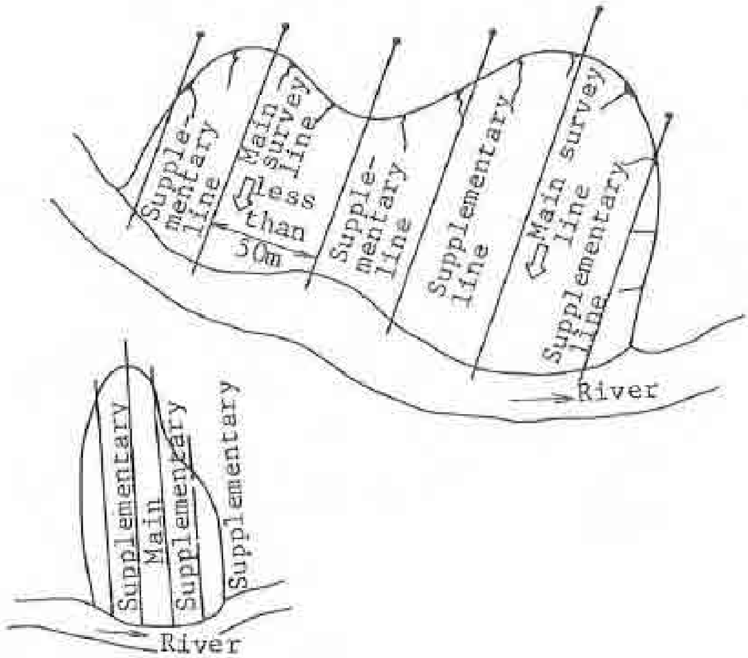


Fig. 2-4 Setting of main and supplementary lines

(III) Position of investigative borings

Along survey lines, vertical borings are made with intervals listed below: Table 2-1

Table 2-3

Estimated thickness of landslide (vertical)	Depth of boring	Interval of investigative boring point (on main survey lines)	Interval of investigative boring point (on supplementary lines)
Less than 15m 15 – 20m More than 50m	More than 20m More than 25m More than 30m	Less than 20m Less than 30m Less than 50m	Less than 40m Less than 60m Less than 100m

Investigative borings should be all core borings, and the diameter of bore holes should be larger than 66mm. Depth of boring are listed in Table 2-3. Drilling is stopped when it drills into bed rock about 5 m, and then accounts are settled with the budget in which 30 m is used as a standard depth. Along the main survey line, at least one boring should be made in the uphill stabled area. Including this one, at least four borings are necessary along the main line, because the stability analysis of a moving mass require at least three borings.

Along supplementary lines, boring points are set corresponding the every other boring points on the main measurement line. This allows drawing cross sections of the landslide through the points of boring on supplementary lines. Therefore, a topographic map of bed rock surface in the area of landslide can be drawn. On the block which is the subject of the stability analysis, boring points are set corresponding the interval of boring point executing on the main survey lines.

Along the main survey line, moreover, boring points are set at major points of topographic changes, and borings which are deeper than 30 m are planned, when the existence of faults, shattered zones or intrusive rock is estimated.

(IV) Measuring

A strain gage pipe measuring the slip surface position is set in every bore hole in the area of landslide activities. Groundwater prospecting is done, and groundwater level is checked in every bore hole.

State of movement of the land surface is checked by extensometers with about 0.2mm accuracy. More than two strain meters on the main survey line and more than one on a supplementary line, should be set in the area of landslide including the toe area and main cracks in the head area. On the middle slope of a landslide, strain meters should be set at clear cracks or at abrupt drops.

Slope tilt-meters must be set on stable lands and in the uphill area along the main measurement line to check the stability of upper slope. This instruments are also set at points of unclear movement in the area of landslide.

Groundwater tracing and water quality test should be planned when it is necessary. Groundwater tracing, which is used to confirm the estimated groundwater flow, is almost always performed.

2.2 Geologic Investigation (Boring investigation)

(1) Purpose

Investigative borings are used not only for checking underground structure and geology of the area of landslide, but they are also used for points of investigations listed below.

① Survey on slip surface
② Observation of groundwater level
③ Extracting undisturbed samples for soil tests
④ In situ soil test for standard penetration test
⑤ Groundwater prospecting
⑥ Various prospecting (electric prospecting, natural radioactivity prospecting, etc.)
⑦ Water quality test, water sampling point and tracer inserting point for groundwater tracing
⑧ Measurement of soil temperature, gas pressure and others.

Position, diameter and depth of boring should be determined according to the purpose of the investigation. Diameter of bore holes should be larger than 66mm, otherwise geologic observations by the core sampling become difficult.

Borings should have enough depth to go through the slip surface and into bed rock at least 5m (to confirm the bed rock). In the case of the investigation on geologic structure, deeper drilling is needed. The depth of boring can be roughly determined from cross sections and ground planes of the area when the bulge phenomena does not observe on the toe area.

To obtain undisturbed samples for soil tests, diameter of boring should be larger than 86mm.

(2) Coring

Investigations are performed in all coring in principle. Efforts to make core extraction rate close to 100 percent should be made. Especially, dry boring or semi-dry boring is used in the case of soft layers.

Every 5m of an extracted core is put into a core box (which is 1m long and has five lines of grooves). When the core extraction rate is low, partition boards are used to put in order. Core boxes should always be located near the boring machine during the operation, and extracted cores should immediately be put into boxes in order. Putting the extracted cores together after laying them in disorder must be avoided. Slime is put into a vinyl bag which is marked to indicate the content. Desired core extraction rates are, better than 90% in Tertiary sedimentary rock, better than 70% in schist (except siliceous schist), better than 60% in Mesozoic and Paleozoic sedimentary rock, and in igneous or plutonic rock. Even in coarse Quarternary lavd strata, which have large difference in hardness among them, and volcanic detritus, efforts should be made to make a core extraction rate better than 30%. A color photograph is taken on each arranged core box, and the photographs are put in the report.

(3) Core examination

Core examination is the most important part of the survey. An experienced expert is expected to work, after his thorough reconnaissance of the area of landslide.

Main points of core examination are listed below.

(a) Color: Sliding masses in the areas of sedimentary or metamorphic rock, which changes its color to yellowish or brownish color due to weathering accelerated by infiltration of water through cracks, shows clear contrast to bed rock. In the case of volcanic detritus, a sliding mass shows less contrast to bed rock, but a bluish gray or white clay layer usually is observed the bottom of a moving mass. The clay layer can be detected, because it shows a good continuity between boring cores, and because it make core extracting rate better.

Colors of a layer which is expected to form a slip surface are usually bluish gray, black or green in Neogene strata, dark gray or greenish gray in metamorphic rock, and grayish white in volcanic deteritus.

(b) Rock texture: Some cores of the moving mass show the original rock texture when they are cut, while others do not show any more. The former indicates a landslide in the youth stage or younger, and the latter represents a landslide in the middle or old aged stage. Preservation of rock texture becomes an important factor in choosing suitable measures for protective planning.

(c) Lithology and size of gravel: If the lithology of gravel in a moving mass is different condition from that of the bed rock, it can be estimated that the gravel was carried from uphill or upstream by landside activities. This can be used as a clue to judge the history and type of the landslide. Size of gravel also can be used in the same way. When organic material is found it should be examined if the organic material is related to the landslide activities, or if it is older than the landslide.

(d) Matrix: Properties of matrix (sandy or clayey) can be a clue to judge the moving configuration of landslide.

(e) Shape of gravel: Gravel becomes more rounded as a landslide becomes old (angular → subangular → subrounded → rounded). Existence of terraces can be assumed, when different lithology of gravel are found.

(f) Geologic structure (faults, etc.): A key bed in bed rock, if it is found, is very useful to estimate lines of geologic structure.

(g) Dikes: If dikes of andesite or liparite are found in sedimentary rock, it can be estimated that the bed rock is fractured.

(4) Groundwater level during drilling

During the operation of boring, groundwater level should be checked in every morning before drilling starts. Depth of an aquifer or existence of artesian groundwater can be estimated as shown in Figure 3-16.

(5) Use of bentonite and cleaning bore holes

Use of bentonite should be minimized, because water level check is performed in a bore hole. The amount of bentonite used should be recorded.

Bore holes should be carefully cleaned after drilling, especially when groundwater prospecting, groundwater tracing or a water quality test is planned.

(6) Maintenance of bore holes

After drilling, a vinyl chloride pipe with strainer holes is inserted in a whole length of bore hole to protect the hole wall. Inside of the hole should be washed well, and the mouth of the hole is fixed by concrete casing larger than 30cm × 30cm × 10cm.

(7) Arrangement of data

(a) Geologic column: The description is the most important section of a geologic column. With professional observative description on lithology and characteristics of soil, the mechanism of landslide at the point must be mentioned in this section. Phenomena which occurred during the drilling should also be mentioned. Quality of description in this column will govern the result of the boring investigation.

(b) Geologic section: In a geologic section figure along a line of investigative borings, geology, distribution of bed rock, faults, shattered zones, estimated position of slip surface and cracks are shown with a topographic section. Geologic views of landslide activities are illustrated in the section.

3. Slip Surface Investigation

3.1 Strain meter

(1)Measurement by underground strain meter

An underground strain meter is a vinyl chloride(PVC) pipe inside of which a paper strain gage is stuck (Figure 1)

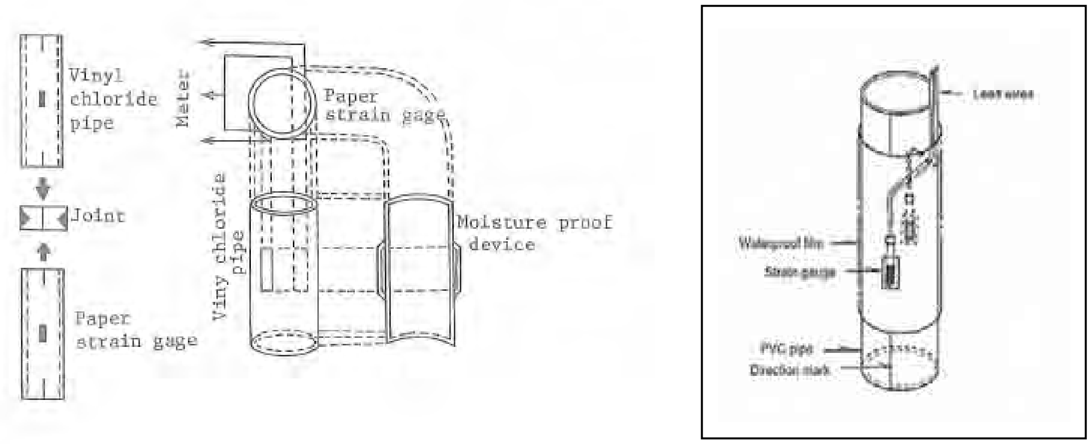


Fig .3-1 Pipe underground strain meter

Outside diameter of the pipe is about 52mm, and a 66－72mm diameter bore hole is necessary to accommodate the pipe depending on a number of gage and cord. Space between the pipe and bore hole wall is filled with fine sand.

When the landslide moves on the slip surface the pipe is bent around the slip surface and its strain is transferred to the gage. The gage usually contains a couple of paper strain gages, one of which is put on an opposite side of the pipe to the other. The set of gage can offset gage changes caused by temperature change or other causes, and a compressed side and a pulled side of the pipe can be measured as plus and minus strain.

Although the maximum strain and its direction can be measured by using four strain in a section in theory, strain of the pipe does not usually coincide with the sliding direction of landslide, and does not be transferred directly to the pipe , therefore in these days two gages type for one direction are used only to confirm the position of slip surface. Gages are usually put in a pipe with 1m intervals.

Adjusting a bore hole and filling the space between the pipe and the wall of a bore hole are problems in instrument the gage. Irregularity of the wall of the bore hole may caused the damage of the gage in its insertion, and insufficiency of filling material may cause extrusion of clay, clogging by gravel and instability of the pipe, all of which cause disorder of data. As the filling material, fine sand poured by water or chemical grout is commonly used.

(2) Observation

Measurement method is the same as a standard strain gage method, and strain difference between two gages is measured. To make it accurate, measurement is made twice with switching cords of front and back gages.

The sum value of the readings of the two gages at a measurement is usually about twenty thousands micro, and this value can be to check errors.

In principle, the measurement should be made once every day, and twice a week when the changes are small. If the interval of measurement is too long and a rapid change occurs, it becomes difficult to judge whether the change depends on an accumulation of landslide movement or it is caused by malfunction of the gage. A meter which has 5 micro minimum reading is good enough. Results are arranged with transforming 10^3 micro into 1 cm. the value 10^3 micro is the minimum to judge the movement of landslide.

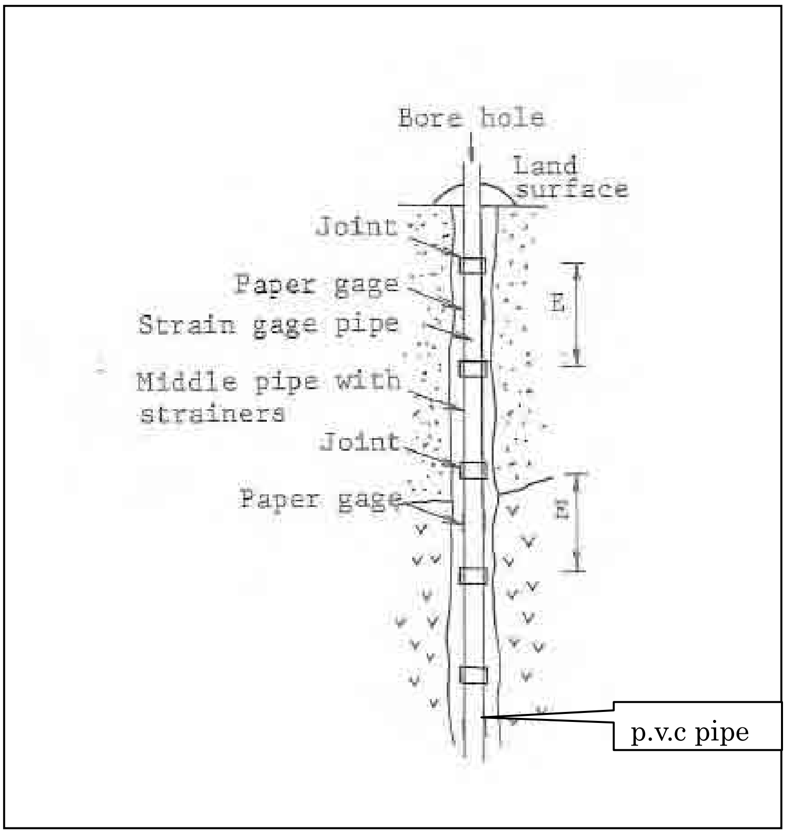


Fig.3-2 Setting of a pipe strain gage

(3) Arrangement of data

An example of data arrangement with depth in a bore hole is shown in Figure 3. This arrangement supposed that bottom value is zero by regarding the stable mass, and all the measurements above this zero value point are accumulated. The slip surface location can be recognized in the graph, because the line of accumulated strain shows a relatively straight line except near the slip surface.

Another way to arrange data is plotting each measured value as it is at each depth with a vertical line as a datum. Lines drawn by this method of data arrangement look more complicated than the former method, because the line returns close to the datum line after a large curve showing a change in strain near the slip surface. However, this method is convenient, because no cumulative calculation is required.

After drawing strain columns, a graph of cumulative strain change with time near the slip surface should be drawn for point where the trend in cumulative change is not clear in the strain column, as shown in the lower part of Figure 3.

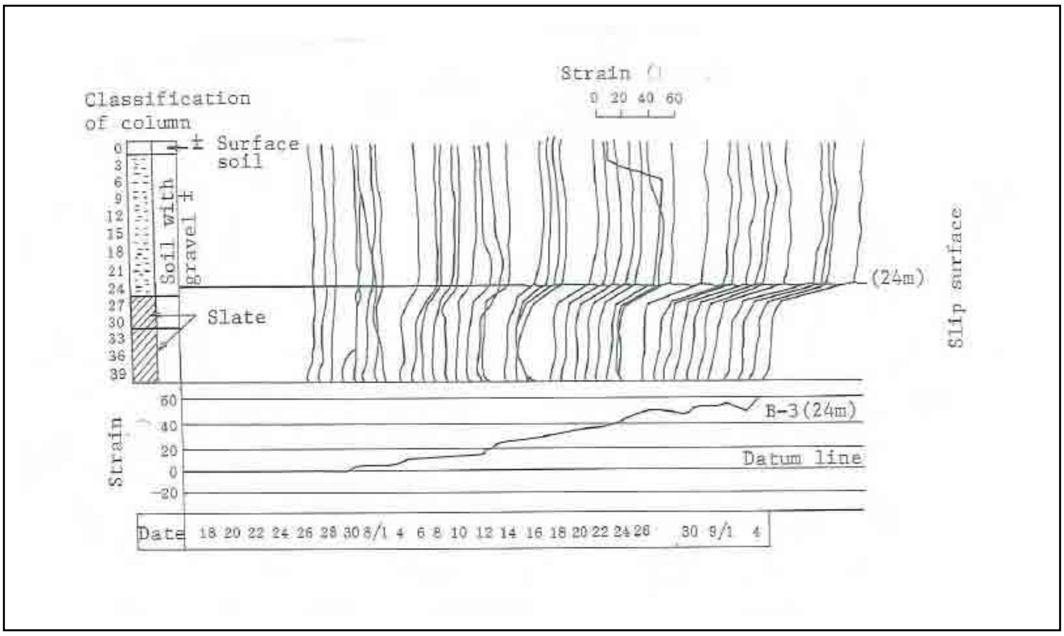


Fig.3-3 Figure showing an example of cumulative strain graph by an undergrounds strain meter.

A strain change of 10^3 micro is usually regarded as the change caused by a landslide. In the area of landslide with movement of some mm/day, a clear bend will appear in the strain column within 10 days.

(4)Criterion of pipe strain gage

In Japan, the discrimination using the results obtained from pipe strain gage is carried out according to the criterion shown as below table.

Table 3-1 Criterion of pipe strain gage

Danger degree of activity	Daily activity amount	Accumulative activity amount	Accumulative tendency to some direction	Movement type	Quality of activity
A	over 10^2 /day	over $5*10^3$ /month	Greatly remarkable	Accumulative activity	Activity movement
B	over 10^2/ day	over 10^3 /month	remarkable	Accumulative activity	Slowly movement
C	under10^2 /day	over10^2 /month	existed	*Accumulative *Intermittent *Recurring	Necessity of continuous measurement
D	over 10^2/ day	over 10^3 /month	No-existed	*Intermittent *Recurring	Local slope activity no-relating landslide activity

(5) Setting the pipe strain gauge

(a) The P.V.C pipes the order of depth so as not to getting entangled.

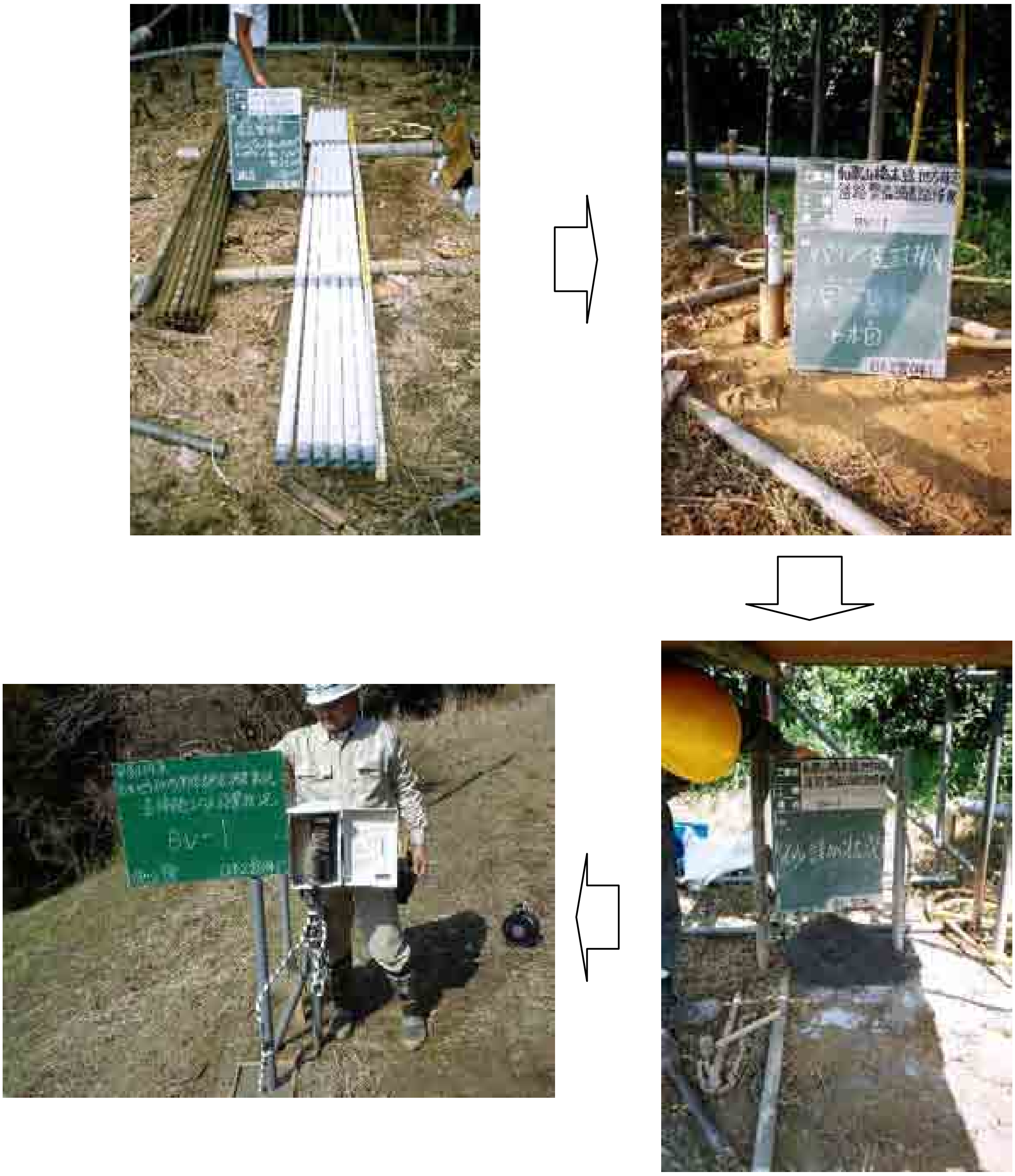
(b) While inserting the P.V.C pipes into the borehole, paint the glue at the joint and tighten the screw. Then Fix the joint by adhesive tapes.

(c) Insert the P.V.C pipes slowly with lead wires equally winding around the pipes. Be careful not to damage the strain gauge and lead wires.

(d) When all P.V.C pipes are inserted, pull out casing pipes, and fill the sand between the borehole and P.V.C pipes.

(e) Fix the head of pipe by concretes.

Picture3.1 Process of setting the pipe strain gauge



4. Surface Movement Survey

Landslide deformations are usually found with occurrence of cracks on the land surface. Although unusual phenomena like water level changes in a well or muddy spring water may occur before the cracks, a landslide is realized as a cause of these phenomena only when the cracks, on slopes are found.

Measuring cracks or bulges on the land surface is the easiest way to know the condition of a landslide. Accumulation of strain on the surface can be observed through tension and compression phenomena of the moving mass, after the movement at a slip surface occurs. Therefore, movement of the slip surface , can be observed in a short time in the case of land-slides in rock, composing rock of which can collapse with a small strain, but in the case of landslides like landslides in colluvium, which consist of relatively thick and plastic soil. It is difficult to observe strain on the surface unless the movement of landslide is large, because the strain due to sliding is absorbed into soil mass. The movement of land-slide early stages, which has only small amount of movement, cannot be detected without directed underground measurement. It is safe to assume that observed micro-phenomena on the surface occurred with certain delay after the movement of landslide.

To measure the movement of landslide on the surface, surveying landslide phenomenon in the area, measuring expansion and contraction of the land surface between two stakes and measuring tilting of the land surface are used. Purpose and method of surface movement surveys are explained as shown in Figure 4. However, because a moving area of landslide is more than 5ha (20~30ha are not rare) and an area of landslide sometimes covers 30~40ha, It is difficult to cover all the area by a dense measuring net. Therefore, an area which represents movement of the landslide must be chosen from the results of field reconnaissance, and meters should be set in this area. When expansion of the landslide activity can be expected meters should be set up to cover the area of land-slide with referring topography and geology.

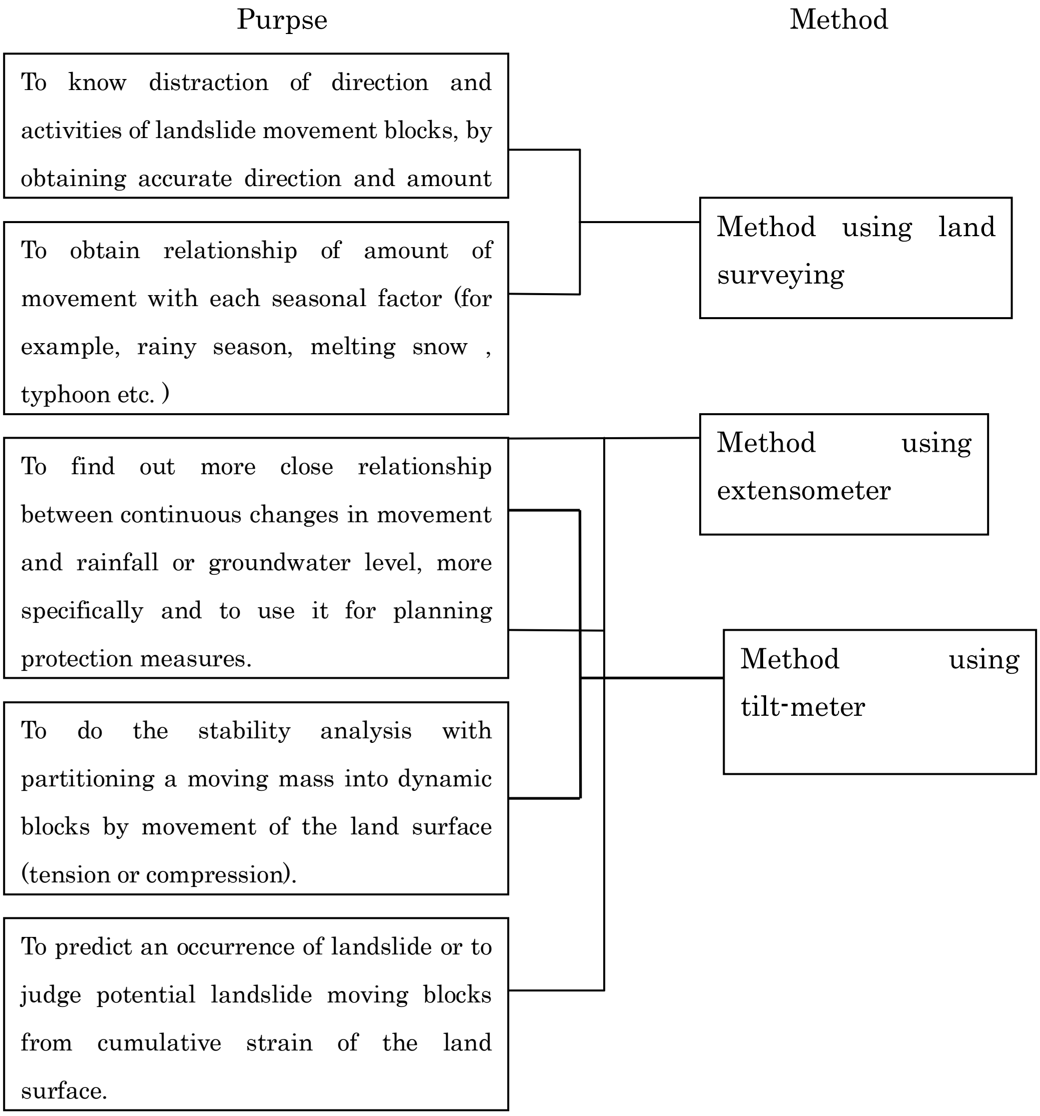


Fig.4-1 Purpose and method of surface movement survey

4.1 Extensometer

(1) Measurement of the land surface movement by extensometers

Extensometers are set parallel to the direction of movement of the landslide along survey lines. Along supplementary survey lines, and in middle or toe area of the landslide extensometers are set at suitable points where clear crack or steps land are located.

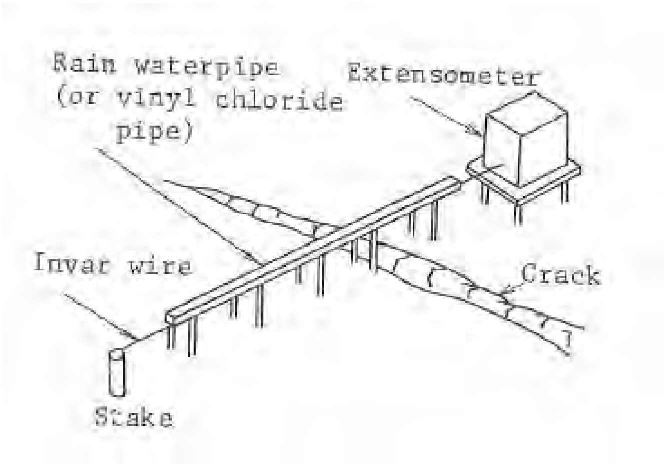


Fig.4-2 Setting of an extensometer

Picture: extensometer

This is the most common method to measure the movement of landslides. The device is set across a crack at a slide of landslide head or across other fractures as shown in figure 5. The device is mechanically simple. A wire is stretched between two stakes set on both sides of a crack, and extension and contraction of the wire is measured. An invar wire, which does not change with temperature, is commonly used. The wire is pulled out by expansion of the crack, and it is pulled by a weight or a spring, when the land surface is compressed at. The movement of the invar wire is enlarged five times by equipped gears in a recorder, and it is recorded on a rotating drum.

Because the minimum reading of recording paper with a direct reading type is 1mm, its accuracy of analysis becomes 0.2mm. Although the preci-sion can be increased by using electric resistance to record the rota-tion of drum electrically, this precision is almost useless, because errors caused by a spring of the drum, wind and transforming system (tension of wire and the way in which the protection tube is installed) may be larger. Except the special case that requires high accuracy (there are some examples of 20 times accurate measurements), this kind of precision is unnecessary.

While measurement itself is easy, some matters need special attention when the device is set. Stakes should be driven into the ground at least 50cm. If possible, stakes are set in excavated holes and they are fixed by concrete about 10cm thick with more than 50cm long sides, to prevent a shake of stakes by wind or to prevent being destabilized by surface erosion. To avoid a swing of the wire with wind, a protection tube is installed. The protection tube should be installed not to touch the wire and stakes at both ends, because it causes errors with temperature change. The length of the wire should be less than 20m, and the suitable length is about 10m.

(2) Observation

Some recorders can run for a month and others can run for a week or a day. Even a long run recorder is used, it is desired to check every day and to write down the time of checking on the recording paper. Because meters installed in field often experience unexpected breakdown, the minimum effort must be made to avoid a lack of measurement.

(3)Arrangement of data

The results of measurement are arranged in a graph in which cumulative movement is on the vertical axis and time (data) is on the horizontal axis, to be able to compare with rain fall or groundwater level, as shown in Figure 4-3.

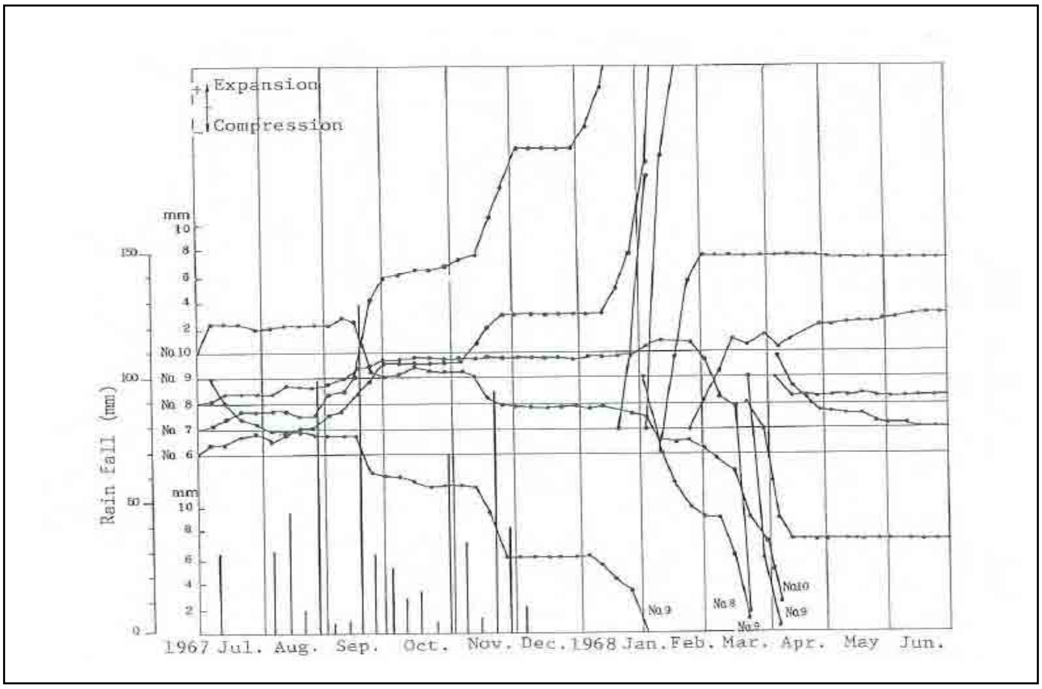


Fig.4-3 Example of measurement of the land surface movement using an extensometer

(4)Criterion of extensometer

In Japan, the discrimination using the results obtained from extensometer is carried out according to the criterion shown as below table 4-2.

Table4- 2 Criterion of extensometer

Danger degree of activity	Daily activity amount	Accumulative activity amount	Accumulative tendency to some direction	Movement type	Quality of activity
A	over 1mm /day	over 10mm /month	Greatly remarkable	Tension movement	Activity movement
B	0.1-1mm/ day	2-10mm/ month	remarkable	Tension movement or continuous movement	Slowly movement
C	0.02-0.1mm/ day	0.5-2mm/ month	existed	Tension or compression movement	Necessity of continuous measurement
D	If any over 0.1mm	No-noticed	No-existed	No-regulation	Local slope activity no-relating landslide activity

Picture. Setting of extensometer

(5)Vertical extension meter

It is vertical extension meter to improve, and to have made this general extensometer. This measures the slide surface by setting it up in the bore hole. This machine can be used for a long term, and there is few, cheap advantages to damage.

Picture: Vertical extension meter

4.2 Tilt-meter

(1) Measurement of movement of the land surface by tilt-meters

Tilt-meters are commonly used for measurement of the land surface deformation in the area of landslide. Although a tilt-meter is put as a point measurement, it is thought to indicate the deformation of land surface of the area around the point. However, in the area where the movement of landslide is intense and many cracks divide the landslide into small blocks, records of tilt-meters are diverse and it is difficult to catch a trend of movement. Tilt-meters are used commonly in the area of potential landslide. When they are used in the area of active landslide, the purpose is to judge whether the landslide is in an active stage or in an ending stage.

The land surface is said to have invisible tilting which is caused by natural shifts of weather, earthquake, or tide. Judging from the analyses of tilt-meter records, the average of its tilting is estimated as 3 sec/day in a hill area, and it is less than 5-6 sec/day in mountain areas. When tilting larger than this amount is observed, the area can be regarded as a potential landslide area if the tilting has a cumulative trend. On a stable land mass where the strain is recovered, on the other hand, the tilting will show a trend returning to the original state.

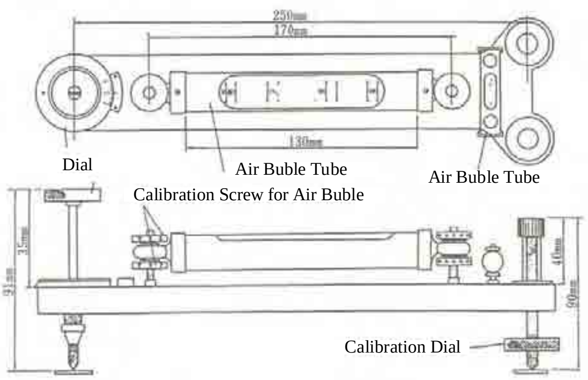


Fig. 4-3 Water bubble type tilt-meter

The common tilt-meter those which is a hand-operated water bubble type tilt-meter (Figure 4-3).

This is easy to operate and to install, but measurement must be done manually every day. The tilt-meter which can record the movement of a bubble auto-matically is developed, but it costs a lot to maintain a battery or to install cords (a 24V battery or 100V. AC electricity is used) in remote areas, where landslides usually occur.

(2) Setting of tilt-meter

A problem of installation of a tilt-meter is its foundation. A water bubble tilt-meter is very sensitive with the accuracy of 1.2' of tilt angle to 1°of graduated plate rotation, and it may tilt only by the weight of an observer if the foundation is not firm enough.

When the tilt-meter is installed, surface soil is excavated about 20cm at first, and a wooden pile (1m long and 10cm in diameter) or a triangular, cross section steel plate (1m long, 5cm side) is driven into the ground about 80cm. A concrete block is set firmly on its head, and then glass plate (Figure 8) is put horizontally on the surface to complete the installation table. This installation table should be covered by a box to house the meter. A water bubble tilt-meter is convenient to use. Two tilt-meters are set perpendicular each other direction (N-S and E-N directions) on a table, and their main axes (axis with a graduated plate) are set on N and E side.

The direction of tilting, when the main stems of tilt-meters are put on N and E sides , is obtained from Table 4-4.

Measurements sometimes start before the concrete foundation becomes firm and stable. Strain of the foundation itself may disturb the measurement in the early stage.

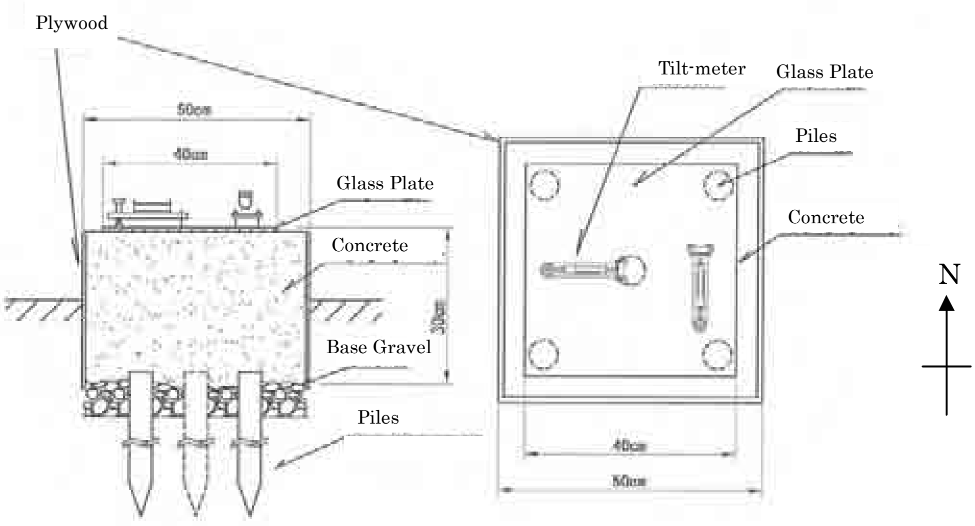


Fig.4-4 Typical Installation of Water Tube Tilt-meter

≪ Ready to protection box≫

1) Settle the protection box above the foundation of concrete to protect the tilt-mater and block the window, rain, and the direct rays.

2) Make the protection box to block the direct rays during measuring the tilt-mater, and lock the cover for the prevention robbery (Figure4-5).

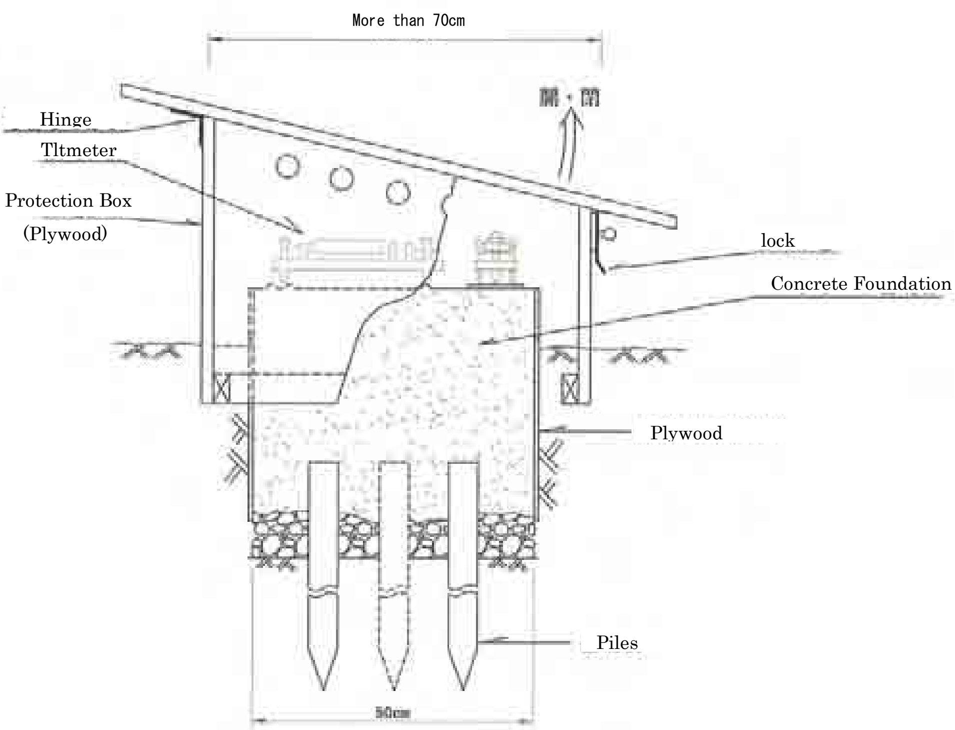
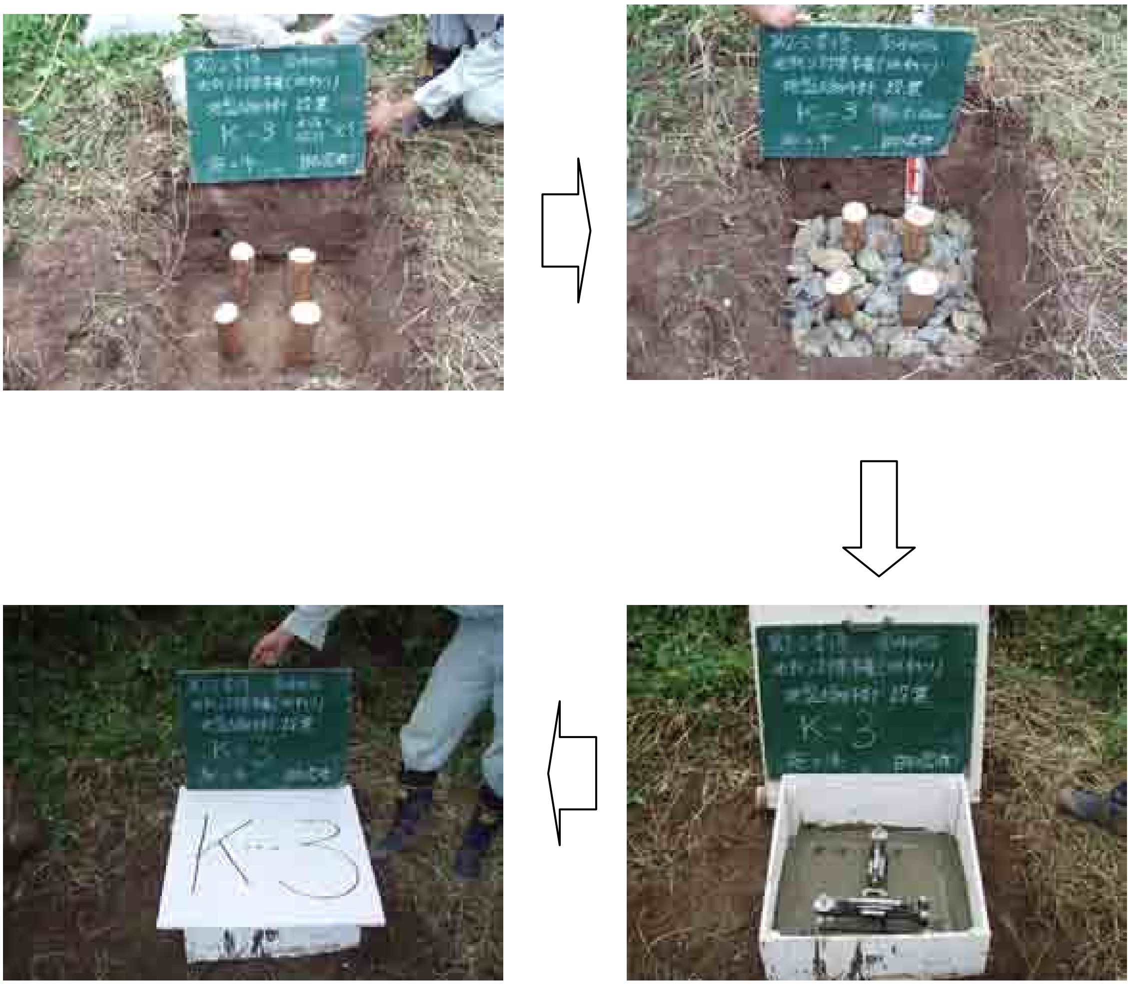


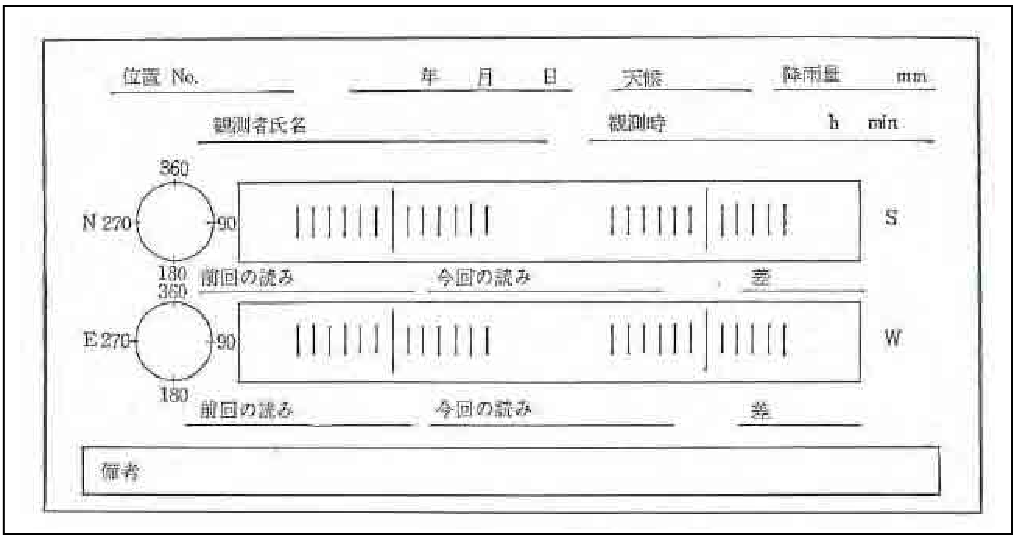
Figure 4-5 Protection Box

Picture:　Process of setting a tilt-meter



(3) Observation of tilt-meter

Table 4-3 Arrangement paper of data



① Enter the Tilt-meter number, date, time, observer's name, weather in an observation form.

② Open the cover of Protection Box without getting sunshine.

③ Before touching the Tilt-meter, Check the shape of air bubble and the tick mark of protractor, and enter these data in an observation form.

④ Center the air bubble with rotating the protractor dial. Be care of rotating too much, because of one tick mark of the air bubble is equal to 10 tick marks of protractor.

⑤ Enter the value on the tick mark and the situation of protractor rotation in an observation form.

⑥ Enter the difference of the tick mark of protractor between this time and late time. In the case of the values of each times crossing zero, be care of the sign and the value of difference.

⑦ Close the cover of Protection Box.

(4) Tilt-meter monitoring analysis

Table 4-4 Form for analysis

Plate	Number of days (n)	Tilt in N-S direction (Second)	Tilt in E-W direction(Y) (Second)	Maximum tilt $\phi_n=\sqrt{X^2+Y^2}$	Direction of tilt ϕ	N-S cumulative tilt ΣX	E-W cumulative tilt ΣY	$(\theta_n-\bar{\theta}_n)^2$	Note
	1								
	2								
	3								
	⋮								
	⋮								
	⋮								
	n								
Total				$\Sigma\theta_n$	ϕ_N	ΣX	ΣY	$\Sigma(\theta_n-\bar{\bar{\theta}}_n)^2$	

Purpose: to understand the direction and the amount of tilt movement.

① Check the date and observes value (the above value of ⑥) each tilt-meters.

② The real value of tilt movement is 1.2 times the observed value.

③ Compose of the N-S direction and E-W direction, and calculate the maximum amount of tilt movement. The following is the expression.

$$\text{Max}=\sqrt{(N-S)^2+(E-W)^2}$$

④ Calculate the amount of average tilt movement in a day.

Daily movement : $\bar{\theta}_n$ Direction of tilt = Cos ϕ

$$\bar{\theta}_n=\frac{\sum\theta_n}{n} \qquad S=\sqrt{\frac{\sum\left(\theta_n-\bar{\theta}_n\right)^2}{n(n-1)}}$$

Daily movement = $\bar{\theta}$ ±S (S= Standard deviation)

cos ϕ = | N-S | /Max

⑤ Confirm the direction of tilt movement. That is judged by the following table of the sign combinations of observed movement values.

Table4-5 Relation between positive and negative and direction of dip

Sign of movement of N-S direction	−	−	+	+
Sign of movement of E-W direction	−	+	−	+
Tilt direction	N φ° E	N φ° W	S φ° E	S φ° W

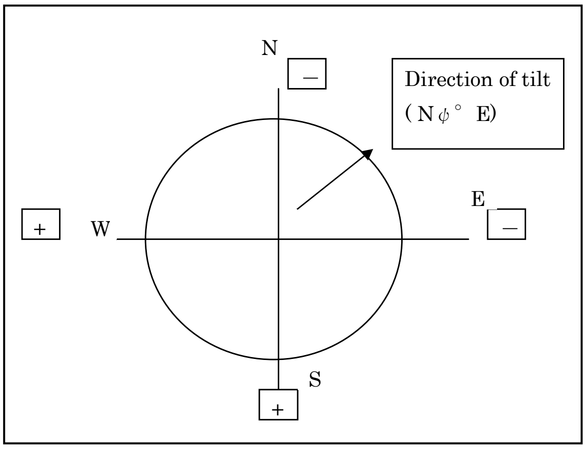


Fig. 4-6 Idea of direction of dip

(5) Arrangement of data

Purpose: to understand the situation of movement in time series.

① Make a line graph that X-axis is time, Y-axis is tilt movement. Put the direction of N-S and E-W on the graph each other.

② To confirm the relation of rainfall, make with a line graph of precipitation.

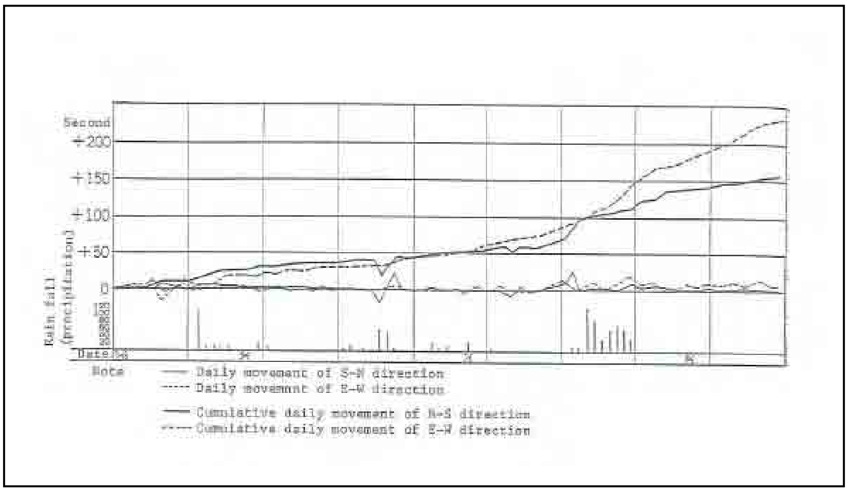


fig.4-7 Figure showing an example of measurement by a tiltmeter

Figure 11 shows an example of measurement by a water bubble type tilt-meter. Activation of the landslide by rain fall accompanying with typhoons in July is clearly shown, and accumulation of land surface deformation with rainfalls before July is also shown.

(6) Criterion of tilt-meter

The judging criterion of landslide activity from the viewpoint of tilt-meter data is as follows.

Table 4-6 Criterion for tilt

Danger degree of activity	Daily activity amount	Accumulative activity amount	Accumulative tendency to some direction	Movement type	Quality of activity
A	over 5 sec /day	over 100 sec /month	Greatly remarkable	existed	Activity movement
B	1-5 sec / day	30-100 sec / month	remarkable	existed	Slowly movement
C	Less1 sec / day	Less 30 sec / month	existed	existed	Necessity of continuous measurement
D	If any over 3 sec/day	No-noticed	No-existed	No-existed	Local slope activity no-relating landslide activity

4.3 Survey pile

(1)Measurement of pile

Along line connecting two points on both stable sides of a land- slide, suitable number of survey piles are set on the moving mass, and movement of heads of those piles are surveyed by a transit. This so-called perspective land survey of landslide is simple, but it can detect the movement of landslide relatively well.

Direct measurement of the movement is possible, if graduated rods instead of piles are used laterally. However, the movement of piles or rods may not show exact direction of the landslide, and other errors, such as tilting of piles, may often occur. In spite of these short-comings, this method can be used to see a general trend of landslide movement.

Triangulation has often been used in observation of large scale landslide movement, because it provides accurate coordinates. However, the larger the landslide area, the further the position of the base line should be, and sometimes it is necessary to set the base line on the stable land in the opposite side of the valley.

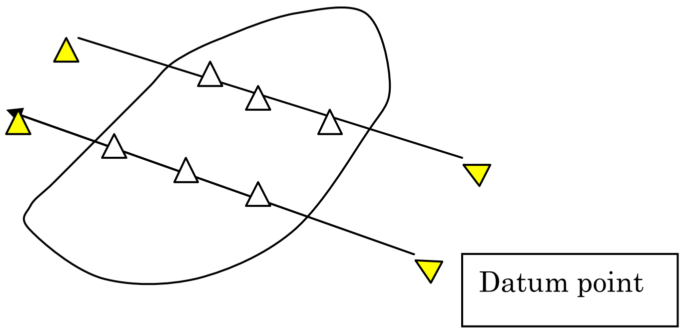


Fig. 12 Measurement of survey piles by a transit

4.4 Sliding measurement using aerial photographs

When a sliding area is so large, and measurement by extensometer and tiltmeter is not enough to cover the area, aerial photographs can be used.

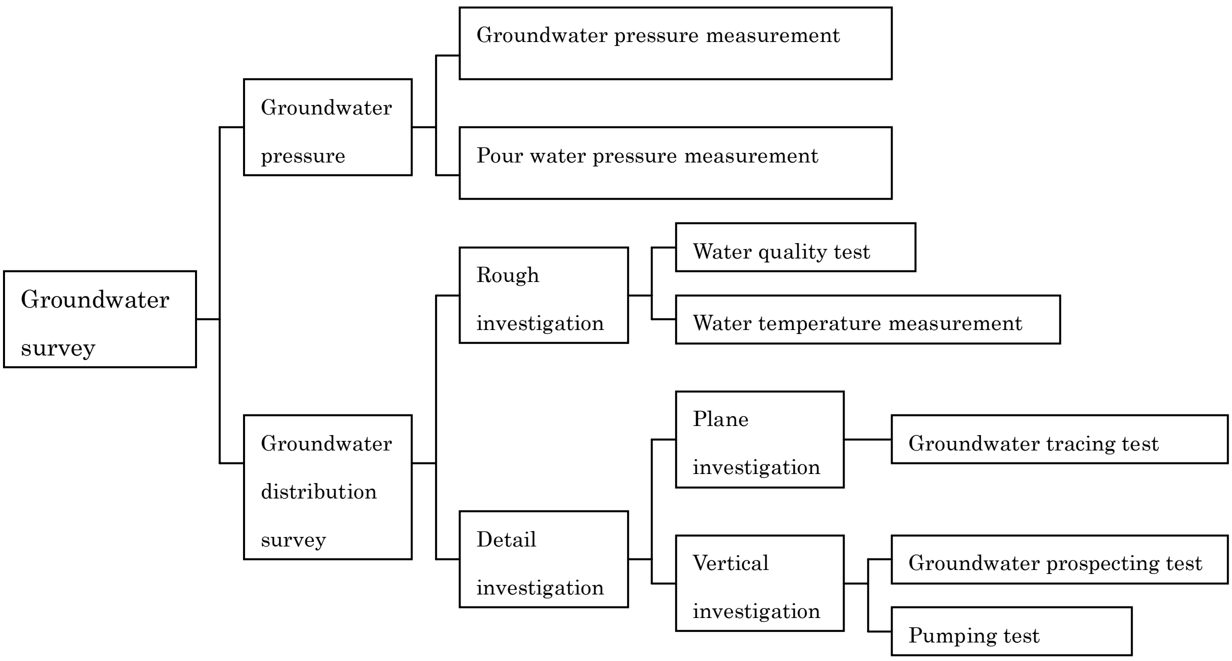
Aerial photographs, which are taken on the same area with a certain time interval, are useful to measure the amount and direction of movement. However, aerial photographs have not often been used, because of the large expense of flying an airplane and taking photographs,

Kamenose landslide , which occurred in Osaka pref. Japan in 1967, is a good example which was well analyzed by aerial photographs. Aerial photographs were taken 11 times from February 21, 1967 to June 22, 1968, because an airport located near the landslide and taking aerial photographs was relatively cheap.

5. Groundwater survey

Groundwater plays an important role in landslide initiation. Application of pore water pressure and decrease of soil strength by increase in water content of soil destabilize a slope, and extracting groundwater is a foundation of measures for landslide control. Careful investigations in order to grasp the condition of groundwater storage are desired, because they provide important data for planning measures of landslide control.

Groundwater survey is conducted mainly on its distribution, courses of supply and flow, and effects on landslide. It is set out in items below.



Measurement of groundwater level and vertical groundwater prospecting should be done, because their results will be very important to plan groundwater drainage works, and to judge its effectiveness.

5.1 Measurement of groundwater level

Vertical bore holds, which were used in geologic investigations, are usually used for measurements of groundwater level.

Measurements can be made manually or automatically. In the case of manual type, groundwater level is measured with a groundwater level detector, which is an ammeter (an electric current meter) with a steel tape having a weight and an electrode at the end, as shown in Figure 13, every day at the same time. Accuracy of this device is about 1cm.

More simply, a covered double wire cord with an ammeter can be used.

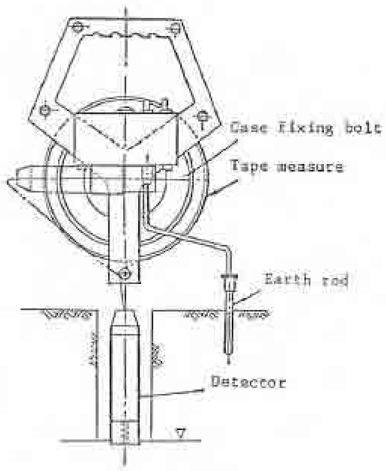


Fig.5-1 Groundwater level detector

A scale marked on the cord is read when the ammeter indicates that the tip of the cord touches the groundwater surface Accuracy of this method is about 5cm, but this can be used in some occasions, because the amount of water level change which affects the stability analysis of landslide is more than 10cm or 0.01 Kg/cm^2 in pore water pressure.

As an automatic recording device, a less expensive tidal gage (Rishirl type) has been used. Because of the limitation of bore hole diameter, a float 32mm in diameter and 45mm long has been used in a protection pipe (45mm in inner diameter) with strainers. However, it has often shown inaccurate measures due to the float wire's sticking to the bore hole wall, because the water surface is usually deep (10-15m) and bore hole is not always straight.

Measurement of groundwater level is useful to investigate the mechanism of groundwater flow in the area of landslide,and the height of groundwater level from the slip surface can be used as a substitute of pore water pressure which is necessary for the stability analysis.

5.2Vertical groundwater prospecting

Groundwater level in a bore hole shows a water head of permeable layers, but it alone does not indicate which layer or how many layers groundwater is flowing through.

Normal groundwater has electric resistively 6000 -7000Ω, and the resistively can be easily lowered by mixing small amount of electrolyte. With using this property, a method to measure the surface of groundwater flow and discharge has been developed. Measurement by this method provides very useful data for groundwater drainage works.

A logging detector (a bunch of electrode cords), which has electrodes at an interval of 25cm, is inserted into a investigative bore hole, and background resistively of each depth is measured. The detector is once extracted, and electrolyte (commonly salt, 0.5% of water in the hole) is mixed into water in the hole to lower the resistively to about 500Ω. The detector is reinserted immediately, and measurements are made at 5, 10, 15, 30 and 60 minutes after the insertion. Taking the measurement at 5 minute as a datum, changes in resistively are calculated and plotted as shown in Figure 14. Rapid increase in resistively at the point of groundwater flow is clearly shown in the graph. Because the rate of change in resistively is proportional to groundwater discharge, discharge is ought to be calculated from the resistively change. However, accurate calculation of discharge is impossible, because of difference among individual electrodes or strainers.

The most important point in this method is complete mixture of electrolyte. The best way to mix is that a vinyl hose 4mm in inside diameter, in which a solution of electrolyte is flowing, is moved from the bottom of the hole to the groundwater surface 2 -3 times. Mixing by bubbles of air pumped to the bottom of the hole sounds good, but it (10 -15 minutes of operation) may create uneven water quality or a section of decreased resistively.

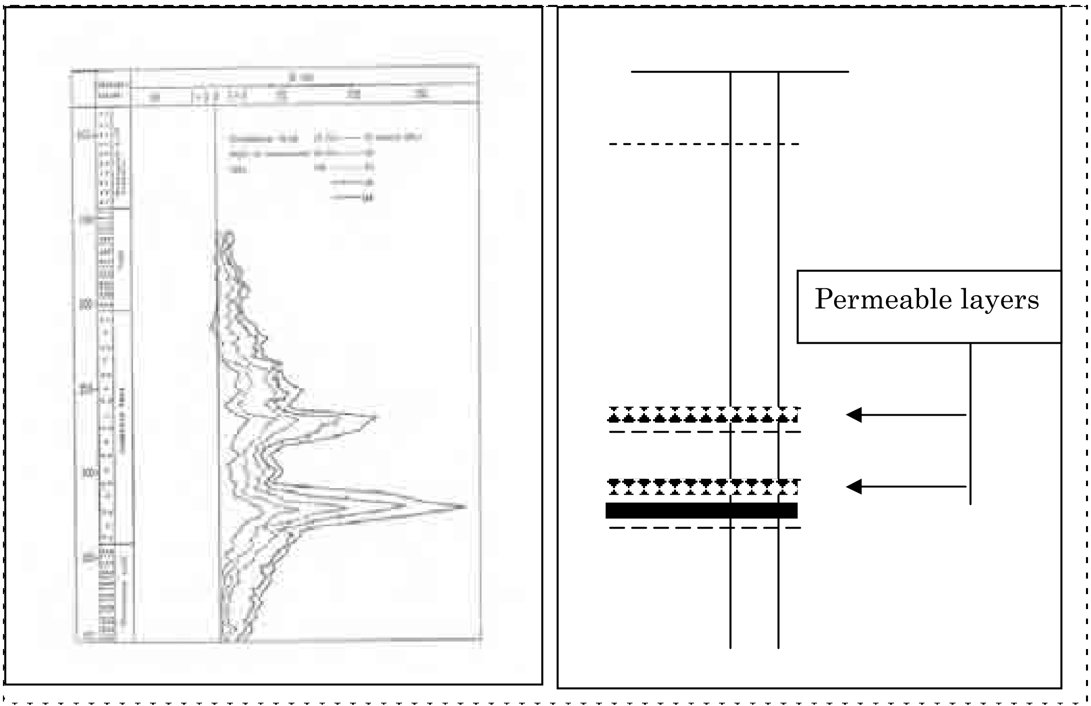


Fig.14 Example of vertical groundwater prospecting

The most important point in this method is complete mixture of electrolyte. The best way to mix is that a vinyl hose in inside diameter, in which a solution of electrolyte is flowing, is moved from the bottom of the hole to the groundwater surface 2 -3 times. Mixing by bubbles of air pumped to the bottom of the hole sounds good, but it (10 -15 minutes of operation) may create uneven water quality or a section of decreased resistively.

The continuous limit of measuring time is 3 hours, though it sometimes difficult to judge the surface of groundwater flows within the time, in the case of small discharge. In few cases, the background resistively of groundwater is less than 0.5Ω. As in Seseki district, Matsushiro, Nagano pref. where measurement was impossible, because resistively did not lower even after a large amount of salt was added. In this case water of high resistively should be poured, and decrease of resistively should be measured.

This measurement must be done in bore holes near the head of landslide or along the main survey line. This method is the best to find permeable layers for water drainage boring, or to decide the depth of water drainage wells. The surface of groundwater flow locates at a boundary of strata, and it is often found in a zone of cracks. Analysis should be done with referring to the geology of the area.

5.3 Measurement of pore water pressure

Groundwater level should be used in stability analyses only as a substitution, and pore water pressure at the slip surface must be used if it can be measured. Because groundwater level in a bore hole often show a change caused by losing water through cracks, or it shows water level of a major aquifer, changes in pore pressure of each aquifer and slip surface cannot be known.

5.4Groundwater tracing test

After tracers, such as water-soluble colors and inorganic chemicals, are mixed in groundwater through bore holes, detection of the tracer is conducted at springs, bore holes, wells, streams, ponds or swamps in and around the area of landslide. The water flowing paths can be estimate and this velocity can be calculated, and the result is used as a fundamental data for ground-drainage works. Groundwater quality should be checked at least once a day for a week before the test, because the same material resembling to the tracer may naturally exist in the groundwater.

The bore hole, in which the tracer is thrown, should be in the head area of landslide, and a large amount of water should be poured in to increase the hydraulic head for the increase of permeability. Sampling water at the permeable layer is desired, and in a bore hole water should be sampled at the layer of groundwater flow, which is detected by the groundwater prospecting.

Water sampling is done at all the sampling points between an interval of 0.5, 1, 4, 8 hours after the tracer put in, and after that, the sampling and the test is performed once every day.

Points, where the tracer is detected, should be recorded on a map, and the way of groundwater flow on the map is estimated from changes with time. A coefficient of permeability is calculated by dividing the distance from the bore hole, in which the tracer is thrown, to the sampling point, where the tracer is detected, with the time from throwing to detecting. The coefficient is generally 10^{-1} – 10^{-3} cm/sec.

Salt or fluorescein soda（reagent）, which are harmless, are good as a tracer. There are disadvantages of these materials. Salt requires large amount, because $c1^{-}$ ion is commonly found in natural groundwater, and fluorescein soda is easily absorbed by clay particles.

Manganese sulfide（SO_4^{-}）, potassium(K) dichromate（C r） or radio isotope is possibly used in without the damage from agricultural chemicals, but it is not common.