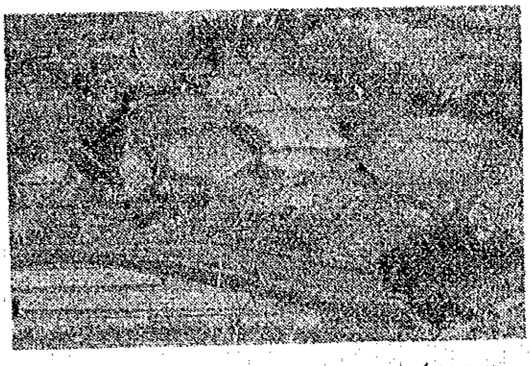


P.132 Diagram 5-1 SENMAIDA (in Japan)
(Thousand terraced fields)

not yet evident. Following to the study of the map, the following are to be investigated in the actual landcreep area.

1) Positions of sunken and protruded topography.

2) Positions, directions, length, and width of cracks.

3) Movement direction of the creeping land.

4) Directions and positions of faults, if any.

5) Positions of ponds, swamps, marshland, and spring.

6) Positions of abnormaly phenomena such as heeled houses and trees as well as cracked roads, etc.

These investigation results are then inscribed into a 1/5000 scale topographical map which is to be utilized for the planning of landcreep prevention works.

4. Geological Survey

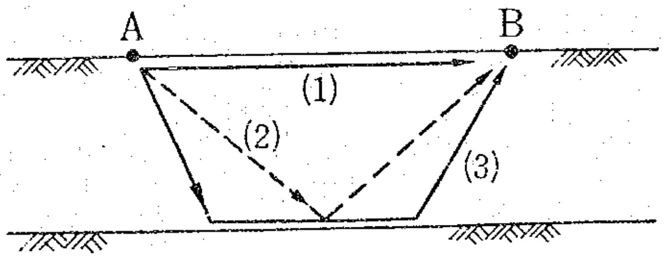
Cause and scope of the landcreep can also be estimated from detailed geological structure investigation since landcreep exhibit close relations with the geological structure of the topography, such as frequent generation in areas with particular types of geological structure. The following methods of survey are generally performed.

(1) On - Site Survey

The overall geological structure of the subject are may be reviewed by studying the geological structure chart. However, it is further necessary to survey the strike, incline, thickness, and existence of faults, etc. of the underlying rock at the site of the landcreep.

(2) Seismic Prospecting

This method of investigation employ the elasticity wave (earthquake wave) feature to change the transmittal speed while transmitted through the ground depending on the hardness of the geological structure. Therefore, the geological structure is determined with the measurement of the elasticity wave transmittal speed. Furthermore, the thickness of the stratum may also be determined by measuring the difference in the transmittal time, for the elasticity wave transmittal time varies depending on the direct, reflected, and refracted waves as illustrated in diagram 5-2.



(a) Direct Wave (b) Reflected Wave (c) Refracted Wave

Diagram 5-2 Seismic

Survey points are to be placed in lattice form through the subject area when performing the investigation.

(3) Electrical Prospecting Method

Geological structure may also be determined with this method which employs the electrical characteristic where the conductivity varies in accordance with the geological structure. Actual investigations

are accomplished by taking measurements of the electrical resistance (Specific resistance) between two points.
This electrical resistance investigation may be segregated into horizontal investigation where the two measurement points are established horizontally, and vertical investigation where the two points are vertically established. The former of the two is suitable for the location of the distribution of ground water. Furthermore, boring holes are used for the vertical investigation.
As with the seismic wave investigation, survey points are to be placed in lattice form throughout the subject area when performing the investigation.

(4) Natural Radiation Measurement

Vaporized Radon and Thoron are often found to be released from through the crust faults and fractured zones when such conditions are existent. Therefore, existence of such faults and fractured zones may be determined by measuring these natural radiations.

(5) Boring

This is a method where vertical holes are bored into the landcreep ground in order to obtain core samples for visual determination of the geological structure as illustrated in diagram.
Accurate results may be obtained with this method. However, it is necessary to employ this method in conjunction with other methods since it is highly costly and therefore prohibitive to bore throughout the subject area.

Diagram 5-3 Boring Core Samples

5. Ground Surface Shift Survey

To investigate and analyze the timing, volume, direction, and speed of the landcreep are highly useful for the prediction of landcreep generations as well as are essential data for the planning of landcreep prevention measures. Following methods are available for the landslide movement volume investigation.

(1) Surveying with Level Post

Landcreep volume may be measured with the placement of level post in the subject area and the measurements taken from them. Diagram 5-4 illustrates the placement of level post in rows and diagram 5-5 illustrates lattice form placement. Level post are to be placed throughout the subject area with the control point on immovable ground.

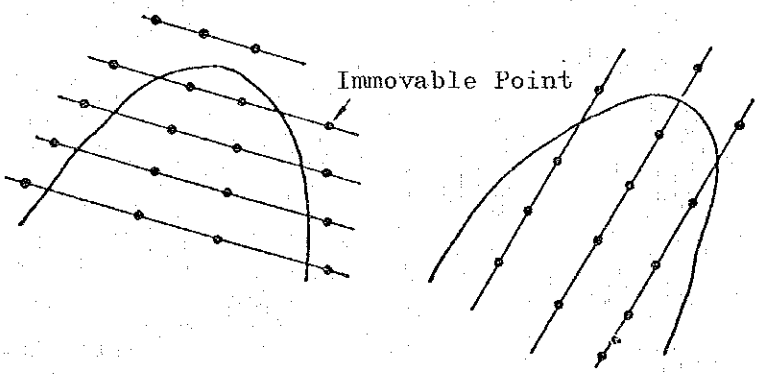


Diagram 5-4 Row Formed Level Post Placement

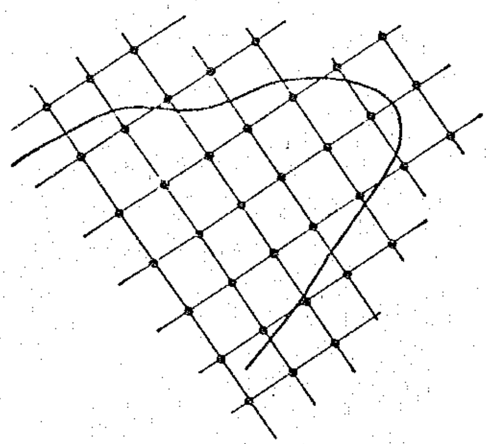


Diagram 5-5 Lattice Formed Level Post Placement

2) Expansion Gauge

Landcreep volumes may be determined by measuring the survey line expansion caused by the movement of the land, with expansion gauges placed in the vicinity of the landcreep area border. The expansion gauge is placed on immovable ground with poles driven in the subject landcreep area, normally in the stress cracked sections of the Crown of the landslide area with tension cracks along the movement direction.

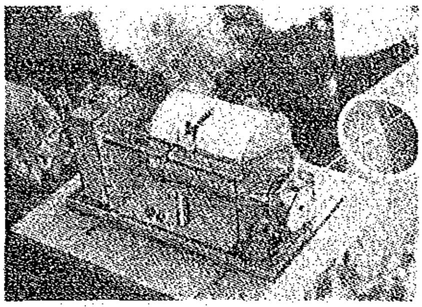


Diagram 5-6 Expansion Meter

(3) Tilting Gauge

Methods employing level posts and expansion gauges are methods where the landslide volume is measured directly, where as the method employing the tilting gauge is used for estimating the landslide volume indirectly with the change in the incline of the topography.
A pair of pneumatotubes are placed perpendicularly each other within the tilting gauge as illustrated in diagram 5-7. The movement of the bubbles within these pneumatotubes are measurable with the adjustment volume of the screw. The tilting gauge is suitable for measuring the minimal movements of the earth caused by the landslide.

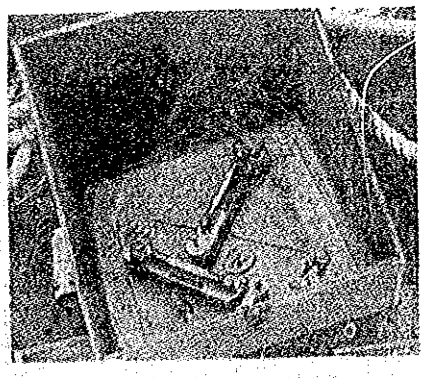


Diagram 5-7 Tilting Gauge

6. Sliding Surface Survey

The following methods are available for accurate means of the position of the sliding surface.

(1) Investigation by Boring

This is a method where the sliding surface is determined from the columnar section obtained by boring, and landcreep clay are generally foung in the sliding surface. Boring survey lines are established in the deepest estimated sliding surface, but is also desirable to be established beyond the landslide area for both ends of the boring line, in order to detect the existence of the latent sliding surface as illustrated in diagram 5-8.

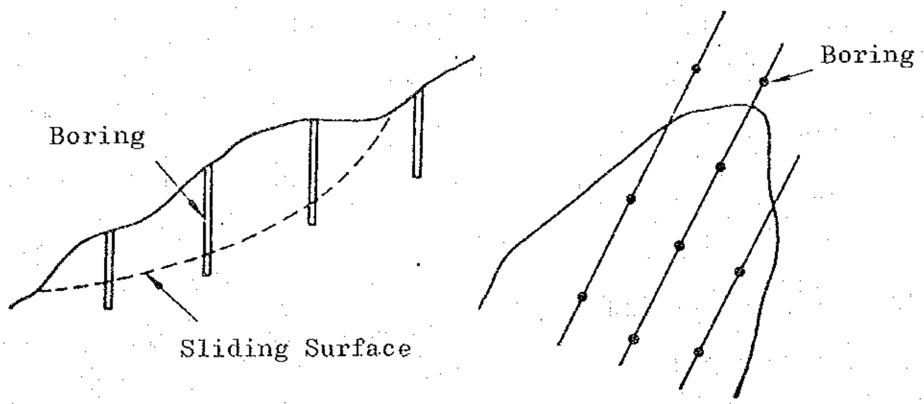


Diagram 5-8 Boring

(2) Investigation Using Strain Gauge

This is the method where the volume of strain is measured with electrical resistance strain gauge (Diagram 5-9) placed in the vicinity of the sliding surface using the boring hole. This method is suitable for measuring slight movements, and sliding surface position and its shift may be evidently observed as the measurement results are accumulated strain as seen in diagram;5-10.

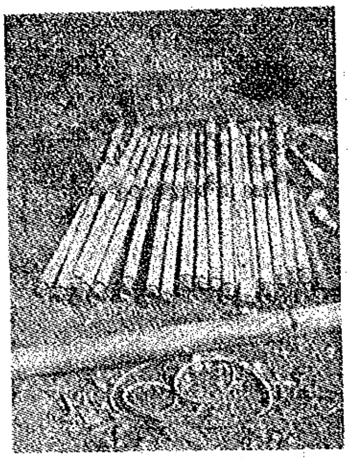


Diagram 5-9 Electrical Resistance Strain Gauge

7. Ground Water Survey

Landslide are often caused with ground water. This is due to the increase of sliding surface pore water pressure caused by the elevation of the ground water level resulting in the reduction of the sliding plane resistance.

The following methods are available for ground water level survey.

(1) Ground Water Level Survey

Ground water levels and landslides exhibit close relations in accordance with various landslide data. Existing wells and boring holes are used for ground water level observation.

Additionally, the water level must be observed after every rainfall. Observations are made by lowering ropes or with the installation of a self-recording water level gauge.

(2) Pore Water Pressure Gauge

Direct pore water pressure measurements may be taken with the installation of a pore water pressure gauge on the sliding surface. On the contrary, accurate pore water pressure measurements are scarce, since accurate installation of this equipment is difficult due to the thickness of the sliding surface being generally thin, as well as by the necessity to remove the earth pressure from the top. Therefore,

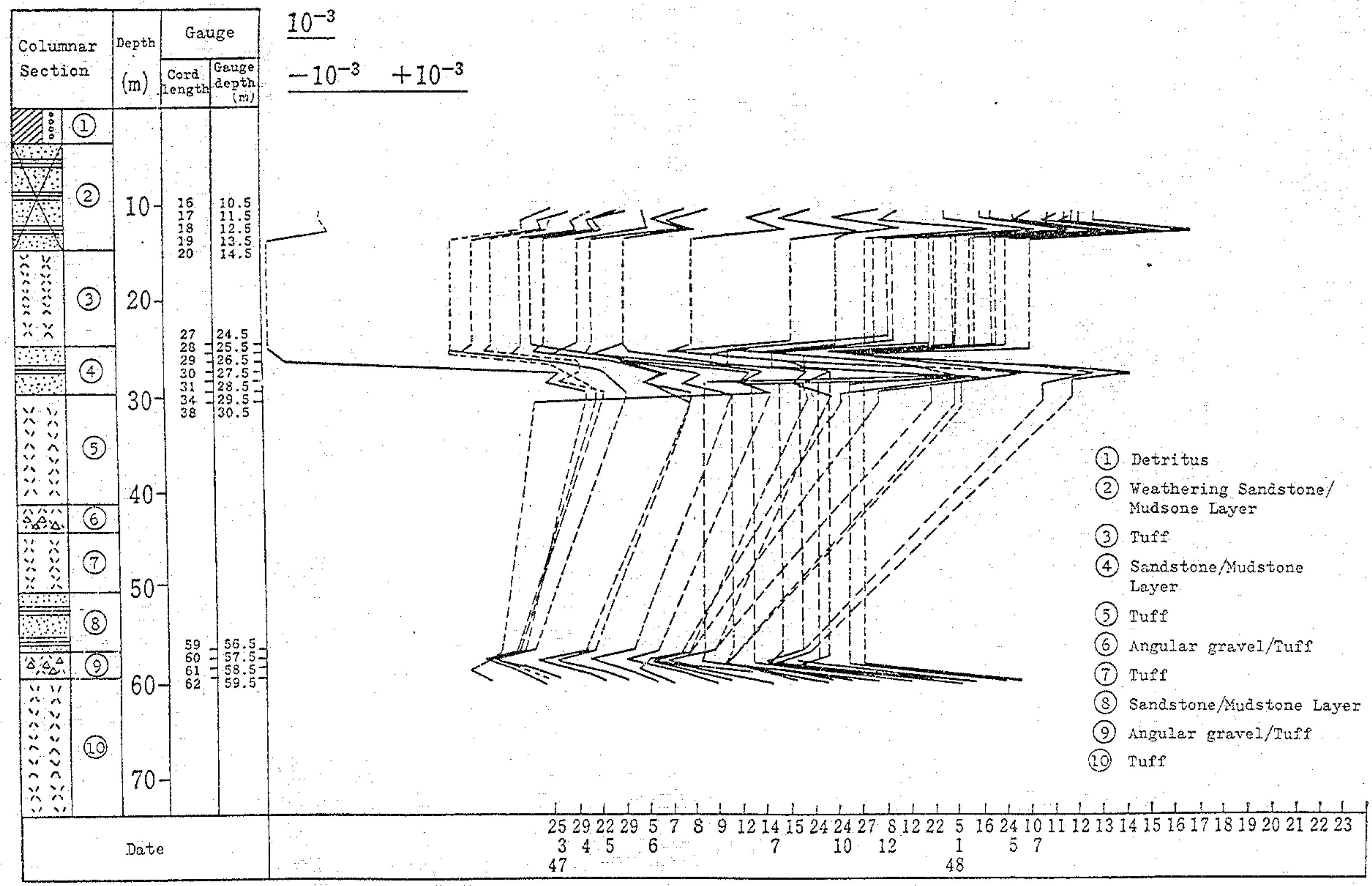


Diagram 5-10 Accumulated Strain Graph

pore water pressure are usually described with the ground water level.

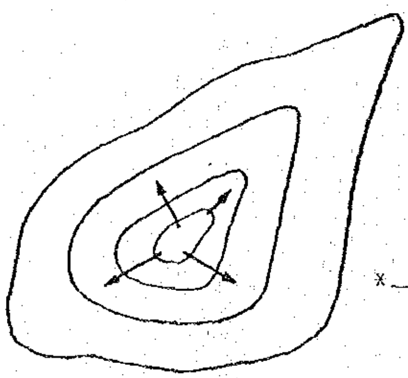
Diagram 5-11 Pore Water Pressure Gauge

(3) Conditions of Ground Water Flow

The following methods are available to determine the entry routes and distribution of ground water.

1) Ground Water Level Method

The flow conditions of ground water may be investigated by drawing ground water surface contour lines as illustrated in diagram 5-12 with water level measurements taken from existing wells and boring holes.



x ⟶ are the directions of ground water flow.

Diagram 5-12 Ground Water Level Countour Line Schematic

(2) Chemical Substance Application Method

Ground water routes may be determined with the application of chemical substances in the upstream for detection of downstream, when ground water routes may be guessed from the topographical and geological structure conditions, etc. in the vicinity of the landslide area.

Pigment, ion and radiation detection methods are available depending on the employed chemicals.

Section 2 Landslide (Landcreep) Prevention Work

1. Slope Stabilization

Slipping and sliding surfaces of slopes are generally in the form of a curve.

Therefore, these slipping and sliding surfaces are often assumed to be in the form of arc in the calculations for landslide stabilization.

The following are the consideration for a single block taken from the landslide clod segregated into width units. (Diagram 5-13)

Now, with;

$\widehat{ABC}$: Sliding Surface

O : Center of the arc $\widehat{ABC}$

R : Radius

W : Soil weight per width unit

ℓ : Sliding surface length width unit

U : Pore water pressure

θ : Angle where the B point tangent becomes horizontal

C : Sliding surface soil cohesion

ϕ : Internal friction angle of soil on the sliding surface

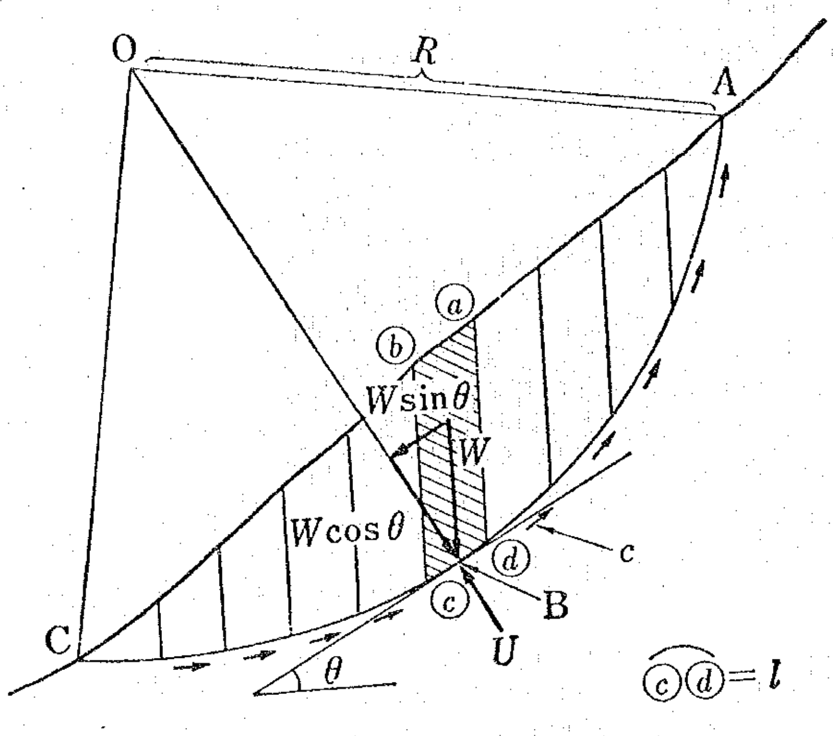


Diagram 5-13 Analysis for Slope Stabilization

The moment of the slippage generative force becomes:

(equation) $M_1 = RW \sin\theta$

and the slippage resistance moment become:

(equation) $M_2 = R\ \{(W\cos\theta - U)\tan\phi + cl\}$

Since the factor of safety is applicable for all of the blocks when the overall landcreep safety factor is F.S., it becomes:

(equation) $$F.S. = \frac{\Sigma M_2}{\Sigma M_1} = \frac{\Sigma\{(W\cos - U)\tan\phi + cl\}}{\Sigma W\sin\theta}$$

Therefore, the slope is stabilized when FS >1.0 and landslide occurs when FS <1.0.

W, l, and θ here are obtained on the graph, and U thru ground water investigation, as well as c and φ through soil shearing test.

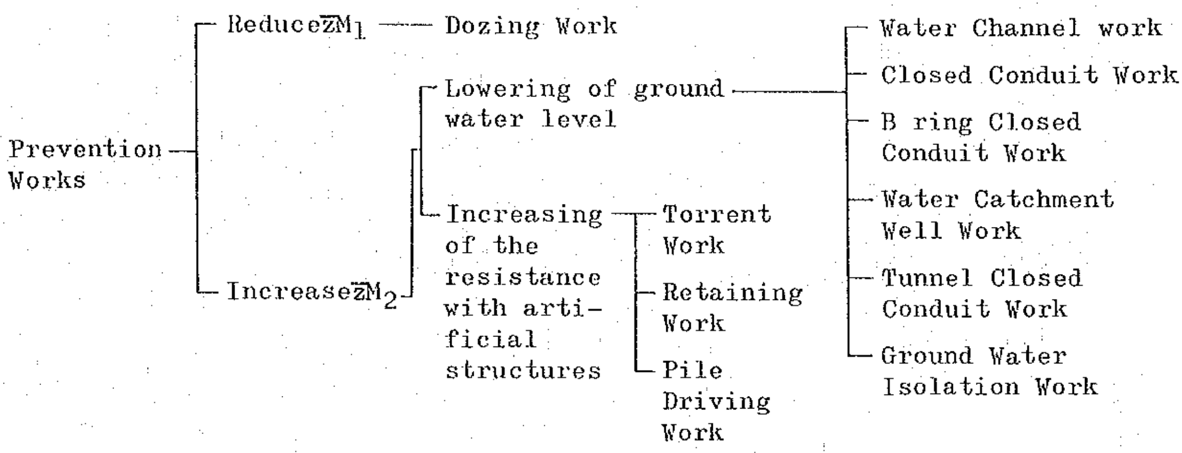
2. Landslide Prevention Work Plans

Landslide prevention works are normally planned with safety factor between 1.1 - 1.2 with the methods described below.

1) By reducing (equation) $\Sigma M_1 = \Sigma RW \sin\theta$

2) By increasing (equation) $\Sigma M_2 = \Sigma R \{ W \cos\theta - U) \tan\phi + cl$

The following are landslide prevention works segregated in accordance with aforementioned principle.



3. Types of Landslide Prevention Work

(1) Dozing Work

Efficient results may be attained by removing the top of the landslide slopes with dozing work as illustrated in diagram 5-14. However, it is suggested that this work should be executed during the dry season in conjunction with water way works since the ground water level may elevate excessively by rainfall and surface water infiltration.

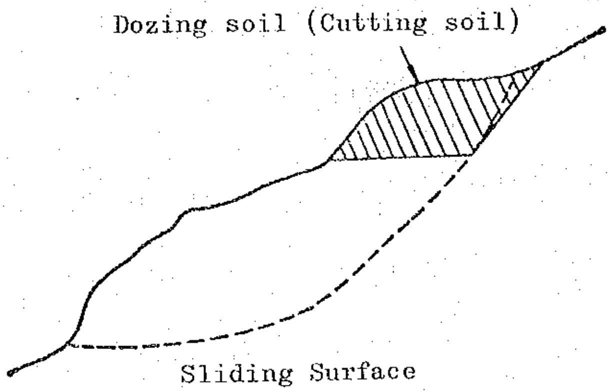


Diagram 5-14 Dozing Work

(2) Water Channel and Closed Conduit Works

Landslide slopes exhibit large numbers of tension and compression crack generations caused by the movement of the land as well as ponds and lakes where rain and surface water are often infiltrated. Therefore, it is urgently required to treat these water with water channel works. Additionally, flexible structures are employed in landslide areas since they may be destroyed by the movement of the land. Furthermore, closed conduit works intended for the drainage of near surface infiltration, are to be executed in conjunction with water channel works.

(3) Boring Closed Conduit Work

Boring closed conduit work are executed in places where ground water are distributed widely in shallow sections of the landslide terrain. It is important this is case to drain the water in the upper sections of the slope as illustrated in diagram 5-15. Additionally, large drainage effects may be attained by executing the work in a radial form through the sliding surface.

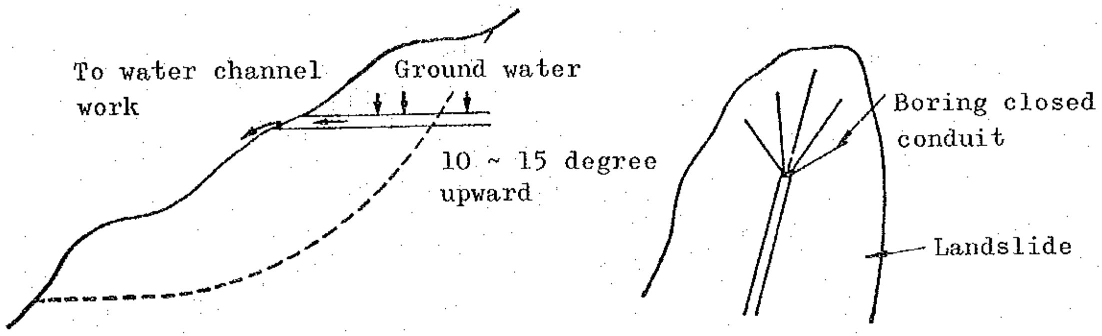


Diagram 5-15 Boring Closed Conduit Work

(4) Water Catchment Well Work

Water catchment wells are bored with boring applied from the sides for the catchment of water in areas where large volumes of ground waters exist in the form of water veins. The collected water is then drained by boring. There are water catchment wells made by methods such as concrete lining and liner plate inserting.

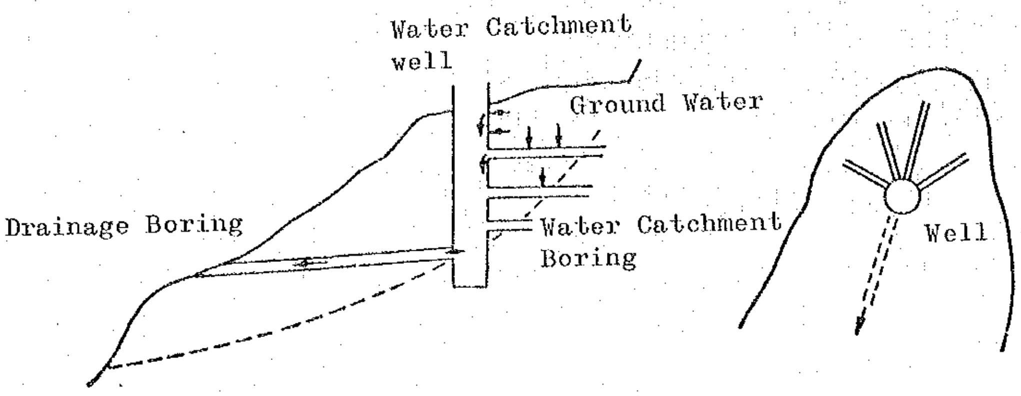


Diagram 5-16 Water Catchment Well

5) Tunnel Closed Conduit Work
Tunnel closed conduit works are executed in broad landslide areas where abundant ground water exist in the deep ground as illustrated in diagram 5-17. It is necessary to confirm the positions of the water veins before the execution since tunnel excavation in landslide areas are costly and hazardous. Moreover, tunnel excavations are required to be applied within rigid immovable terrain. Ground water are collected with horizontal and vertical borings spread out from the tunnel, and are then drained through the tunnel.

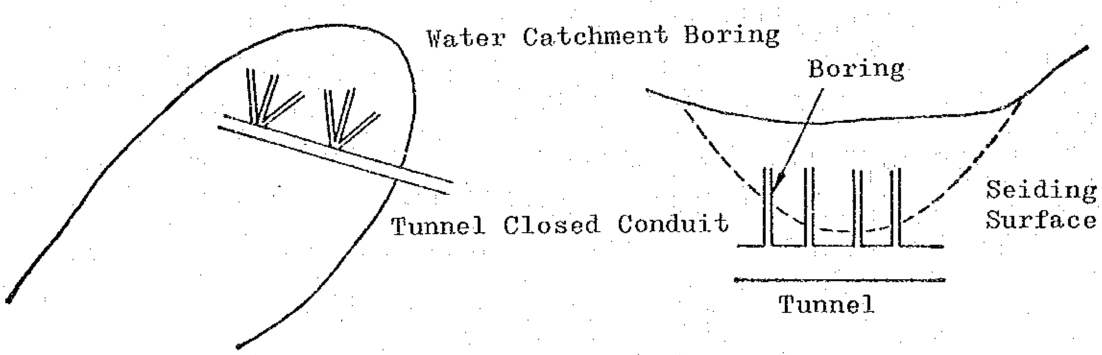


Diagram 5-17 Tunnel Closed Conduit Work

(6) Ground Water Isolation Work

Ground water entry into the landslide are isolated and drained with this work as illustrated in diagram 5-18 when the flow routes of ground water are known beforehand. Burial of concrete structures and insertion of mortar as well as chemicals are some of the methods for this work.

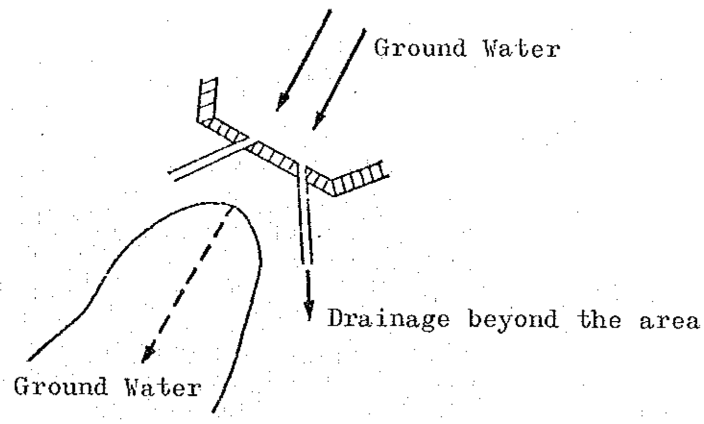


Diagram 5-18 Ground Water Isolation Work

(7) Torrent Work

Landslides generated along torrentside tend to become enlarged due to the falling of slopes caused by the foot attacking of run-offs. Therefore, it is necessary to protect the foot with the execution of revetment and spur dyke works. Additionally dam works are executed at times to form sediment on slope foot in order to attain landslide resistance effect with the sediment Diagram 5-19. Such dams are effective against minor landcreeps.

8) Retaining Work

This is a method where retaining works are applied to the end of the landslide in order to resist the earth pressure of the slope. It must be performed when planning this work to analyze the stability of the slope and calculate the size of the corresponding structure. Furthermore, this method is employed for minor and secondary landslide, for large stress cannot be expected with retaining works. Moreover, flexible structured retaining works such as cylinder and crib works are most suitable and widely used in landslide areas.

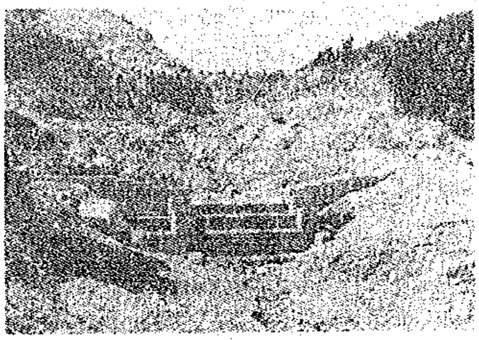


Diagram 5-19 Torrent Work Executed in Landslide Area

Pile Driving Work

This work is a method where piles are driven into the landslide ground to resist the landslide earth pressure with the resistance of the piles. It is important here that these piles be driven into immovable grounds. Additionally two or three rows of piles are normally driven in zigzag form. Positioning of the piles must be determined carefully since secondary sliding surface as illustrated in diagram 5-20 may be generated when the height of piles are too low or too high.

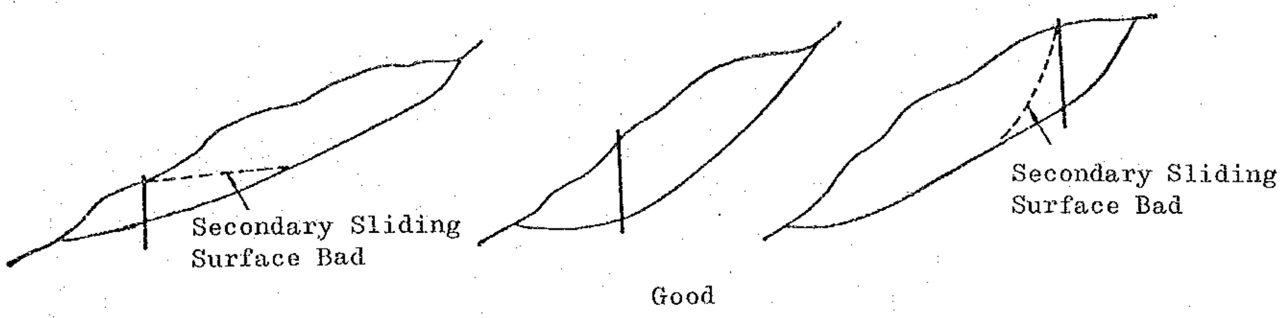


Diagram 5-20 Pile Positions

The following conditions must be fulfilled when designing the pile driving work.

1) Piles must be able to withstand the cantilever moment.

2) Piles must be able to withstand the shearing stress.

3) Soil around the pile must not become destroyed by shearing.

4) The foundation earth beneath the pile should not become destroyed.

Steel pipe, H framed steel, ferro concrete piles, and wood piles are the variations of piles, with steel pipes used most commonly.

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