Annex B
(informative)

Training materials

B.1 Summary of case study

B.2 Catchment and river profile

B.3 Design flood

B.4 Design capacity of culvert

B.5 Erosion protection

B.6 Design remarks

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ANNEX

B.1 Summary of case study

The Project for
the Capacity Development of Road Services
in the Democratic Republic of Timor-Leste

Case Study for Culvert Design

Summary of Training in 2017

March 2018

Filomena Correia Carvalho de Almeida

Rationale for Drainage Structure Design

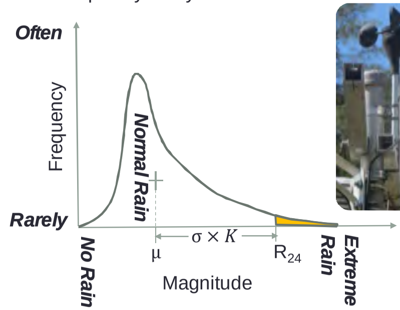
Present Condition
- Bridge Design Manual exists
- Implementation of flow checks for culvert constructions are seldom implemented
- Flooding and overtopping occur during heavy rains
- Roads structures become damaged

Solution
- Acquisition of technical knowledge through the case study of Sesurai Culvert
- Practical training for design calculations
- Provision of a technical guideline for culvert design in Timor-Leste

Location & Condition of Case Study

Design Check of Culvert

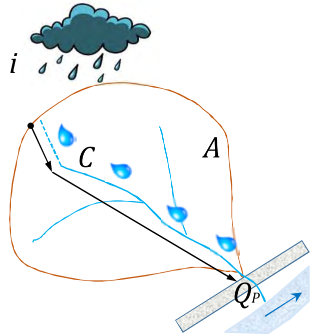
- Rainfall analysis: probable rainfall using Gumbel distribution, $R_{24} = \mu + \sigma \times K$
  - Synthetic procedure (because of data deficiency): frequency analysis of Dili ↗ scale up to Same



Data collection → Rainfall analysis → Flood calculation → Open-channel hydraulics → Protection works

Design Check of Culvert

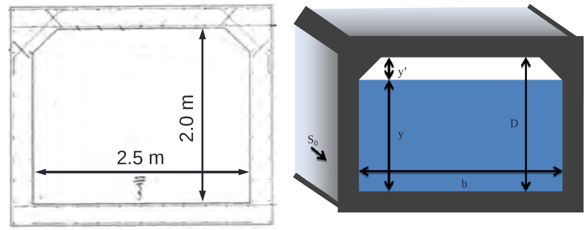
- Flood calculation using Rational Method, $Q_P = \frac{1}{3.6} CiA$
  - Rainfall intensity using Mononobe formula, $i = \frac{R_{24}}{24}\left(\frac{24}{t_c}\right)^{0.6}$



Data collection → Rainfall analysis → Flood calculation → Open-channel hydraulics → Protection works

Design Check of Culvert

- Open-channel hydraulics using Manning discharge formula, $Q = \frac{A^{5/3} \times S_0^{1/2}}{P^{2/3} \times n}$

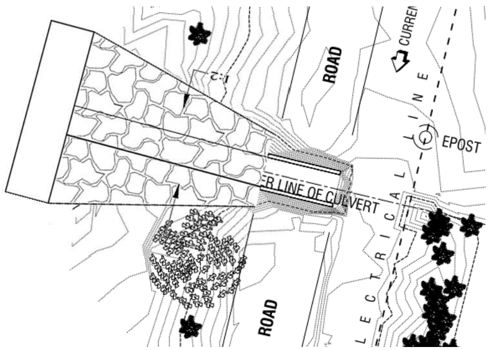


- Discharge capacity of culvert > discharge of catchment, $Q > Q_P$ ∴ sufficient culvert ✔

Data collection → Rainfall analysis → Flood calculation → Open-channel hydraulics → Protection works

Design Check of Culvert

- Protection works: erosion protection measures for outlets



Data collection → Rainfall analysis → Flood calculation → Open-channel hydraulics → Protection works

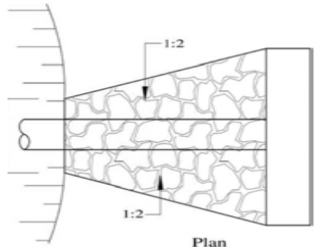
Recommendations

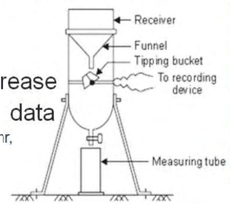
From now: construction of protection works at outlet

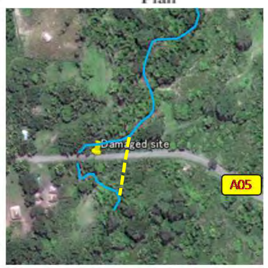
Next time: ensure minimum recommended gradient of culvert

Next time: improvement of river alignment

Institutionally: increase collection of rainfall data (15-min, 30-min, 1-hr, 2-hr, 3-hr, 6-hr, 12-hr, 24-hr intervals)







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ANNEX

B.2 Catchment and river profile

The Project for
the Capacity Development of Road Services
in the Democratic Republic of Timor-Leste

Case Study for Design Check

Road Drainage (1)

March 2017

JICA Expert Team

2

Today's Training

How to Make a Catchment Basin

3

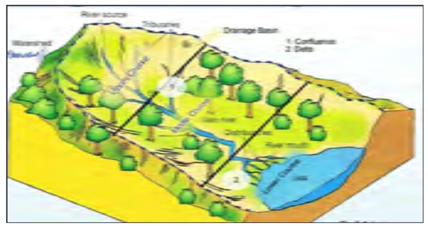
Contents

1. What is a Catchment Basin?
2. Basin Map of Other Country
3. Location of the Study Site
4. Practice-1 Making a Basin Boundary
5. Practice-2 Making a River Profile
6. Next Step

4

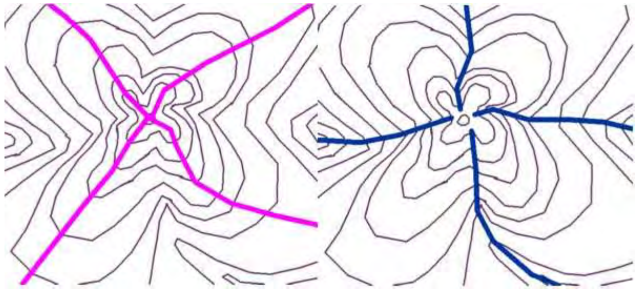
What is a Catchment Basin?

A catchment basin is an extent or an area of land where all surface water from rain converges to a single point at a lower elevation, usually the exit of the basin, where the waters join another body of water, such as a river, lake, reservoir, estuary, wetland, sea, or ocean. Source: Wikipedia

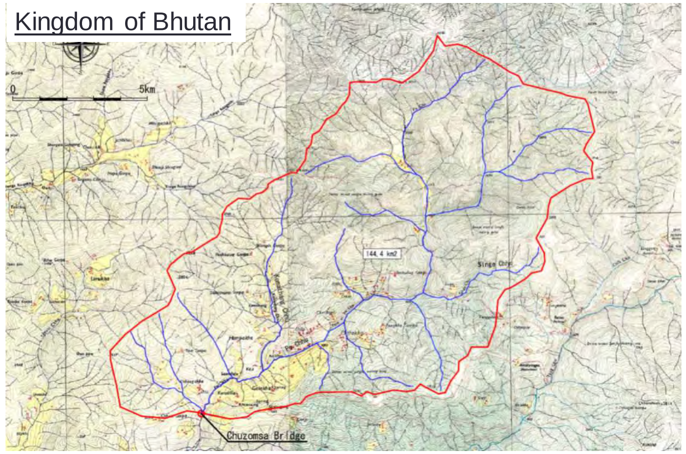


What is a Catchment Basin?

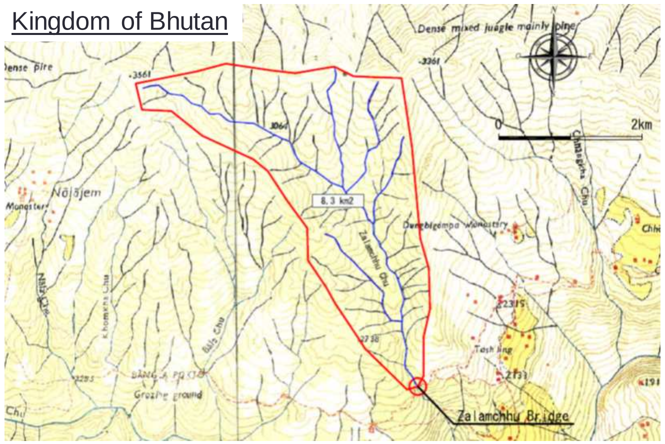
- ✓A right-angle line to convex (Purple line) : Ridge
- ✓A right-angle line to concave (Blue line) : Valley (River)



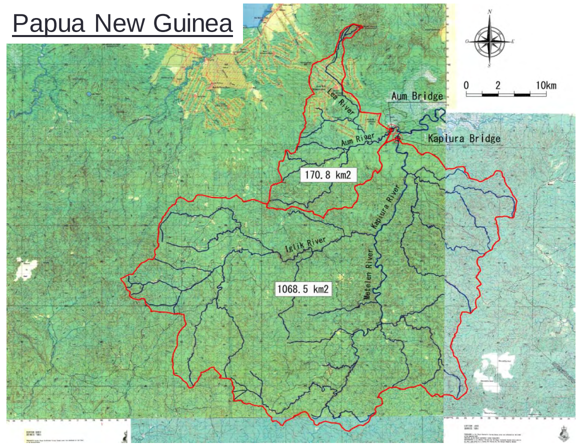
Basin Map of Other Country (1)



Basin Map of Other Country (2)

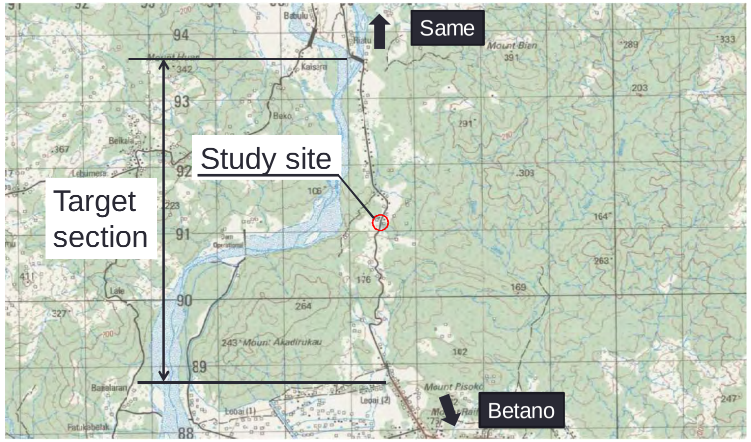


Basin Map of Other Country (3)



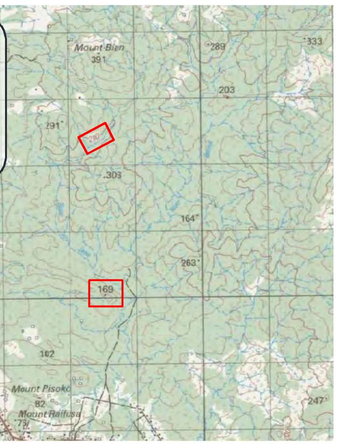
Location of the Study Site

Practice-1 : Making a Basin Boundary

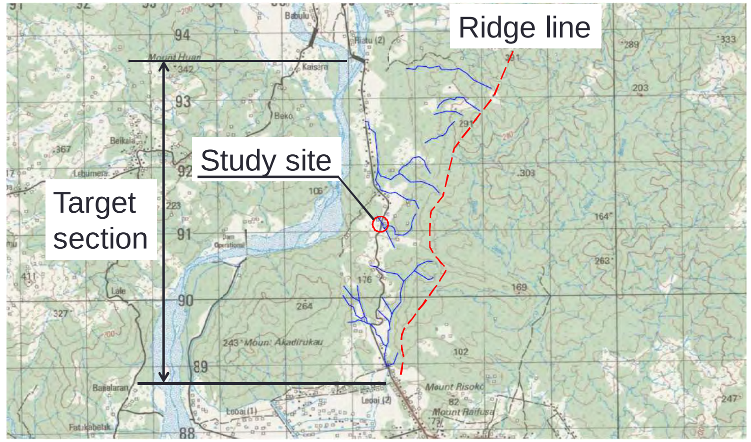


STEP1 : Check Item of Topographic Map

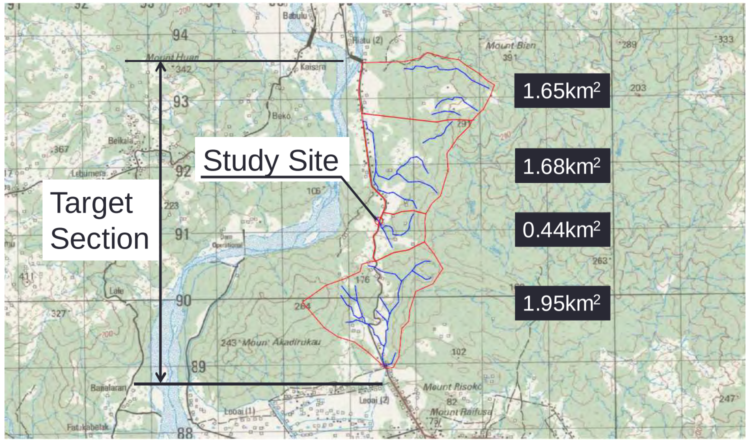
- ✓ Interval of contour line
- ✓ Crest of a hill
- ✓ River network
- ✓ Road network



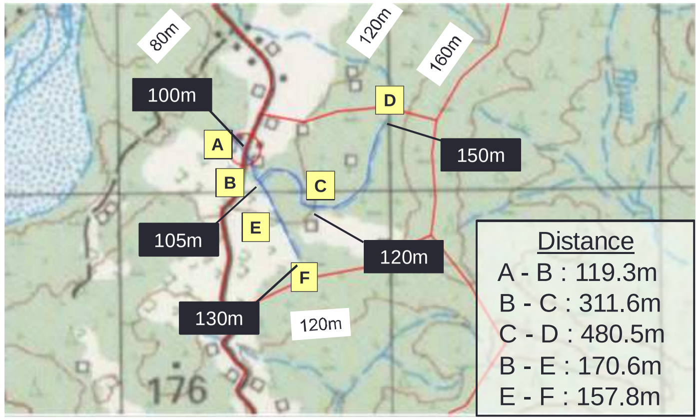
STEP2 : Confirmation of River Network



STEP3 : Separete a Boundary Line



Practice-2 : Making a River Profile

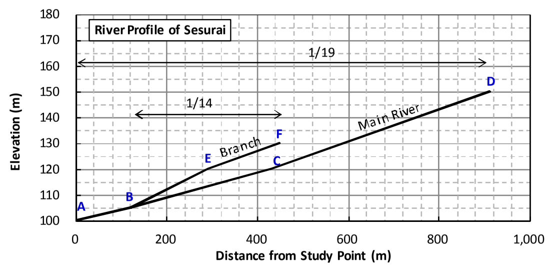


Practice-2 : Making a River Profile

Main River	Distance (m)	Total Dis (m)	EL. (m)	Riverbed Slope	Branch River	Distance (m)	Total Dis (m)	EL. (m)	Riverbed Slope
D									
C					F				
B					E				
A		0.00			B				

Practice-2 : Making a River Profile

Main River	Distance (m)	Total Dis (m)	EL. (m)	Riverbed Slope	Branch River	Distance (m)	Total Dis (m)	EL. (m)	Riverbed Slope
Upstream					Upstream				
D	480.50	911.40	150	1/19					
C	311.60	430.90	120		F	157.80	447.70	130	1/14
B	119.30	119.30	105		E	170.60	289.90	120	
A		0.00	100		B		119.30	105	



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ANNEX

B.3 Design flood

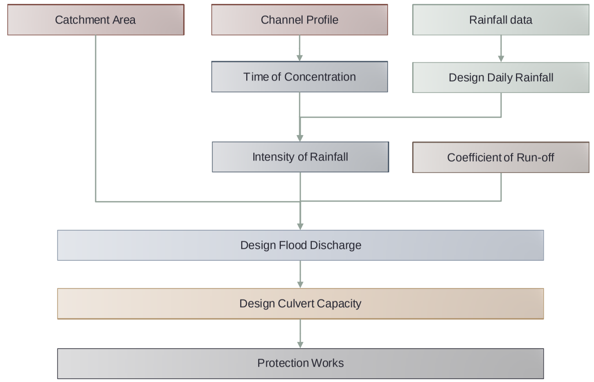
The Project for
the Capacity Development of Road Services
in the Democratic Republic of Timor-Leste

Case Study for Design Check
Road Drainage (2)

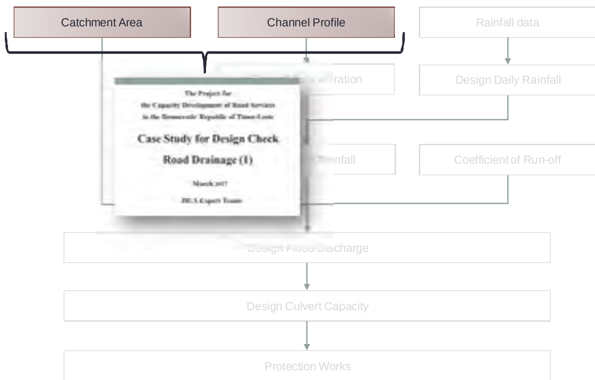
August 2017

JICA Expert Team

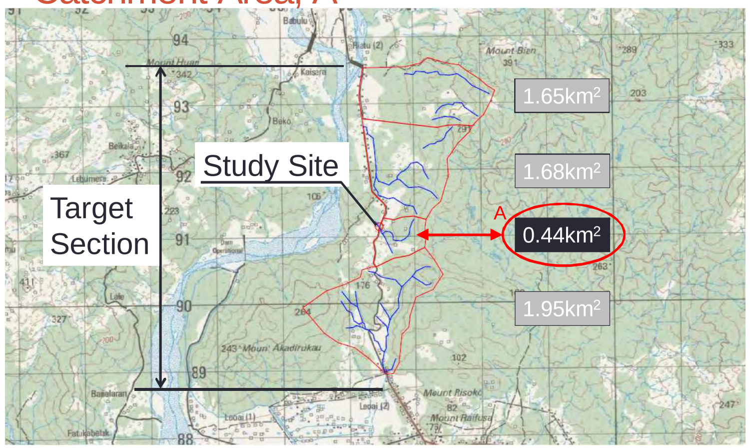
Overview of Design Process



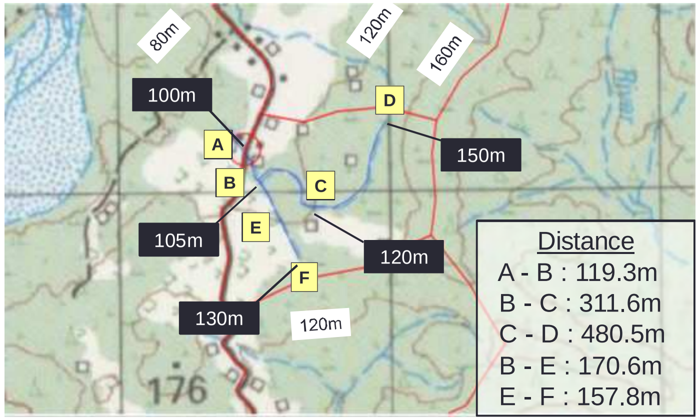
Contents of Road Drainage (1)



Road Drainage (1) review: Catchment Area, A

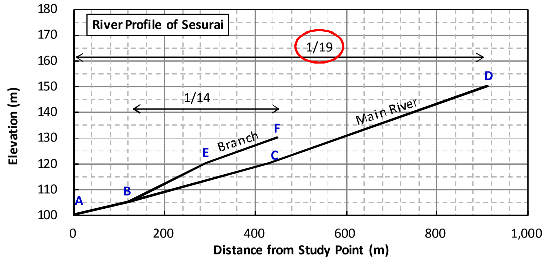


Road Drainage (1) review: Channel Profile

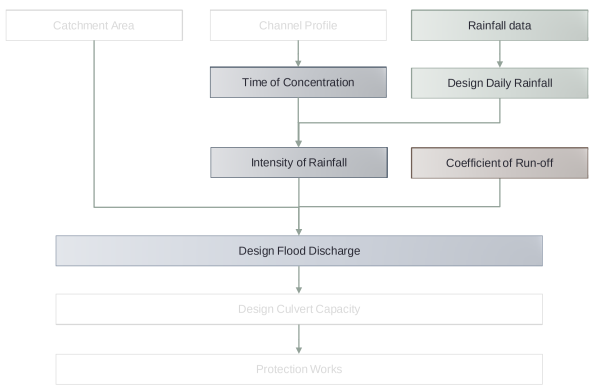


Road Drainage (1) review: Channel Profile, L & G

Main River	Distance (m)	Total Dis (m)	EL. (m)	Riverbed Slope	Branch River	Distance (m)	Total Dis (m)	EL. (m)	Riverbed Slope
Upstream		L		G	Upstream				
D	480.50	911.40	150	1/19					
C	311.60	430.90	120		F	157.80	447.70	130	1/14
B	119.30	119.30	105		E	170.60	289.90	120	
A		0.00	100		B		119.30	105	



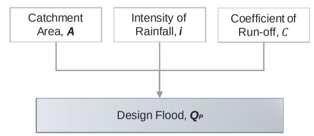
Contents of Road Drainage (2)



Overall Lecture Goal: Design Discharge

Modelling:

- Relationship between rainfall and stream flow through empirical rainfall–runoff prediction
- Rational Method will be applied
  - Peak discharge only
  - Ease of use
  - Relatively simple representation of infiltration/evaporation/storage using a coefficient
  - Applicable < 15.0 km²
  - Best suited ≤ 0.8 km²

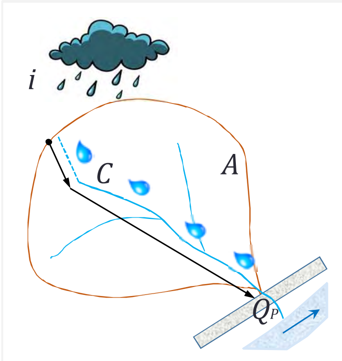


(Note: other methods exist, such as Talbot, ReFH, and SCS Method)

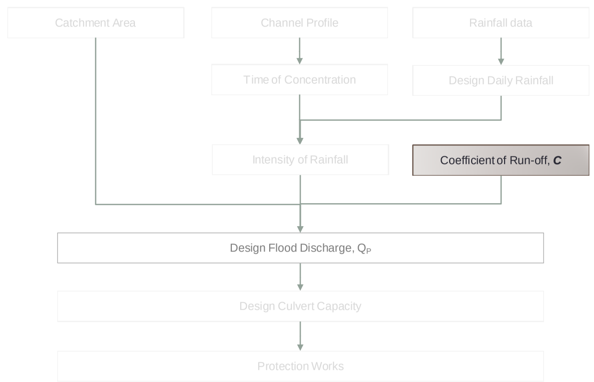
Overall Lecture Goal: Rational Method

- $Q_P = \frac{1}{3.6} \times C \times i \times A$

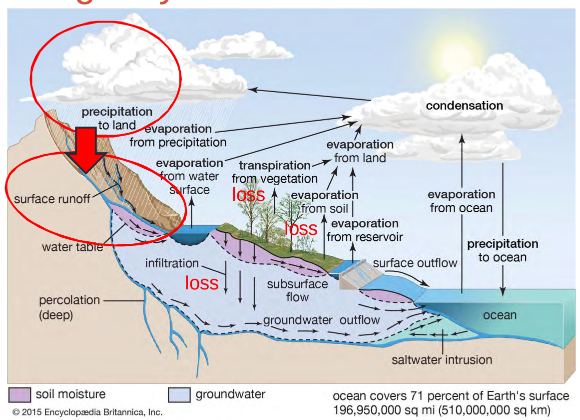
Where:
- Q_P = design discharge (m³/s)
- C = coefficient of run-off
- i = intensity of rainfall (mm/hour)
- A = catchment area (km²)



Run-off Proportion



Run-off Proportion: Hydrologic Cycle



Run-off Proportion : Coefficient of Run-off, *C*

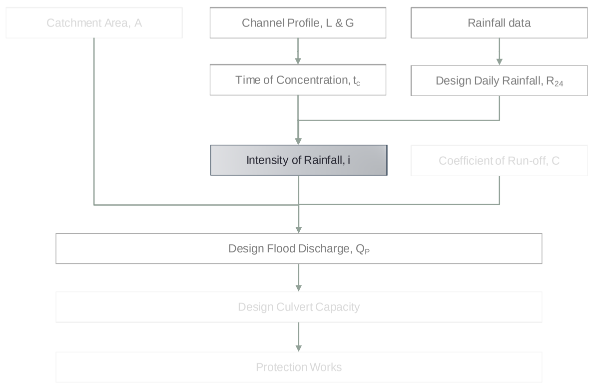
- Represents proportion of rainfall that becomes run-off
- Infiltration / evaporation / storage accounted for using the coefficient
- Must be weighted if you have different area types within the drainage area
- Adopt: $C = 0.75$, considering study site is gentle mountainous land

Catchment Terrain	Coefficient	Average Value
Road surfaces and sloped surfaces	0.70 – 1.00	0.85
Steep mountainous land	0.75 – 0.90	0.83
➡ Gentle mountainous land	0.70 – 0.80	0.75
Undulating land and woods	0.50 – 0.75	0.63
Flat farmlands	0.45 – 0.60	0.53
Rice paddy (fields)	0.70 – 0.80	0.75
Urban areas	0.60 – 0.90	0.75
Forest zones	0.20 – 0.40	0.30
Catchment areas of mountain streams	0.75 – 0.85	0.80
Catchment areas of small rivers on flat land	0.45 – 0.75	0.60
Catchment areas of major rivers of which more than half run on flat land	0.50 – 0.75	0.63

Source: Manual for Highway for Works in Japan (2009)

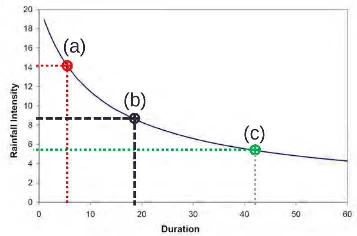
(Note: Limited to catchments < 15.0 km² because water storage becomes complex and coefficient cannot accurately represent catchment)

Rainfall Intensity



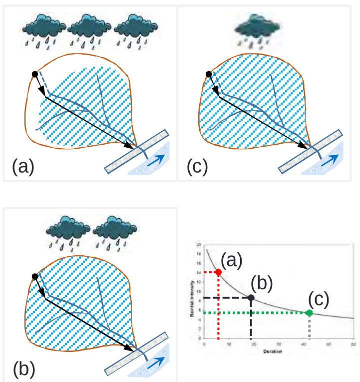
Rainfall Intensity: Intensity-Duration Relationship

- General climate trends: storm intensity α storm duration (inverse relationship)
- (a) high intensity-short duration
- (b) critical intensity when duration = time of concentration
- (c) low intensity-long duration
- Time of concentration is when all parts of the watershed begin contributing to the run-off from the basin



Rainfall Intensity: Critical Intensity

- (a) high intensity, but duration < time of concentration so not all catchment contributes
- (b) duration > time of concentration so all catchment contributes, but low intensity
- (c) duration = time of concentration, so intensity is highest possible with all catchment contributing



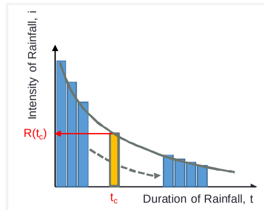
Rainfall Intensity: Mononobe's Formula

- $i = \frac{R_{24}}{24}\left(\frac{24}{t_c}\right)^{0.6}$

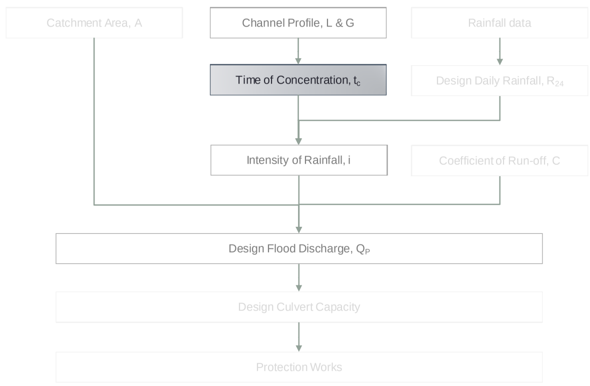
Where:

- i = intensity of rainfall (mm/hour)
- R_{24} = design daily rainfall (mm/day)
- t_c = time of concentration (hour)

- If rainfall data has 5-min, 10-min … 1-hour records, then intensity-duration-frequency (IDF) charts could be developed and other methods could be used

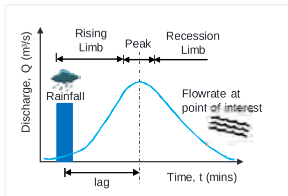


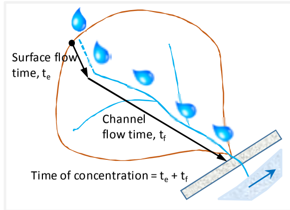
Time of Concentration



Time of Concentration

- Different areas of a watershed contribute to run-off at different times after rainfall begins
- Time of concentration
  - Time of flow from the farthest point in the watershed
  - Time at which all parts of the watershed begin contributing to the run-off from the basin
- Lag time
  - Time from the centre of mass of rainfall to hydrograph peak





Time of Concentration: Kraven Formula

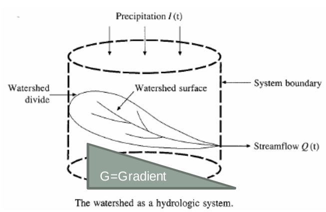
- $t_f = \frac{L}{W}$

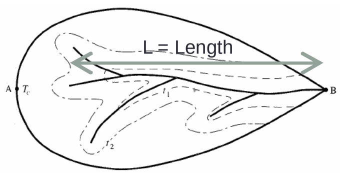
Where:

- t_f = time of channel flow (s)
- L = watercourse length (m)
- W = run-off velocity (m/s) see table →

- Empirical equation based on basin data

(Note: other methods exist, such as Kirpich or Hatheway formulae)

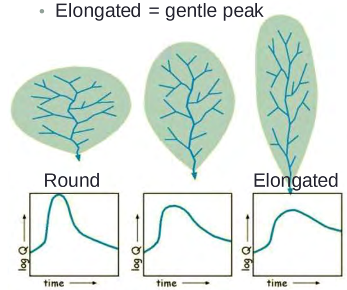


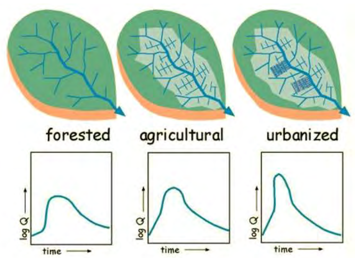


Watercourse Gradient, G	Run-off Velocity, W (m/s)
over 1/100	3.5
1/100 – 1/200	3.0
below 1/200	2.1

Time of Concentration: Catchment Influence

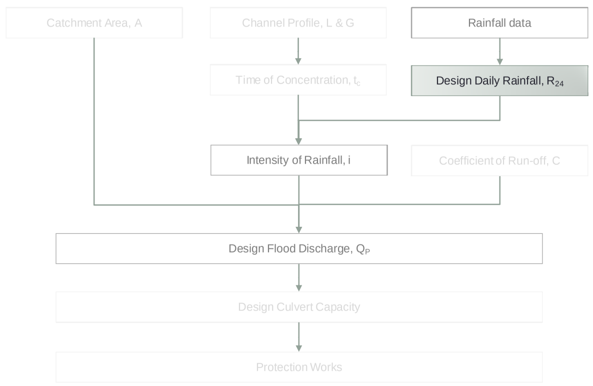
- Shape of catchment
  - Round = sharp peak
  - Elongated = gentle peak





- Land use of catchment
  - Natural = gentle peak
  - Urbanized = sharp peak

Design Daily Rainfall

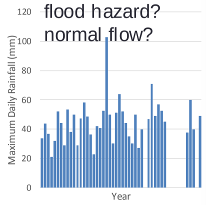


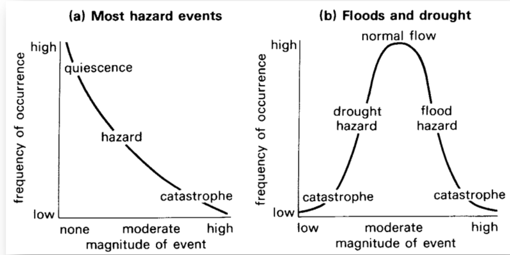
Design Daily Rainfall: Frequency–Magnitude Relationship

- Magnitude of extreme events is related to their frequency of occurrence

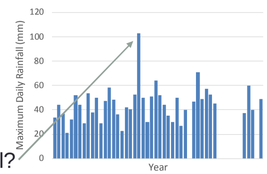
$$Magnitude \propto \frac{1}{Frequency\ of\ occurence}$$

- Frequency analysis relates magnitude of events to their frequency of occurrence through probability distribution





Design Daily Rainfall: Appropriate Design



Q) Why not just use maximum historical rainfall?

A) Too much: Over-design for road conditions / usage and not economically efficient

A) Too little: Records may not contain the largest probable rainfall / flood hazard level

Adopt: T = 10-year return period, considering road importance and O&M

Table 3-5-2 Standard Recurrence Period of Rainfall Applicable to Drainage Facilities

Class	Level of Drainage Capacity	Recurrence Period of Rainfall (a)	Recurrence Period of Rainfall (b)
A	High	3 years	More than 10 years(c)
B	Normal		7 years
C	Low		5 years

Note; (a) Applicable to normal road drainage such as road surface or small scale slope
(b) Applicable to important road drainage such as transverse drainages which remove runoff water from large scale natural slope or located at important flat urban area where local drainage is difficult
(c) 30 years is advisable for very important transverse drainage from the viewpoint of road maintenance and operation

Source: Manual for Highway Earthwork in Japan

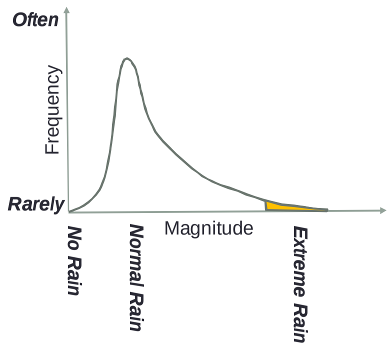
Design Daily Rainfall: Return Period (***recurrence interval***)

- Return Period (years) represents probability
- T−year event has p% probability of occurring each year
- $T = \frac{1}{1-p} \Leftrightarrow p = 1 - \frac{1}{T}$

E.g. 10-year event (1 time in a 10-year period)

= 10% probability of occurring each year

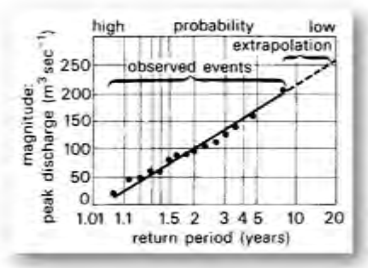
= top 90% percentile on a probability distribution chart



Design Daily Rainfall: Prediction

- Frequency analysis is used to predict the chance of occurrence of an event over a specified period of time
- Low-probability high-magnitude event can be extrapolated from data of observed events
- Representation of dataset using ***Gumbel Distribution***

(Note: other distribution methods exist, such as Exponential and Pearson III)



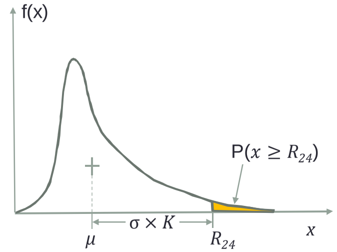
- Developed by Emil Julius Gumbel in 1940s
- Also known as Generalized Extreme Value distribution Type-1 (GEV-1)

Design Daily Rainfall: Gumbel Distribution

- Magnitude of an extreme event calculated as a departure from the mean expressed by a number of standard deviations
- $R_{24} = \mu + \sigma \times K$

Where,

- R_{24} = magnitude of rainfall for a given return period (mm/day)
- μ = mean or 'location parameter'
- σ = standard deviation or 'scale parameter'
- K = frequency factor (from -1 to 5) that depends on the probability distribution and return period, T



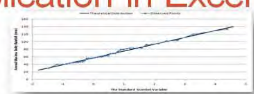
Design Daily Rainfall: Gumbel Distribution – theory

- $R_{24} = \mu + \sigma \times K$

Where:

- R_{24} = design daily rainfall for a given return period (mm/day)
- μ = mean of rainfall records (mm) = $\frac{\sum x_i}{n}$
  - x_i = an individual record (mm)
  - n = number of records
- σ = standard deviation of rainfall records = $\sqrt{\text{var}} = \sqrt{\frac{\sum(\log x_i - \mu)^2}{n-1}}$
- K = frequency factor = $-\frac{\sqrt{6}}{\pi} \times \left(\gamma + \ln\left(\ln\frac{T}{T-1}\right)\right)$
  - π = mathematical constant = 3.1415
  - γ = Euler–Mascheroni constant = 0.5772
  - T = return period (years)

Design Daily Rainfall: Gumbel Distribution – application in Excel

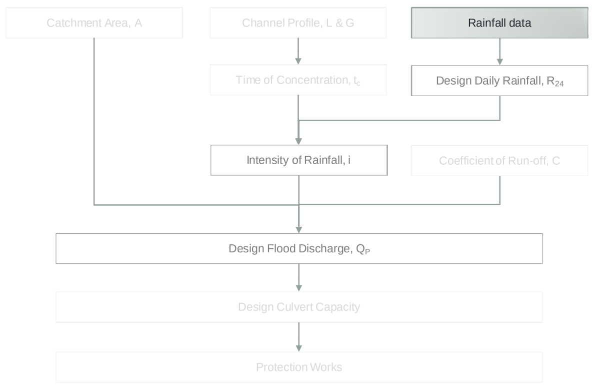


- $R_{24} = \mu + \sigma \times K$

Where:

- R_{24} = design daily rainfall for a given return period (mm/day)
- μ = AVERAGE(allRecords) or
  SUM(allRecords)/COUNT(allRecords)
- σ = STDEV.S(allRecords) or
  Deviation=(Record-μ)^2 then
  σ = SQRT(SUM(allDeviations)/(COUNT(allDeviations)-1))
- K = (-SQRT(6)/PI()*
  (0.5772+LN(LN(returnPeriod/(returnPeriod-1)))))

Rainfall Data



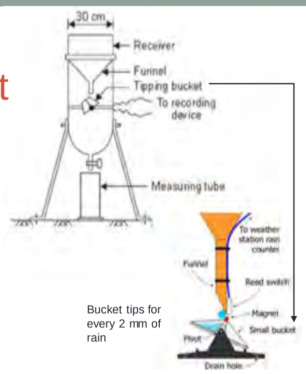
Rainfall Data: Weather Stations

Rainfall Data: Records & Measurement

Ideal:
- 30-min / 1-hr / 24-hr rainfall records
- Long record (30+ years)
- 1 or more stations in or near catchment

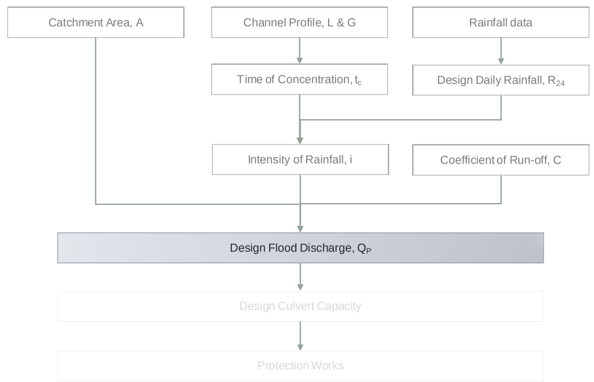
Actual:
- Same station is nearest to project site
- Same daily rainfall records for only 7 years
- Same monthly rainfall records since 1950s
- Dili daily rainfall records for 34 years (w/ gaps)

Synthetic (compensative) procedure:
- Calculate maximum 24-hour rainfall using Dili dataset
- Scale maximum 24-hour rainfall to Same using comparative monthly rainfall



Tipping Bucket Rain Gauge

Design Flood Discharge



Design Discharge: Rational Method

- $Q_P = \frac{1}{3.6} \times C \times i \times A$

Where:
  - Q_P = design flood discharge (m³/s)
  - C = coefficient of run-off, see slide 12
  - i = intensity of rainfall (mm/hour), see slide 16
  - A = catchment area (km²), see Road Drainage (1)
  - $\frac{1}{3.6}$ = units balancing
- Empirical equation based on basin data

Design Discharge: Assumptions

- Limitation to < 15 km² because water storage becomes complex and coefficient is not accurate
- Significant ponding (ponds, wetlands) does not exist within the catchment area
- Rainfall intensity is uniform over the catchment during rainfall
- Maximum run-off rate occurs when rainfall duration ≥ time of concentration
- Frequency for rainfall and run-off are equal

Summary of Equations

- Rational Method

$$Q_P = \frac{1}{3.6} CiA$$

- Mononobe's Formula

$$i = \frac{R_{24}}{24}\left(\frac{24}{t_c}\right)^{0.6}$$

- Kraven Formula

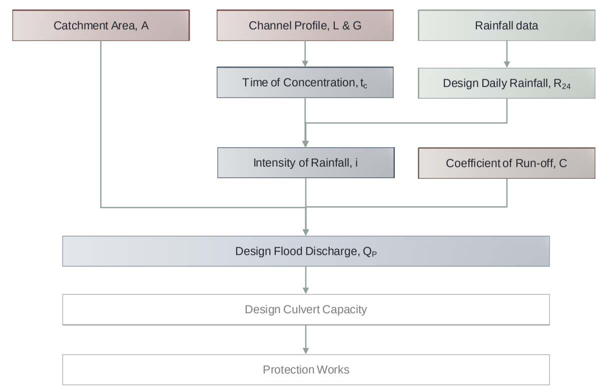
$$t_f = \frac{L}{W}$$

- Gumbel Distribution

$$R_{24} = \mu + \sigma \times -\frac{\sqrt{6}}{\pi} \times \left(0.5772 + ln\left(ln\frac{T}{T-1}\right)\right)$$

- Q_P = design discharge (m³/s)
- C = coefficient of run-off
- i = intensity of rainfall (mm/hour)
- A = catchment area (km²)
- R_{24} = design daily rainfall (mm/day)
- t_c = time of concentration (hour)
- L = watercourse length (m)
- G = watercourse gradient
- W = run-off velocity (m/s)
- μ = mean (mm)
- σ = standard deviation
- T = return period (years)

Summary of Progress



ANNEX

B.4 Design capacity of culvert

The Project for
the Capacity Development of Road Services
in the Democratic Republic of Timor-Leste

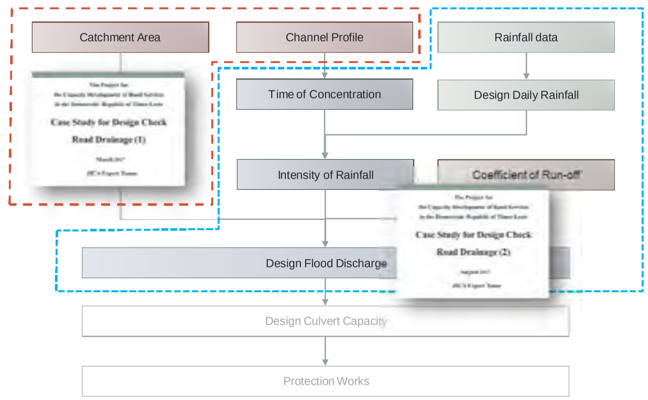
Case Study for Design Check

Road Drainage (3)

November 2017

JICA Expert Team

Contents of Road Drainage (1) & (2)



Overall Lecture Goal: Culvert Design Capacity

Open channel hydraulics:

- Select culvert geometry (shape & size)
- Calculate culvert design discharge capacity using Manning formula for uniform flow velocity:

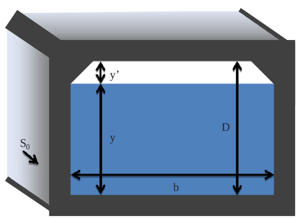
$$V = \frac{1}{n} R^{2/3} S_0^{1/2}$$

$$\Rightarrow Q = A \times V = \frac{A}{n} R^{2/3} S_0^{1/2} = \frac{A^{5/3} \times S_0^{1/2}}{P^{2/3} \times n}$$

- Check culvert design discharge capacity is more than channel / river design flood discharge

(culvert) $Q > Q_P$ (channel or river)

- Consider type of flow & erosion



- Q = design capacity of culvert (m³/s)
- A = area of flow (m²)
- V = velocity of flow (m/s)
- R = hydraulic radius (m) = $\frac{A}{P}$
- P = wetted perimeter (m)
- n = Manning's coefficient of roughness
- S_0 = gradient of culvert (or bed slope)

Culvert Capacity: Hydraulic Radius

Area of flow:

- $A = b \times y$

Where:

- b = width of culvert (m)
- y = depth of flow (m) = $0.8 \times D$

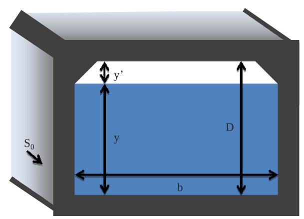
Recommended margin, $y' = 20\%$ to compensate for sedimentation

Wetted perimeter

- $P = b + 2 \times y$

Hydraulic radius

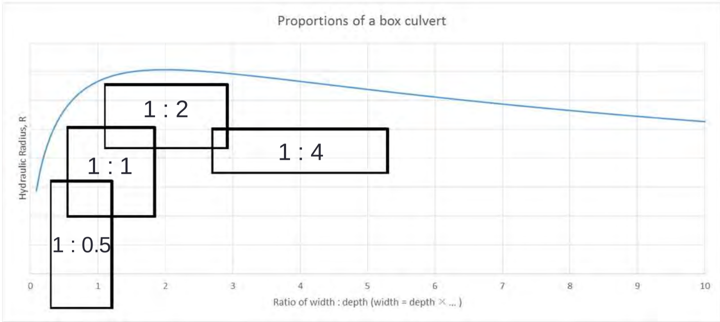
- $R = \frac{A}{P}$



- Q = design capacity of culvert (m³/s)
- A = area of flow (m²)
- V = velocity of flow (m/s)
- R = hydraulic radius (m) = $\frac{A}{P}$
- P = wetted perimeter (m)
- n = Manning's coefficient of roughness
- S_0 = gradient of culvert (or bed slope)

Culvert Capacity: Hydraulic Radius

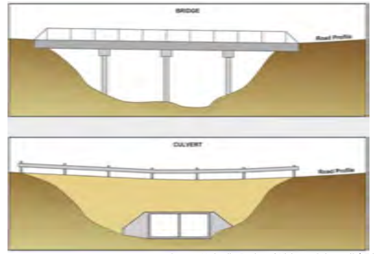
For optimal hydraulic radius ($R = \frac{A}{P}$):
width = 2 × depth



Culvert Capacity: Dimensions (size)

- Range of application for conventional culverts:
- Max. internal height ≤ 5.0 m (D)
- Max. internal width ≤ 6.5 m (b)
- Cover depth (soil) ≥ 0.5 m

Source: Table 8.1.2, Manual for Highway Earthworks in Japan – Culvert Guideline (2009)



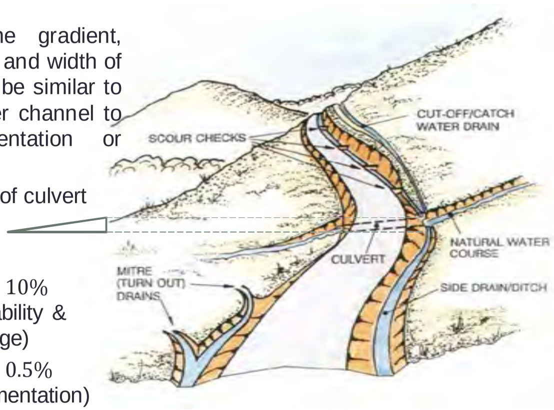
- Bridge vs Culvert consider:
  - Cost
  - Hydraulics
  - Debris
  - Land-use / environment

Source: Hydraulic Design of Highway Culverts (3rd Ed.), Federal Highways Association

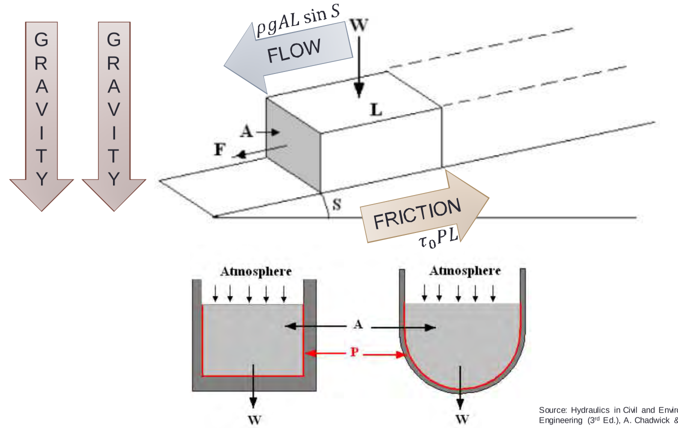
Topographical Data of Project Site: Gradient of Culvert (Bed Slope)

In principle, the gradient, bottom elevation and width of a culvert should be similar to the original water channel to prevent sedimentation or erosion.

- S_0 = gradient of culvert (bed slope)
- $S_0 \leq 0.100$ *or* 10% (ensure workability & prevent slippage)
- $S_0 \geq 0.005$ *or* 0.5% (prevent sedimentation)



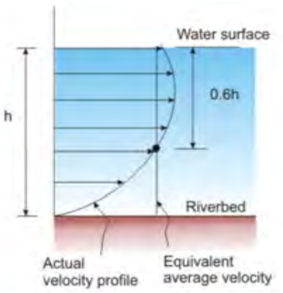
Culvert Capacity: Manning Coefficient of Roughness



Source: Hydraulics in Civil and Environmental Engineering (3rd Ed.), A. Chadwick & J. Morfett

Culvert Capacity: Manning Coefficient of Roughness

Manning's n for Closed Conduits Flowing Partly Full



- Determines frictional resistance of a channel
- Reasonable accuracy for artificial channels

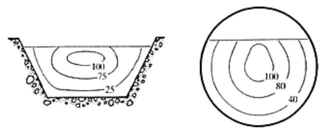


Figure 5.4 Velocity distributions in open channels. (*Note.* Contour numbers are expressed as a percentage of the maximum velocity.)

Source: Hydraulics in Civil and Environmental Engineering (3rd Ed.), A. Chadwick & J. Morfett

Culvert Capacity: Manning Coefficient of Roughness

Manning's n for Closed Conduits Flowing Partly Full

Type of Conduit and Description	n values
7. Concrete:	
Culvert, straight and free of debris	0.011
Culvert with bends, connections, and some debris	0.013
Finished	0.012
Sewer with manholes, inlet, etc., straight	0.015
Unfinished, steel form	0.013
Unfinished, smooth wood form	0.014
Unfinished, rough wood form	0.017

Source: Open-channel Hydraulics (1959), V.T. Chow

Type of Conduit and Description	n values
Cast in-situ concrete box culvert	0.012 – 0.022

Source: Hydraulic Design of Highway Culverts (3rd Ed.), Federal Highways Association

Type of Conduit and Description	n values
Factory-made concrete products	0.013
Cast in-situ concrete	0.015

Source: ARR No. 55 Translation of Japanese Highway Design Manual (1979), O.G. Ingles

Flow Profile

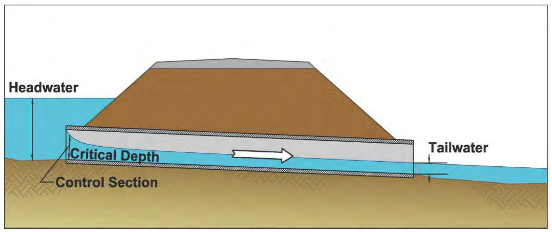


Figure 1.17. Typical inlet control flow section.

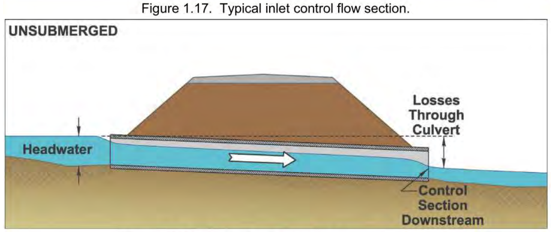


Figure 1.18. Typical outlet control flow conditions.

Source: Hydraulic Design of Highway Culverts (3rd Ed.), Federal Highways Association

Flow Profile: Undesirable Design Conditions

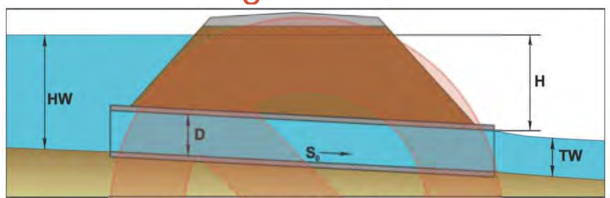


Figure 3.29. USGS flow type 4 and 6.

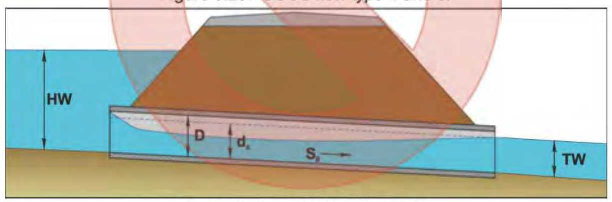
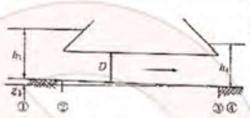
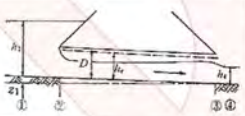
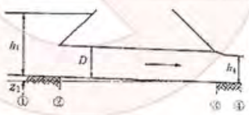


Figure 3.26. USGS flow type 5.

Source: Hydraulic Design of Highway Culverts (3rd Ed.), Federal Highways Association

Flow Profile:
Undesirable Design Conditions

Type	Hydraulic Condition	From of Flow	Remarks
4	Full capacity flow throughout (the exit is submerged) $D < h_4$		This may occur as an extraordinary event but should not be used for designing.
5	Rapid flow at the exit $h_4 \leqq D \leqq (h_1 + z_1 - z_2)/1.5$		ditto
6	Full capacity flow throughout (free discharge at the exit) $h_4 \leqq D \leqq (h_1 + z_1 - z_2)/1.5$		ditto

Source: Manual for Highway Earthwork in Japan

Flow Profile:
Reasonable Design Conditions

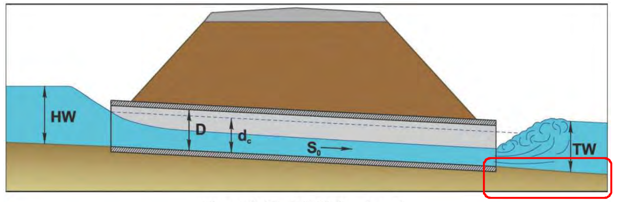


Figure 3.25. USGS flow type 1.

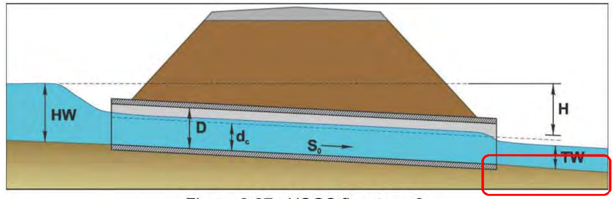
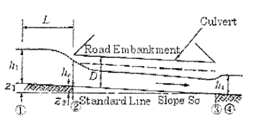
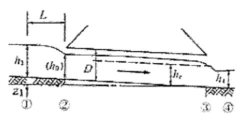


Figure 3.27. USGS flow type 2.

Source: Hydraulic Design of Highway Culverts (3rd Ed.), Federal Highways Association

Flow Profile:
Reasonable Design Conditions

Type	Hydraulic Condition	From of Flow	Remarks
1	The critical depth occurs at the entrance. $D > (h_1 + z_1 - z_2)/1.5$ $h_4 < h_c$ $S_0 > S_c$		Measures to prevent scouring are necessary against hydraulic jump may occur near the exit.
2	The critical depth occurs at the exit. $D > (h_1 + z_1 - z_2)/1.5$ $h_4 < h_c$ $S_0 < S_c$		The introduction of scouring prevention measures is desirable at the exit.

Source: Manual for Highway Earthwork in Japan

Flow Profile:
Desirable Design Conditions

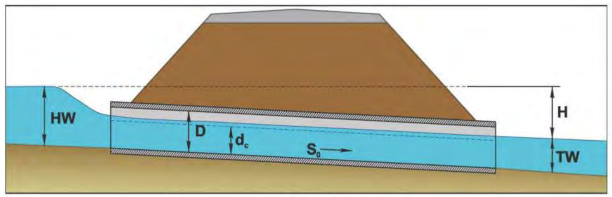
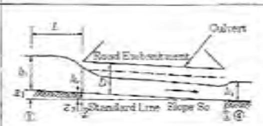
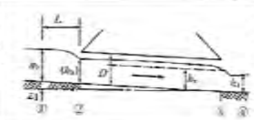
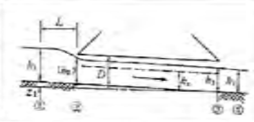


Figure 3.28. USGS flow type 3.

Source: Hydraulic Design of Highway Culverts (3rd Ed.), Federal Highways Association

Flow Profile: Desirable Design Conditions

Type	Hydraulic Condition	Form of Flow	Remarks
1	The critical depth occurs at the entrance. $D>(h_1+z_1-z_2)/1.5$ $h_t<h_c$ $S_0>S_c$		Measures to prevent scouring are necessary against hydraulic jump may occur near the exit.
2	The critical depth occurs at the exit. $D>(h_1+z_1-z_2)/1.5$ $h_t<h_c$ $S_0<S_c$		The introduction of scouring prevention measures is desirable at the exit.
3	Gentle flow throughout (subcritical flow) $D>(h_1+z_1-z_2)/1.5$ $h_c<h_t\leq D$		The most desirable condition for designing.

Source: Manual for Highway Earthwork in Japan

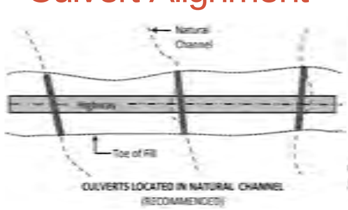
Other Considerations: Critical Depth and Flow Conditions

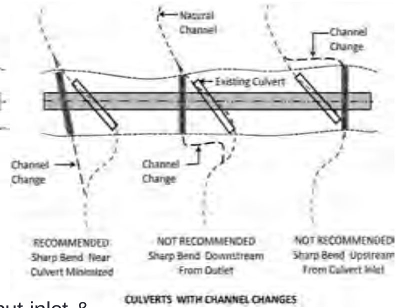
- For rectangular channels only, critical depth:
- $y_c = \left(\frac{\left(\frac{Q_P}{b}\right)^2}{g}\right)^{\frac{1}{3}}$
- Where:
  - Q_P = design flood discharge of catchment (m³/s)
  - b = width of culvert (m)
  - g = gravitational acceleration = $9.81\ m/s^2$
- Measurement of normal flow conditions on site:
  - downsteam (tailwater) depth
  - upstream (headwater) depth
  - natural channel slope
- Conventional range of average flow velocity for concrete box culverts:

0.6 – 3.5 m/s

Source: Table 3-7, Manual for Highway Earthwork in Japan (2009)

Other Considerations: Culvert Alignment





Source: Road Design Manual (3rd Ed.), Wyoming Department of Transport

- If possible, put inlet & outlet in natural channel of river
- Channel change can minimize culvert length & cost, but sharp bends should be avoided (<45°)

Summary of Equations

- Discharge formula

$Q = A \times V$

- Manning formula

$V = \frac{1}{n} R^{2/3} S_0^{1/2}$

- Discharge & Manning formula

$Q = \frac{A^{5/3} \times S_0^{1/2}}{P^{2/3} \times n}$

- Area of flow, $A = b \times y$
- Wetted perimeter, $P = b + 2 \times y$
- Hydraulic radius, $R = \frac{A}{P}$
- Critical flow depth

$y_c = \left(\frac{\left(\frac{Q_P}{b}\right)^2}{g}\right)^{\frac{1}{3}}$

- Q = design capacity of culvert (m³/s)
- Q_P = design flood of channel (m³/s)
- A = area of flow (m²)
- V = velocity of flow (m/s)
- n = coefficient of roughness
- R = hydraulic radius (m)
- S_0= gradient of culvert (m/m)
- b = width of culvert (m)
- y = depth of flow (m)
- g = gravitational acceleration (m/s²) = $9.81\ m/s^2$

ANNEX

B.5 Erosion protection

The Project for
the Capacity Development of Road Services
in the Democratic Republic of Timor-Leste

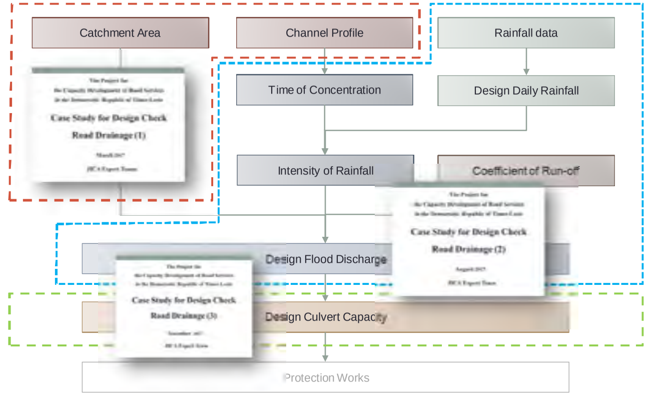
Case Study for Design Check

Road Drainage (4)

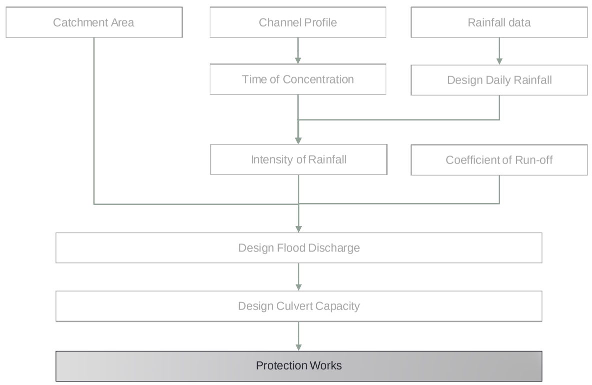
February 2018

JICA Expert Team

Contents of Road Drainage (1), (2) & (3)



Contents of Road Drainage (4)



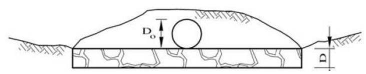
Overall Lecture Goal: Erosion Protection Measures

Guidance:

- Evaluation of necessity
- Calculation of normal flow depth
- Calculation of Froude number

$$Fr = \frac{V}{(g \times y)^{0.5}} = \left(\frac{{Q_P}^2 \times b}{g \times A^3}\right)^{1/2}$$

- Selection of protection measure
- Dimensions of protection measure



Source: Source: Drainage Manual (6th Ed.), The South African National Roads Agency SOC Ltd.

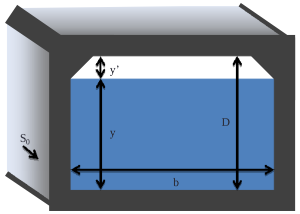
Source: Hydraulic Design of Highway Culverts (3rd Ed.), Federal Highways Association

Erosion Protection: Evaluation of Necessity

Calculation of flow velocity with Manning formula:

- $V = \frac{1}{n} \times R^{2/3} \times S_0^{1/2}$

  Where:
  - $V =$ velocity of flow (m/s)
  - $R =$ hydraulic radius (m)
  - $S_0 =$ gradient of culvert (m/m)
- Conventional range of flow velocity for box culverts: 0.6 – 3.5 m/s
- $V \geq 3.5\ m/s \Rightarrow$ protection measures recommended



- $V =$ velocity of flow (m/s)
- $R =$ hydraulic radius (m) $= \frac{A}{P}$
- $A =$ area of flow (m²)
- $P =$ wetted perimeter (m)
- $S_0 =$ gradient of culvert (bed slope)

Erosion Protection: Calculation of Normal Flow Depth

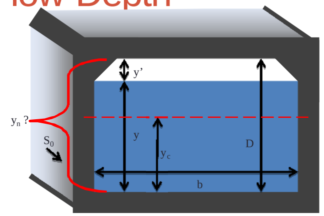
Calculation of normal flow with discharge & Manning formula:

- $Q = \frac{y_n \times b}{n} \left(\frac{y_n \times b}{2 \times y_n + b} \right)^{2/3} \times S_0^{1/2} \approx Q_P$

  Where:
  - $Q =$ discharge of culvert (m³/s)
  - $Q_P =$ discharge of channel (m³/s)
  - $y_n =$ normal depth of flow (m)
  - $b =$ width of culvert (m)
  - $S_0 =$ gradient of culvert (m/m)

Change y_n until $Q \approx Q_P$

- Trial and error method is simple, but can be slow
- Newton-Raphson Method can be quicker, but more difficult



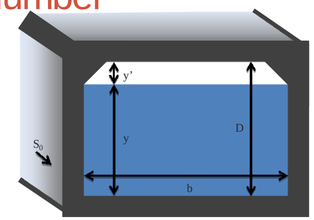
- $Q =$ design capacity of culvert (m³/s)
- $Q_P =$ design flood of channel (m³/s)
- $y_n =$ normal depth of flow (m)
- $y_c =$ critical depth of flow (m)
- $y\ =$ design depth of flow (m)
- $b =$ width of culvert (m)
- $S_0 =$ gradient of culvert (bed slope)

Erosion Protection: Calculation of Froude Number

Calculation of type of flow with Froude formula:

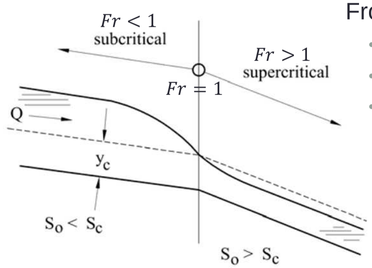
- $Fr = \frac{V}{(g \times y)^{0.5}} = \left(\frac{Q_r^2 \times b}{g \times (y_n \times b)^3} \right)^{0.5}$

  Where:
  - $Q_P =$ discharge of channel (m³/s)
  - $y_n =$ normal depth of flow (m)
  - $b =$ width of culvert (m)
  - $g =$ gravitational acceleration (m/s²)



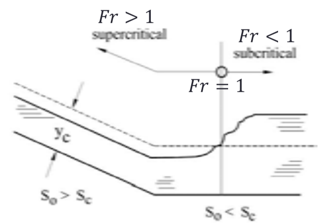
- $V =$ velocity of flow (m/s)
- $Q_P =$ design flood of channel (m³/s)
- $y_n =$ normal depth of flow (m)
- $b =$ width of culvert (m)
- $g =$ gravitational acceleration (m/s²) $= 9.81\ m/s^2$

Erosion Protection: Calculation of Froude Number



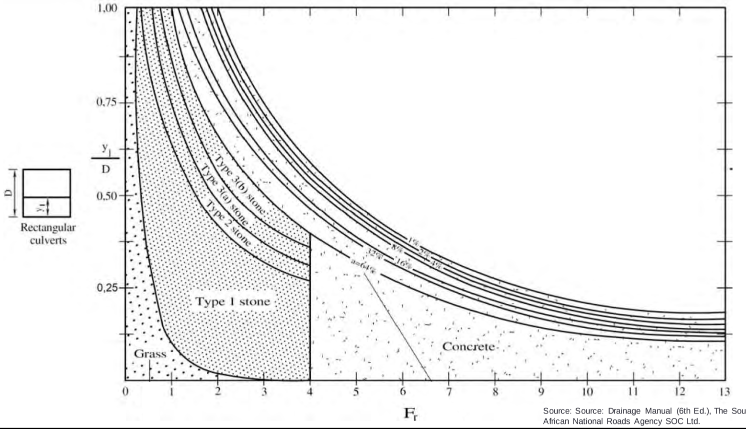
Froude number indicating flow type:

- $Fr > 1$: supercritical flow (fast)
- $Fr = 1$: critical flow (change point)
- $Fr < 1$: subcritical flow (slow)



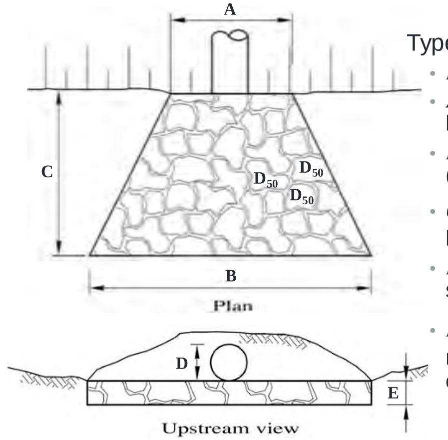
Source: Source: Drainage Manual (6th Ed.), The South African National Roads Agency SOC Ltd.

Erosion Protection: Selection of Protection Measure



Source: Source: Drainage Manual (6th Ed.), The South African National Roads Agency SOC Ltd.

Erosion Protection: Dimensions of Protection Measures

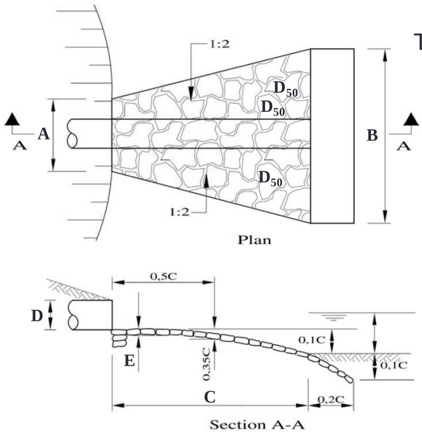


Type 1 stone stilling basin:

- D : height of culvert (m)
- $A = 3 \times D$: width of stone basin at outlet (m)
- $B = A + C$: width downstream (m)
- $C = 3.0792 \times \frac{Q}{D^{1.6}} + 2.4384$: length of stone basin (m)
- $E = 0.5 \times D \times Fr$: thickness of stone basin (m)
- $D_{50} = 0.0883 \times \frac{Q^{1.333}}{D^{2.333}}$: minimum size of stones in 50% of basin material (m)

Source: Source: Drainage Manual (6th Ed.), The South African National Roads Agency SOC Ltd.

Erosion Protection: Dimensions of Protection Measures

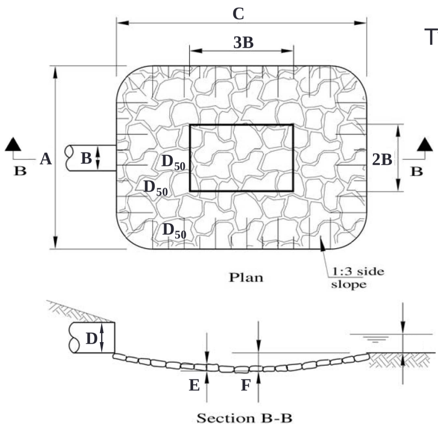


Type 2 stone stilling basin:

- D : height of culvert (m)
- $A = 3 \times D$: width of stone basin at outlet (m)
- $B = 5 \times D$: width downstream (m)
- $C = 5 \times D$: length (m)
- $E = 2 \times D_{50}$: thickness (m)
- $D_{50} = 0.0707 \times \frac{Q^{1.333}}{D^{2.333}}$: minimum size of stones in 50% of basin material (m)

Source: Source: Drainage Manual (6th Ed.), The South African National Roads Agency SOC Ltd.

Erosion Protection: Dimensions of Protection Measures

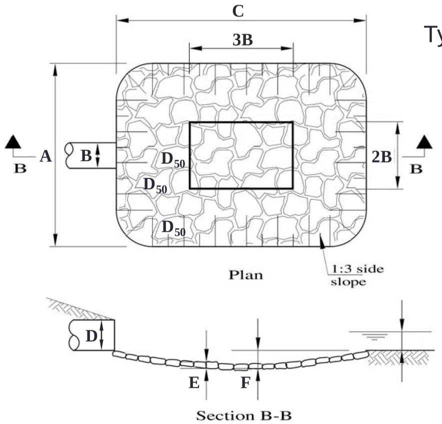


Type 3a stone stilling basin:

- D : height of culvert (m)
- B : width of culvert (m)
- $A = 2 \times D + 6 \times F$: width of stone basin (m)
- $C = 3 \times D + 6 \times F$: length (m)
- $F = 0.5 \times D$: depth (m)
- $E = 2 \times D_{50}$: thickness (m)
- $D_{50} = 0.0552 \times \frac{Q^{1.333}}{D^{2.333}}$: minimum size of stones in 50% of basin material (m)

Source: Source: Drainage Manual (6th Ed.), The South African National Roads Agency SOC Ltd.

Erosion Protection: Dimensions of Protection Measures

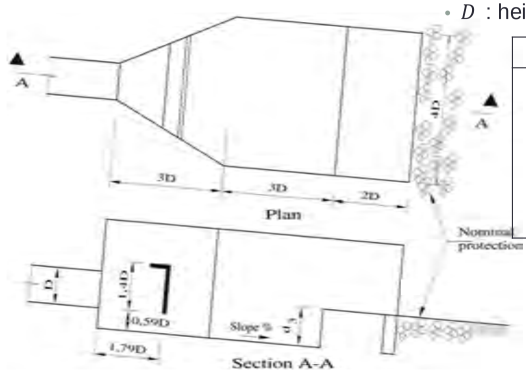


Type 3b stone stilling basin:

- D : height of culvert (m)
- B : width of culvert (m)
- $A = 2 \times D + 6 \times F$: width of stone basin (m)
- $C = 3 \times D + 6 \times F$: length (m)
- $F = D$: depth (m)
- $E = 2 \times D_{50}$: thickness (m)
- $D_{50} = 0.0362 \times \frac{Q^{1.333}}{D^{2.333}}$: minimum size of stones in 50% of basin material (m)

Source: Source: Drainage Manual (6th Ed.), The South African National Roads Agency SOC Ltd.

Erosion Protection: Dimensions of Protection Measures



Type 5 concrete stilling basin:

- D : height of culvert (m)

a%	d_3 / D
1	0.59
2	0.59
4	0.71
8	0.92
16	1.25
32	1.92
64	Not recommended

Source: Source: Drainage Manual (6th Ed.), The South African National Roads Agency SOC Ltd.

Summary of Equations

- Area of flow, $A = b \times y$
- Wetted perimeter, $P = b + 2 \times y$
- Hydraulic radius, $R = \frac{A}{P}$
- Manning formula

$$V = \frac{1}{n} R^{2/3} S_0^{1/2}$$

- Discharge & Manning formula

$$Q = \frac{A^{5/3} \times S_0^{1/2}}{P^{2/3} \times n}$$

- Froude number (box culverts)

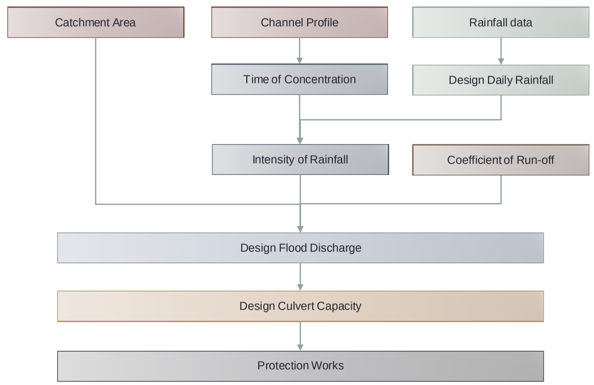
$$Fr = \frac{V}{(g \times y)^{0.5}} = \left(\frac{Q_P^2 \times b}{g \times (y \times b)^3}\right)^{0.5}$$

- Critical flow depth (box culverts)

$$y_c = \left(\frac{\left(\frac{Q_P}{b}\right)^2}{g}\right)^{\frac{1}{3}}$$

- $A =$ area of flow (m²)
- $P =$ wetted perimeter (m)
- $b =$ width of culvert (m)
- $y =$ depth of flow (m)
- $R =$ hydraulic radius (m)
- $V =$ velocity of flow (m/s)
- $n =$ coefficient of roughness
- $S_0 =$ gradient of culvert (m/m)
- $Q =$ discharge (m³/s)
- $Fr =$ Froude number
- $y_c =$ critical depth (m)
- $g =$ gravitational acceleration (m/s²) $= 9.81\ m/s^2$

Overview of Design Process



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ANNEX

B.6 Design remarks

The Project for
the Capacity Development of Road Services
in the Democratic Republic of Timor-Leste

Case Study for Design Check

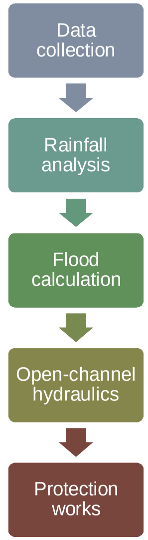
Road Drainage (5)

March 2018

JICA Expert Team

Road Drainage Guidance

- Data collection: rainfall data, site data, topographic data
- Rainfall analysis: probable rainfall using Gumbel distribution, $R_{24} = \mu + \sigma K$
  - Synthetic procedure (frequency analysis of Dili ➡ scale up to Same)
- Flood calculation using Rational Method, $Q_P = \frac{1}{3.6} CiA$
  - Rainfall intensity using Mononobe formula, $i = \frac{R_{24}}{24}\left(\frac{24}{t_c}\right)^{0.6}$
- Open-channel hydraulics using Manning discharge formula, $Q = \frac{A^{5/3} \times S_0^{1/2}}{P^{2/3} \times n}$
- Protection works: erosion protection measures for outlets



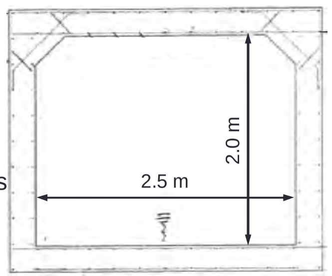
Summary of Design

Return period of design flood: 10 years
Probable daily rainfall in Dili: 131.4 mm
Estimated probable daily rainfall in Same: 435.6 mm

Time of concentration: 0.41 hours
Rainfall intensity: 209.9 mm/hour

Catchment area: 0.32 m²
Coefficient of runoff: 0.75
Slope: 0.5%

Peak discharge of river: 13.99 m³/s
Capacity of culvert: 14.89 m³/s
∴ As built culvert is OK



Design Adjustments (rainfall analysis)

Table 3-5-2 Standard Recurrence Period of Rainfall Applicable to Drainage Facilities

Class	Level of Drainage Capacity	Recurrence Period of Rainfall (a)	Recurrence Period of Rainfall (b)
A	High	3 years	More than 10 years[c]
B	Normal		7 years
C	Low		5 years

Note; (a) Applicable to normal road drainage such as road surface or small scale slope
(b) Applicable to important road drainage such as transverse drainages which remove runoff water from large scale natural slope or located at important flat urban area where local drainage is difficult
(c) 30 years is advisable for very important transverse drainage from the viewpoint of road maintenance and operation

6) tipe dan bahan gorong-gorong yang permanen (lihat Gambar 7) dengan desain umur rencana :

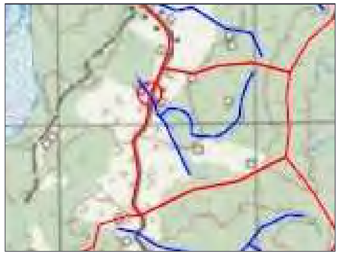
(1) jalan tol : 25 tahun;
(2) jalan arteri : 10 tahun;
(3) jalan lokal : 5 tahun.

Before:
Return period = 30 years

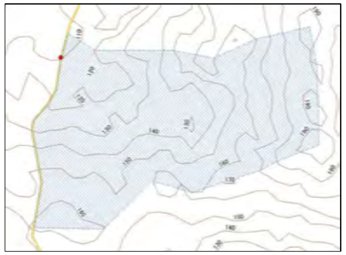
Now:
Return period = 10 years

Source: Manual for Highway Earthwork in Japan
Source: Manual for Highway Earthwork in Japan
Source: Drainase Jalan SNI 03-3424-1994

Design Adjustments (flood calculation)



Cartographic map measurement

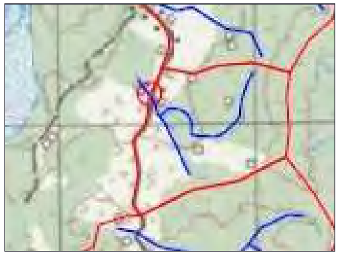


GIS measurement

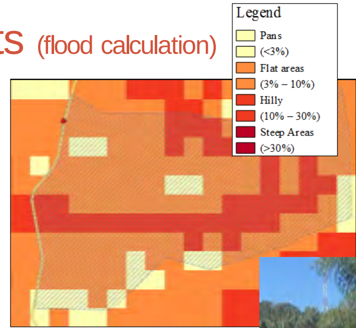
Before:
Catchment area = 0.44 km²

Now:
Catchment area = 0.32 km²

Design Adjustments (flood calculation)



Cartographic map assessment
Mountainous region

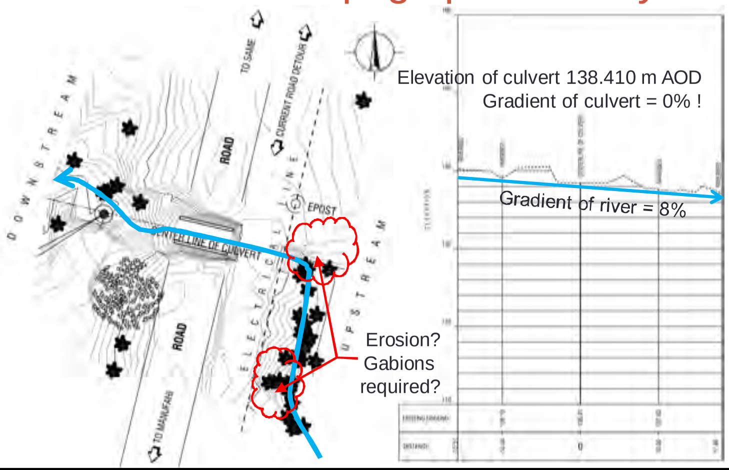


Site + GIS assessment
Average gradient 8%

Before:
Coefficient of runoff = 0.83
(Steep mountainous land)

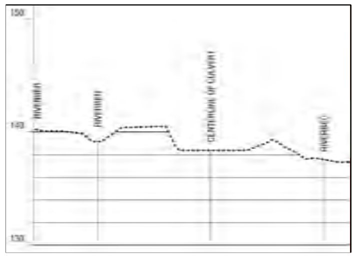
Now:
Coefficient of runoff = 0.75
(Gentle mountainous land)

Site Data from Topographic Survey



Design Adjustments (culvert calculation)

Cartographic + Site assessments

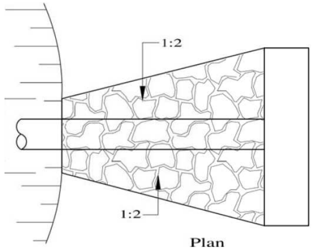


Topographic survey data
Cannot calculate for 0% gradient
∴ use minimum allowable gradient

Before:
Gradient of culvert = 1.5%
(100.090 – 100.000 m AOD)

Now:
Gradient of culvert = 0.5%
(138.440 – 138.410 m AOD)

Recommendations

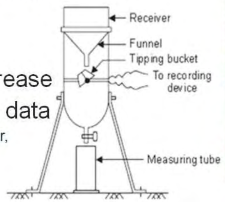


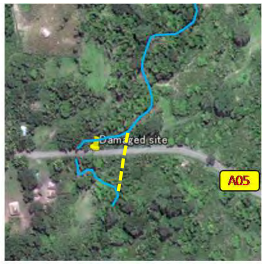
From now: construction of protection works at outlet

Next time: ensure minimum gradient of culvert = 0.5%

Next time: improvement of river alignment

Institutionally: increase collection of rainfall data (15-min, 30-min, 1-hr, 2-hr, 3-hr, 6-hr, 12-hr, 24-hr intervals)

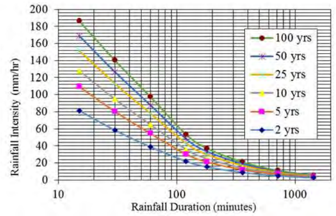




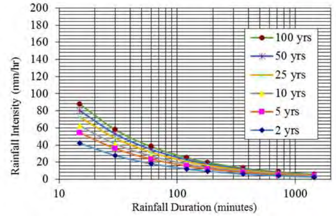
Necessity for Complete Rainfall Data

Example comparison (not in Timor-Leste):

- Intensity-duration-frequency curves



- Mononobe formula prediction



Necessary to record storm events of duration 15-min, 30-min, 1-hr, 2-hr, 3-hr, 6-hr, 12-hr & 24-hr (not only daily maximum)

Annex C
(informative)

Weather stations in Timor-Leste

C.1 Current locations of weather stations (Seeds of Life)

C.2 Historical locations of weather stations (Seeds of Life)

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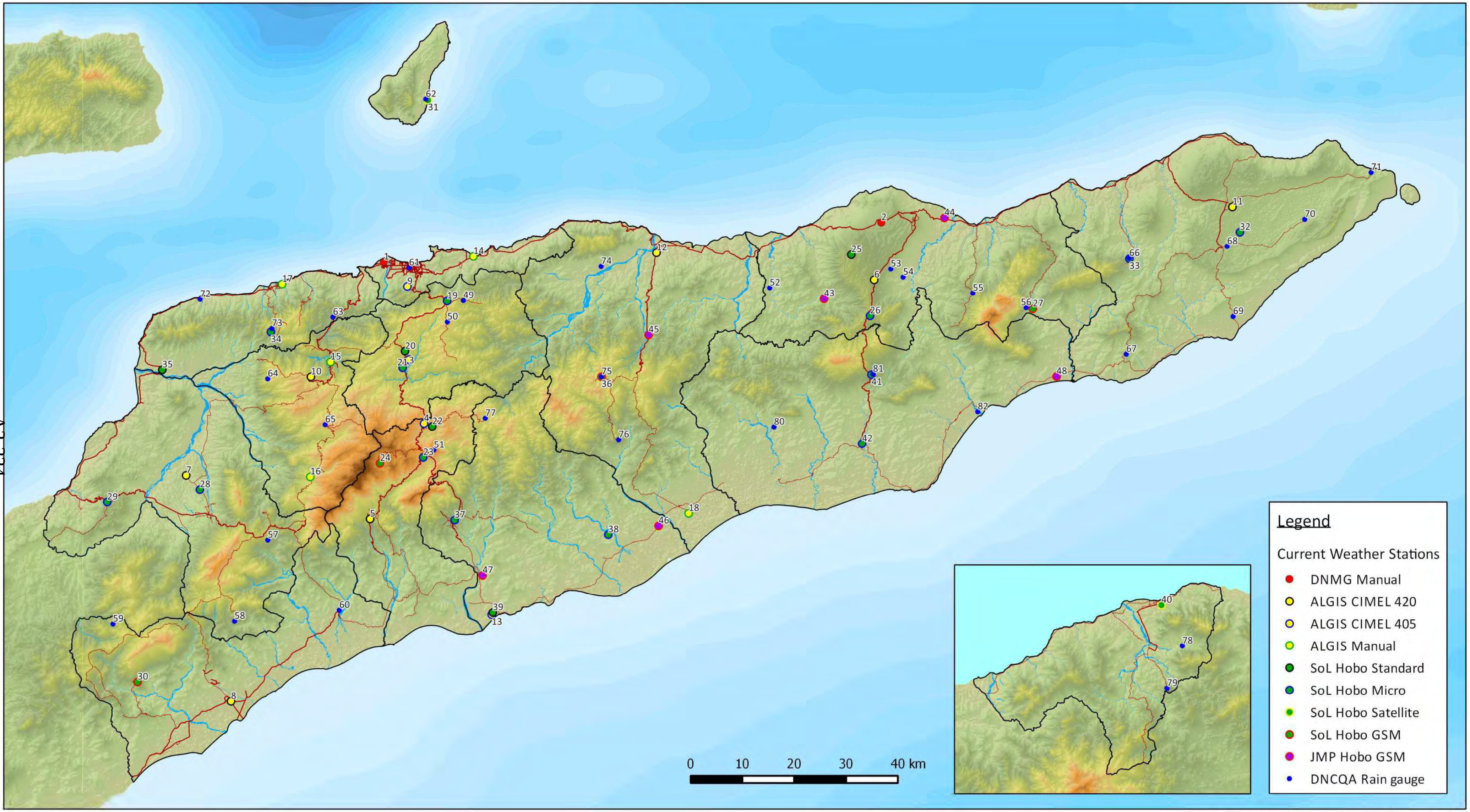
ANNEX

C.1 Current locations of weather stations (Seeds of Life)

Current Weather Stations in Timor-Leste



DNMG
1 Dili Airport
2 Baucau Airport

ALGIS
3 Aileu
4 Maubisse
5 Ainaro
6 Fatumaca
7 Maliana
8 Suai
9 Dare
10 Ermera
11 Fuiloro
12 Manatuto
13 Betano
14 Hera
15 Gleno
16 Atsabe
17 Liquica
18 Natarbora

SoL
19 Acumau
20 Quintal Portugal
21 Seloi Malere
22 Urulefa
23 Aituto
24 Hatobuilico
25 Darasula
26 Venilale
27 Baguia
28 Ritabou
29 Balibo
30 Fohorem
31 Maumeta
32 Fuiloro
33 Luro
34 Fazenda Algarve
35 Loes
36 Laklubar
37 Same
38 Dotik
39 Betano
40 Pante Macassar
41 Ossu
42 Viqueque

JMP
43 Vemase
44 Seical
45 Cribas
46 Sahen
47 Caraulun
48 Irabere

DNCQA
49 Remexio
50 Liquidoe
51 Flexa
52 Waigae
53 Darasula
54 Gariuai
55 Quelicai
56 Baguia
57 Bobonaro
58 Lolotoe
59 Baer
60 Zumalai
61 Dili EDTL
62 Atauro
63 Railaco
64 Fatubessi
65 Lete Foho
66 Luro
67 Iliomar
68 Los Palos
69 Lore
70 Moshes
71 Tutuala
72 Maubara
73 Fasenda
74 Laclo
75 Laclubar
76 Soibada
77 Turiscai
78 Noe-Heno
79 Oesilo
80 Lacluta
81 Ossu
82 Bebui

Weather station location data supplied by National Directorate of Meteorology and Geophysics (DNMG), ALGIS-Agromet (MAF), National Directorate of Water Quality and Control (DNCQA), Seeds of Life (MAF) and Japanese Master Plan project (JMP, MAF). Some validation of locations has been made. Exact locations of DNCQA rain gauges remains uncertain.
Produced by: S Bacon, Seeds of Life, 10/12/2014

Seeds of Life
Fini ba Moris

Table of Current Weather Stations

10/12/2014

A list of latitude, longitude and elevation values are provided for each weather station and rain gauge. All CIMEL and Hobo type weather stations are automatic weather stations. GSM and Satellite refers to the ability to transmit data to the internet with daily updates. Data may be requested by contacting the relevant departments or, for SoL data, go to the website: www.seedsoflifetimor.org

ID	Latitude	Longitude	Elevation	Location	District	Operator	Type
1	-8.54808	125.52766	11	Dili Airport	Dili	DNMG	Manual
2	-8.47895	126.39900	525	Baucau Airport	Baucau	DNMG	Manual
3	-8.71917	125.57167	900	Aileu	Aileu	ALGIS	CIMEL 405
4	-8.83170	125.59810	1500	Maubisse	Ainaro	ALGIS	CIMEL 405
5	-8.99889	125.50361	812	Ainaro	Ainaro	ALGIS	CIMEL 420
6	-8.57940	126.38661	612	Fatumaca	Baucau	ALGIS	CIMEL 420
7	-8.92250	125.18140	135	Maliana	Bobonaro	ALGIS	CIMEL 420
8	-9.31860	125.26000	22	Suai	Covalima	ALGIS	CIMEL 420
9	-8.59110	125.56890	460	Dare	Dili	ALGIS	CIMEL 405
10	-8.74940	125.40000	1165	Ermera	Ermera	ALGIS	CIMEL 420
11	-8.45190	127.01400	375	Fuiloro	Lautem	ALGIS	CIMEL 420
12	-8.53190	126.00530	25	Manatuto	Manatuto	ALGIS	CIMEL 420
13	-9.16660	125.71660	30	Betano	Manufahi	ALGIS	CIMEL 405
14	-8.53836	125.68453	982	Hera	Dili	ALGIS	Manual
15	-8.72340	125.43432	982	Gleno	Emera	ALGIS	Manual
16	-8.92495	125.39885	1165	Atsabe	Emera	ALGIS	Manual
17	-8.58697	125.34950	52	Liquica	Liquica	ALGIS	Manual
18	-8.98912	126.06158	69	Natarbora	Manatuto	ALGIS	Manual
19	-8.61661	125.63850	975	Acumau	Aileu	SoL	Hobo Micro
20	-8.70451	125.56480	980	Quintal Portugal	Aileu	SoL	Hobo Standard
21	-8.73364	125.56070	925	Seloi Malere	Aileu	SoL	Hobo Micro
22	-8.83692	125.61240	1316	Urulefa	Ainaro	SoL	Hobo Standard
23	-8.89135	125.59658	1667	Aituto	Ainaro	SoL	Hobo Micro
24	-8.90146	125.52087	2203	Hatobuilico	Ainaro	SoL	Hobo GSM
25	-8.53510	126.34650	690	Darasula	Baucau	SoL	Hobo Standard
26	-8.64255	126.37929	836	Venilale	Baucau	SoL	Hobo Micro
27	-8.63033	126.66427	309	Baguia	Baucau	SoL	Hobo GSM
28	-8.94717	125.20537	163	Ritabou	Bobonaro	SoL	Hobo Micro
29	-8.96925	125.04325	551	Balibo	Bobonaro	SoL	Hobo Micro
30	-9.28451	125.09632	688	Fohorem	Covalima	SoL	Hobo GSM
31	-8.26482	125.60496	6	Maumeta	Dili	SoL	Hobo Satellite
32	-8.49582	127.02705	358	Fuiloro	Lautem	SoL	Hobo Micro
33	-8.54236	126.83355	409	Luro	Lautem	SoL	Hobo Micro
34	-8.67051	125.32979	919	Fazenda Algarve	Liquica	SoL	Hobo Micro
35	-8.73720	125.13956	22	Loes	Liquica	SoL	Hobo Standard
36	-8.74928	125.90888	1005	Laklubar	Manatuto	SoL	Hobo GSM
37	-9.00091	125.65174	550	Same	Manufahi	SoL	Hobo Micro
38	-9.02642	125.92083	101	Dotik	Manufahi	SoL	Hobo Micro
39	-9.16303	125.71850	9	Betano	Manufahi	SoL	Hobo Standard
40	-9.20623	124.37433	29	Pante Macassar	Oecussi	SoL	Hobo Satellite
41	-8.74562	126.38180	648	Ossu	Viqueque	SoL	Hobo Micro
42	-8.86711	126.36533	51	Viqueque	Viqueque	SoL	Hobo Micro
43	-8.61269	126.29880	88	Vemase	Baucau	JMP	Hobo GSM
44	-8.47092	126.50960	10	Seical	Baucau	JMP	Hobo GSM
45	-8.67554	125.99143	135	Cribas	Manatuto	JMP	Hobo GSM
46	-9.01090	126.00900	21	Sahen	Manufahi	JMP	Hobo GSM
47	-9.09777	125.70060	32	Caraulun	Manufahi	JMP	Hobo GSM
48	-8.74878	126.70591	6	Irabere	Viqueque	JMP	Hobo GSM
49	-8.61583	125.66694	874	Remexio	Aileu	DNCQA	Rain gauge
50	-8.65314	125.63892	1243	Liquidoe	Aileu	DNCQA	Rain gauge
51	-8.87833	125.61528	2015	Flexa	Ainaro	DNCQA	Rain gauge
52	-8.59356	126.20353	82	Waigae	Baucau	DNCQA	Rain gauge
53	-8.56028	126.41556	490	Darasula	Baucau	DNCQA	Rain gauge
54	-8.57472	126.43722	262	Gariuai	Baucau	DNCQA	Rain gauge
55	-8.60278	126.55944	635	Quelicai	Baucau	DNCQA	Rain gauge
56	-8.62833	126.65278	461	Baguia	Baucau	DNCQA	Rain gauge
57	-9.03583	125.32444	794	Bobonaro	Bobonaro	DNCQA	Rain gauge
58	-9.17813	125.26616	850	Lolotoe	Bobonaro	DNCQA	Rain gauge
59	-9.18298	125.05334	208	Baer	Covalima	DNCQA	Rain gauge
60	-9.15899	125.44964	90	Zumalai	Covalima	DNCQA	Rain gauge
61	-8.55833	125.57194	15	Dili EDTL	Dili	DNCQA	Rain gauge
62	-8.26305	125.60107	10	Atauro	Dili	DNCQA	Rain gauge
63	-8.64487	125.43849	777	Railaco	Ermera	DNCQA	Rain gauge
64	-8.75288	125.32426	1087	Fatubessi	Ermera	DNCQA	Rain gauge
65	-8.83361	125.42500	1045	Lete Foho	Ermera	DNCQA	Rain gauge
66	-8.54178	126.83332	403	Luro	Lautem	DNCQA	Rain gauge
67	-8.70990	126.82800	388	Iliomar	Lautem	DNCQA	Rain gauge
68	-8.52056	127.00472	375	Los Palos	Lautem	DNCQA	Rain gauge
69	-8.64368	127.01516	66	Lore	Lautem	DNCQA	Rain gauge
70	-8.47343	127.14074	353	Moshes	Lautem	DNCQA	Rain gauge
71	-8.39139	127.25694	355	Tutuala	Lautem	DNCQA	Rain gauge
72	-8.61361	125.20583	32	Maubara	Liquica	DNCQA	Rain gauge
73	-8.66448	125.33163	1019	Fazenda	Liquica	DNCQA	Rain gauge
74	-8.55583	125.90833	175	Laclo	Manatuto	DNCQA	Rain gauge
75	-8.74917	125.90889	1100	Laclubar	Manatuto	DNCQA	Rain gauge
76	-8.86000	125.93889	680	Soibada	Manatuto	DNCQA	Rain gauge
77	-8.82250	125.70528	1179	Turiscai	Manufahi	DNCQA	Rain gauge
78	-9.27801	124.41099	177	Noe-Heno	Oecussi	DNCQA	Rain gauge
79	-9.35212	124.38418	474	Oesilo	Oecussi	DNCQA	Rain gauge
80	-8.83778	126.21111	108	Lacluta	Viqueque	DNCQA	Rain gauge
81	-8.74472	126.38444	660	Ossu	Viqueque	DNCQA	Rain gauge
82	-8.81100	126.56800	6	Bebui	Viqueque	DNCQA	Rain gauge

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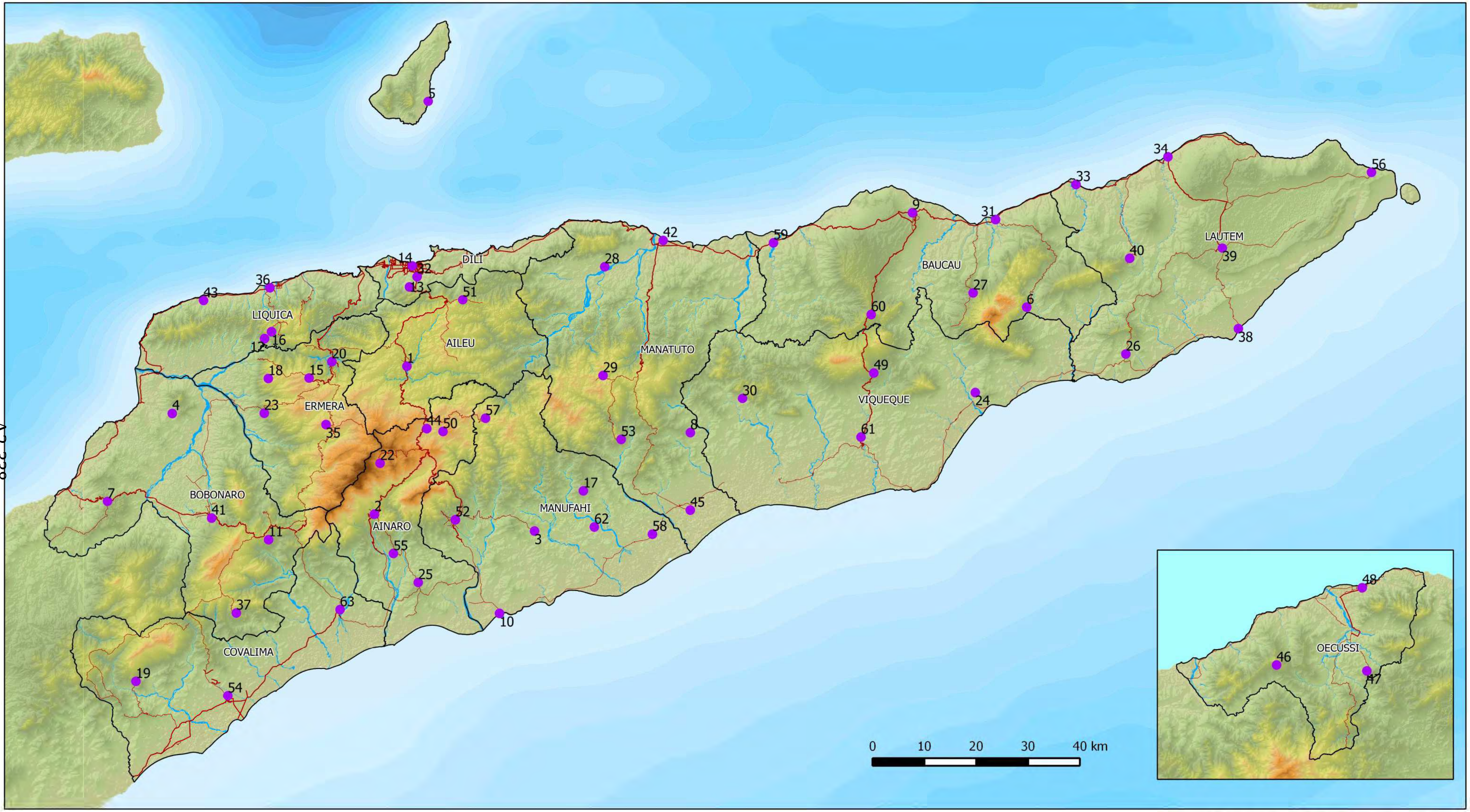
ANNEX

C.2 Historical locations of weather stations (Seeds of Life)

Historical Weather Station Locations in Timor Leste



Station Names:

1	Aileu	8	Barique	15	Ermera	22	Hato Builico	29	Laclubar	36	Liquica	43	Maubara	50	Raimera	57	Turiscae
2	Ainaro	9	Baucau	16	Fasenda Algarve	23	Hato Lia	30	Lacluta	37	Lolotoe	44	Maubisse	51	Remexio	58	Ue Laluho (Quiras)
3	Alas	10	Betano	17	Fatu Berliu	24	Hato Lore	31	Laga	38	Lore	45	Natar Bora	52	Same	59	Vemassi
4	Atabae	11	Bobonaro	18	Fatu Bessi	25	Hato Udo	32	Lahane	39	Lospalos	46	Nitibe	53	Soibada	60	Venilale
5	Atauro Vila	12	Boibau	19	Fohorem	26	Ilomar	33	Laivai	40	Luro	47	Oesilo	54	Suai	61	Viqueque
6	Baaguia	13	Dare	20	Gleno	27	Kelicae (Quelicai)	34	Lautem	41	Maliana	48	Okussi	55	Suro	62	We Berec
7	Balibo	14	Dili	21	Granja E. Marques?	28	Laclo	35	Lete Foho	42	Manatuto	49	Ossu	56	Tutuala	63	Zumalai

Based on data from Santika, 2004, locality names, consultation with GoTL staff and local Timorese people on site.
Produced by: S Bacon, Seeds of Life, 1/7/2014

Seeds of Life
Fini ba Moris

Historical Weather Station Sites

The following is a list of corrected latitude longitude coordinates (CRS WGS84) for the historical weather station sites in Timor-Leste operated during the Portuguese period.

This data was developed based on data from Santika, 2004, as well as locality names, consultation with Timorese Government agriculture staff and, in some cases, consultation with local Timorese people on site over a period of 18 months.

This review was conducted by Samuel Bacon, Cropping Systems Advisor, Seeds of Life, 30/6/2014

ID	Name	Latitude	Longitude	Elevation (m)	Accuracy Range (m)
1	Aileu	-8.731480316	125.5670573	920	500
2	Ainaro	-8.991031847	125.5100699	815	500
3	Alas	-9.020209182	125.790699	202	500
4	Atabae	-8.814458797	125.1558736	387	50
5	Atauro (Maumeta)	-8.267232516	125.6043459	10	100
6	Baaguia	-8.628267285	126.6531209	428	200
7	Balibo	-8.968433411	125.0423568	554	50
8	Barique	-8.847660697	126.0637616	340	100
9	Baucau	-8.462592123	126.4528542	327	6300
10	Betano	-9.16490948	125.7292756	6	2000
11	Bobonaro	-9.035223302	125.3246346	802	100
12	Boibau	-8.682761688	125.3176129	644	50
13	Dare	-8.59238633	125.5714962	524	2000
14	Dili	-8.555630219	125.5763603	5	50
15	Ermera	-8.752111791	125.3956413	1192	100
16	Fasenda Algarve	-8.670781895	125.3298159	916	20
17	Fatu Berliu	-8.949786397	125.8761974	595	1000
18	Fatu Bessi	-8.752883739	125.32426	1092	500
19	Fohorem	-9.283731252	125.0922302	598	1000
20	Gleno	-8.723514814	125.4355461	708	1000
21	Granja E. Marques?	-8.545757752	125.5766558		
22	Hato Builico	-8.901572469	125.5200865	1926	200
23	Hato Lia	-8.814011388	125.3171254	583	600
24	Hato Lore	-8.777441	126.563047	237	50
25	Hato Udo	-9.110377803	125.5869127	470	100
26	Ilomar	-8.710094526	126.8268307	391	500
27	Kelicae (Quelicai)	-8.602779527	126.5592	698	500
28	Laclo	-8.557037219	125.9136757	142	800
29	Laclubar	-8.747689134	125.9107597	1077	200
30	Lacluta	-8.788027782	126.1551055	316	5000
31	Laga	-8.474454458	126.5985186	52	100
32	Lahane	-8.574535239	125.5848825	104	100
33	Laivai	-8.412950456	126.739492	26	100
34	Lautem	-8.364980855	126.9006303	16	100
35	Lete Foho	-8.833688895	125.4252773	1490	800
36	Liquica	-8.593804706	125.3270685	26	20
37	Lolotoe	-9.164203972	125.2681426	819	1000
38	Lore	-8.665525235	127.0239839	12	500
39	Lospalos	-8.524264219	126.9959334	395	100
40	Luro	-8.54235803	126.8335496	413	50
41	Maliana	-8.997716565	125.2248472	253	500
42	Manatuto	-8.510687159	126.0160423	7	500
43	Maubara	-8.616425774	125.2107269	76	50
44	Maubisse	-8.840754203	125.6019015	1463	50
45	Natar Bora	-8.984001851	126.0635675	33	2000
46	Nitibe	-9.337381775	124.2204365	780	2000
47	Oesilo	-9.347738145	124.3790209	475	1000
48	Okussi	-9.201455939	124.3708842	10	500
49	Ossu	-8.743298566	126.3851911	669	50
50	Raimera	-8.845672094	125.630316	1504	5000
51	Remexio	-8.615048918	125.6648466	878	300
52	Same	-9.000628215	125.6520012	556	20
53	Soibada	-8.859389879	125.942488	645	600
54	Suai	-9.309084107	125.2532404	91	500
55	Suro	-9.059763609	125.5434289	432	200000
56	Tutuala	-8.391844574	127.2572222	361	500
57	Turiscae	-8.822692581	125.7048446	1183	500
58	Ue Laluho (Quiras)	-9.025616114	125.9972547	29	1000
59	Vemassi	-8.514754459	126.2093046	45	1000
60	Venilale	-8.641012863	126.3806041	839	500
61	Viqueque	-8.85537985	126.3627711	58	1800
62	We Berec	-9.013184521	125.8954801	127	1000
63	Zumalai	-9.158281701	125.4499118	91	1000

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República Democrática de Timor-Leste

Ministério das Obras Públicas

Direcção Geral das Obras Públicas

Direcção Nacional de Estradas, Pontes e Controlo de Cheias

Matadalan Estrada — Drenajem — Dezenu Culvert

Road Guidelines — Drainage — Culvert Design

Faze EFM

Atensaun

Documentos ida ne'e laos Padraun Nacional Timor Leste. Dokumentus ne'e sei fahe hodi halo revisaun no fo komentario. Materia ida ne bele halo mudansa no sein fo hatene no la refere hanesan padraun nacional.

Benefisiariu ba esbosu hetan convida atu submite, sira nia komentario, notifikasaun kona ba sira nia direitu ba patent nebe relevante no sira hatene no fornese apoio ba dokumentasaun.

Tipu Dokumentu: Spesifikasaun Teknikaocument
Subtipu Dokumentu:
Faze Dokumentu: (EFM) Esbosu Final Matadalan
Dokumentus ho lingua: TDT

Ministério das Obras Públicas
Direcção Geral das Obras Públicas
Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
Enderesu: Avenida da Restauração, Rai Kotu, Comoro, Dili, Timor-Leste
Nu. Kontaktu: +670 3311408

Konteudu

REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTÉRIO DAS OBRAS PÚBLICAS
GABINETE DO VICE-MINISTRO
Av. Nicolau Lobato, Mandarin, Dili, Timor-Leste

Prefasiu

Iha interese ba harii ho qualidade as no ekonomikamente viabiliza infrastrutura hodi servi nasaun, matadalan ida ne'e atu optimija dezeñu garante komponente drainajem nebe prepara ona husi JICA Projeito Desenvolvimento Kapasidade ba Servisu Estrada iha República Democrática de Timor-Leste (CDRS) nebe iha kolaborasaun ho Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC), Ministério das Obras Públicas. Ami hakarak hato'o agradese ba JICA ba kontinua suporta.

Setembru, 2019

Eng. Nicolau Lino Freitas Belo
Vice-Ministro das Obras Públicas
Ministério das Obras Públicas

Prefasiu husi JICA

Japan International Cooperation Agency (JICA) halao ona projetu kooperasaun téknika ida ba desenvolvimento kapasidade kona ba servisu estrada, nebe'e hanaran CDRS, nune atu fasilita DNEPCC jere no halo manutensaun ba infra-estrutura estrada bazea ba actividade soscial no ekonomiku. Ba ida-ne'e nia rohan, JICA despasa ona ekipa espesialista sira husi fulan-Marsu tinan 2016 to'o fulan Dezembru tinan 2019. Hanesan resultadu husi kolaborasaun servisu husi parseira DNEPCC, matadalan ba dezeñu culverts finalisa ona. Ha'u espera katak matadalan ida-ne'e sei kontribui ba dezenvolvimentu infra-estrutura no manutensaun, no valorizasaun relasaun belun di'ak entre nasaun rua.

Ikus liu, ha'u hakarak hato'o ha'u-nia apresiasaun sinceriamente ba funcionariu governu República Democrática de Timor-Leste nia ho equipa peritu.

Setembru, 2019

Masafumi NAGAISHI
Representante Chefe Gabinete JICA iha Timor-Leste
Japan International Cooperation Agency

Agradesimentu

Projetu ba Desenvolvimentu Kapasidade Servisu Estrada iha República Democrática de Timor-Leste (CDRS) hakarak atu fó-agradese ba parte hotu-hotu ne'ebé envolve an hodi prepara matadalan dezenu culvert no espesiál agradesimentu ba M. Soares husi DNEPCC nebe halo revisaun ba matadalan ne'e.

Apoia projetu ne'e, ofisial husi (eis) Ministério de Desenvolvimento e de Reforma Institucional: M. R. M. Cruz, J. L. C. C. P. Mestre and J. Santos; no ofisial husi Ministerio Obras Publiku: C. M. Henrique no especialmente ba R. H. F. Guterres; hodi rekonese.

Durante halo preparasaun ba dokumentus ida ne'e hetan kontribuisaun husi ofisial DNEPCC: M. R. C. Monteiro, J. P Amaral, J. M. G. Sousa, J. G. Carlvalho, I. M. L. Gutteres, N. Lobato, A. Araujo, V. N. P. Araujo, L. R. H. Corbafo, J. Costa, M. F. Costa, R. Costa, S. Laranjinha, D. X. Deus, B. Ferreira, R. C. Freitas, P. C. R. Noronha, C. E. Ximenes; no Organizasaun Internasional Trabalho ou International Labour Organization's (ILO) nudar ekipa asistente teknika ba apoiu programa Desenvolvimento Estrada (R4D-SP): A. O. Asare, K. H. Myaing, S. Done, S. F. Eqbali, V. Sam, D. H. Singh; hodi rekonese.

Hanesan adisional, Programa Fini ba moris: S. Bacon hodi rekonese

Komentariu:

Sei apresia tebes ba komentariu nebe positivu ba posibilidade inkorporasaun ba edisaun tuir mai. Favor fo komentario no sugestaun ba iha enderusu tuir mai ne'e.

Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
Enderesu: Avenida da Restauração, Rai Kotu, Comoro, Dili, Timor-Leste
Nu. Kontaktu: +670 3311408

Introdusaun

Matadalan ida ne desenvolve husi JICA Projetu ba Desenvolvimentu Kapasidade Servisu Estrada iha República Democrática de Timor-Leste (CDRS) nebe kolabora ho Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC), ho objektivu atu desenvolve kapasidade relasiona ho dezenu drainagem cross culvert.

Objetivu hosi dezenu drenajen ne'e atu garante kapasidade husi fasilidade drenajen nian nebe apropriadu, ne'ebé signifika spesifika culverts ho nia kapasidade drenajem bele suficiente atu akomoda volume probable ba stormwater no ho kustu konstrusaun ne'ebe razoavel kompara ho nia benefisu rasik ba aktividade ekonomika. Iha konstextu ultra passa estrada, objektivu husi kaixa culverts atu garante protesaun ba strutura estrada no uzuariu dalan.

Kronolojia kona ba edisaun mak hanesan tuir mai ne'e:

— Edisaun dahuluk ho Ingles Setembru 2019

— Edisaun dahuluk ho Tetun Dili Setembru 2019

Mudansa prinsipál sira ne'ebé kompara ho edisaun uluk mak hanesan tuir mai:

— La iha mudansa

Matadalan Estrada — Drenajem — Dezenu Culvert

1 Ambitu

Matadalan ida ne nia objektivu atu atu fo informasaun pratika ba planeamentu no dezenu ba kaixa culvert ho objectivu atu halo kontrusaun culvert ka re konstrui. Matadalan ida ne'e refere liu ba studu hidraulika no dezennu hidrauliku. Metodologia dezenu nebe aprezenta rekomenda tiha ona bazea ba fasil iha sira nia aplikasaun no konsiste iha abordajen. Kestaun planeamentu ne'ebe mak deskrita tiha ona iha matadalan ne'e mak fo referensia no julgamentu enjinerru tenki uja tuir aplikasaun ne'ebe bazea ba kondisaun terrenu, hanesan detritos.

Matadalan ida ne'e la kobre limpeja, rekondisionamentu, hadia, dezenu strutural ka dezenu padraun ba culvert. Hanesan informasaun relasiona jestaun konstrusaun no manutensaun iha terrenu, favor bele hare iha seksaun ne'ebe relevante iha *Padraun Espesifikasaun* (Seksaun 600 – Drainajem no Estrutura protesaun inclinasaun) (1). Ba aplikasaun ne'ebe envolve mota bo'ot ka travessa ne'ebe naruk, favor bele adopta *Padraun e Manual Dezenu Ponte* (2). Ba orientasaun iha dimensaun strutural no reinforsa, favor hare padraun strutural ne'ebe relevante no padraun dezenu.

Lian nebe uja iha matadalan ida ne'e jeralmente latina atu bele fasilita compresaun enginheiru direccao nian.

2 Referensia normativu

Dokumentus sira tuir mai ne'e refere ba iha testu ka maneira husi konteudo balun nebe representa husi dokumentus ida ne'e. Kona ba referensia nia data, somente aplika edisaun sitada. Kona ba referensia nebe sem data, aplika edisaun ikus husi dokumentus referensia (inklui alterasaun).

Padraun Espesifikasaun (2014) (1)

Padraun e Manual Dezenu Ponte (2012) (2)

Padraun Dezenu Geometrika Estrada (2010) (3)

3 Termu no definisaun

Hanesan referénsia, glosáriu ida kona-ba termu no sira-nia signifikadu hanesan iha lian Ingles, no Tetun, Portugés, Indonesia, no japaun inklui hotu ona iha matadalan ne'e nia kotuk.

Ba objektivu dokumentu ida ne'e, aplika termu no definisaun tuir mai ne'e.

ISO mantein terminalojia baze dadus ba benifisiariu sira atu uja padraun iha enderesu tuir mai ne'e:

— Plataforma navigasaun online ISO: iha https://www.iso.org/obp

3.1
kaptasaun
luan rai ida iha ne'ebe be iha rai okos ka liu ba fatin ne'ebe hanesan

[FONTES: ISO 14055-1:2017(en), 3.2.19]

3.2
culvert
drenajen transversal ka strutura be dalan iha estrada nia okos, rel kereta api, ka kanal, ou liu husi tanggul, ne'ebe ho forma pipa bo'ot ka kanal ne'ebe taka

[FONTES: ISO 6707-1:2017(en), 3.1.2.33]

3.3
periodu retornu
númeru média tinan ne'ebé iha asaun ida-ne'ebé temi estatistikamente exsedidu dala ida verage

[FONTES: ISO 12494:2017(en), 3.8]

3.4
mota
isin lolon natural husi be'e sulin kontinua ka intermitentemente kursu nebe defini tiha ona ba oseanu tasi, lagoa, iha rai nebe hetan depresaun, marsh ka kanal sira seluk

[FONTES: ISO 5667-6:2014(en), 3.9]

3.5
movimentu subcritical
movimenntu iha kanal nakloke nebe ho velosidade critical nebe menus, iha numeru froud nebe menus husi unidade, no iha superfície kiik nebe distúrbius bele lao husi upstream

[FONTES: ISO 772:2011(en), 1.7]

3.6
movimentu supercritical
movimentu iha kanal nakloke nebe boot liu velosidade critical, nebe iha numeru froude nebe boot liu ka diak liu unidade, no iha superfície kiik nebe distirbiu labele lao husi upstream

[FONTES: ISO 772:2011(en), 1.8]

3.7
aliran be
kanal iha leten ka iha superfície rai okos, liu husi be'e nebe halo movimentu

[FONTES: ISO 6107-7:2006(en), 50]

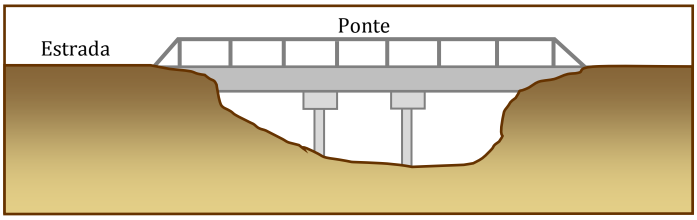
3.8
keliling basah
relasaun entre aliran be nia naruk no fluxo be nian nebe iha kanal nakloke nian laran, bele sukat husi diresaun be ninian fluxo

[FONTES: ISO 772:2011(en), 1.54]

4 Planeamentu

4.1 Seleksaun strutura

Etapa dahuluk ba planeamentu mak seleksaun husi tipu nebe mak apropriadu husi strutura nebe liu aliran be. Tipu prinsipal rua husi strutura ba hakur ponte no culverts. Sira nain rua iha vantajen no desvantajen, hanesan iha Figura 4.1. Bele mos iha fatores balun nebe enjinheiru presiza atu konsidera. Karik ponte mak apropriadu liu, favor refere ba *Padraun e Manual Dezenu Ponte* (2).



Ponte
- Kustu konstrusaun: aas liu
- Movimentu aliran be: menus afeta
- Debris: menus problematiku
- Land-use / ambiental: menus afeta

Culvert
- Kustu konstrusaun: lower (rendah-Indonesian)
- Movimentu aliran be: afeta makas
- Debris: problematika makas
- Land-use /ambiental: afeta makas

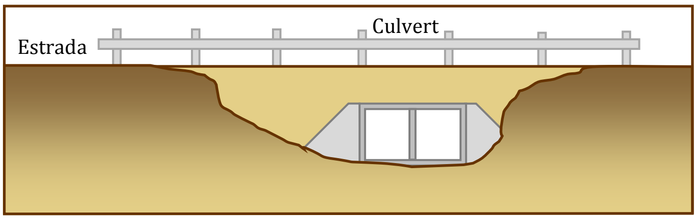


Figura 4.1 — Comparasaun husi aplikasaun husi ponte no culvert

4.2 Observasaun jeral kona ba culvert

Iha various fetiu (kaixa retangular, pipa circular, pipa elíptico, pipa arco, nsst.), material (beton, besi ulir, etc.) and inlets (parede nian liras, parede plana, borda quadrada iha coroa, bisel iha coroa,nsst.). Matadalan ida ne'e sei kobre kaixa culvert nebe halo ho konkretu. Parte culvert ida ne'e hatudu iha Figura 4.2 no Figura 4.3.

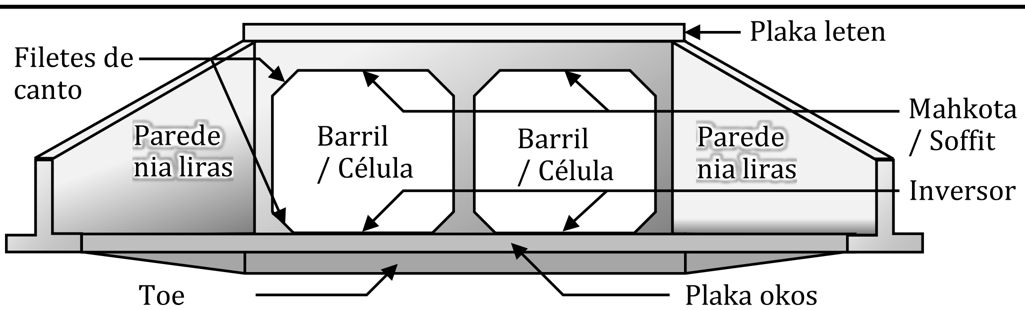


Figura 4.2 — Parte hui culvert iha elevasaun oin

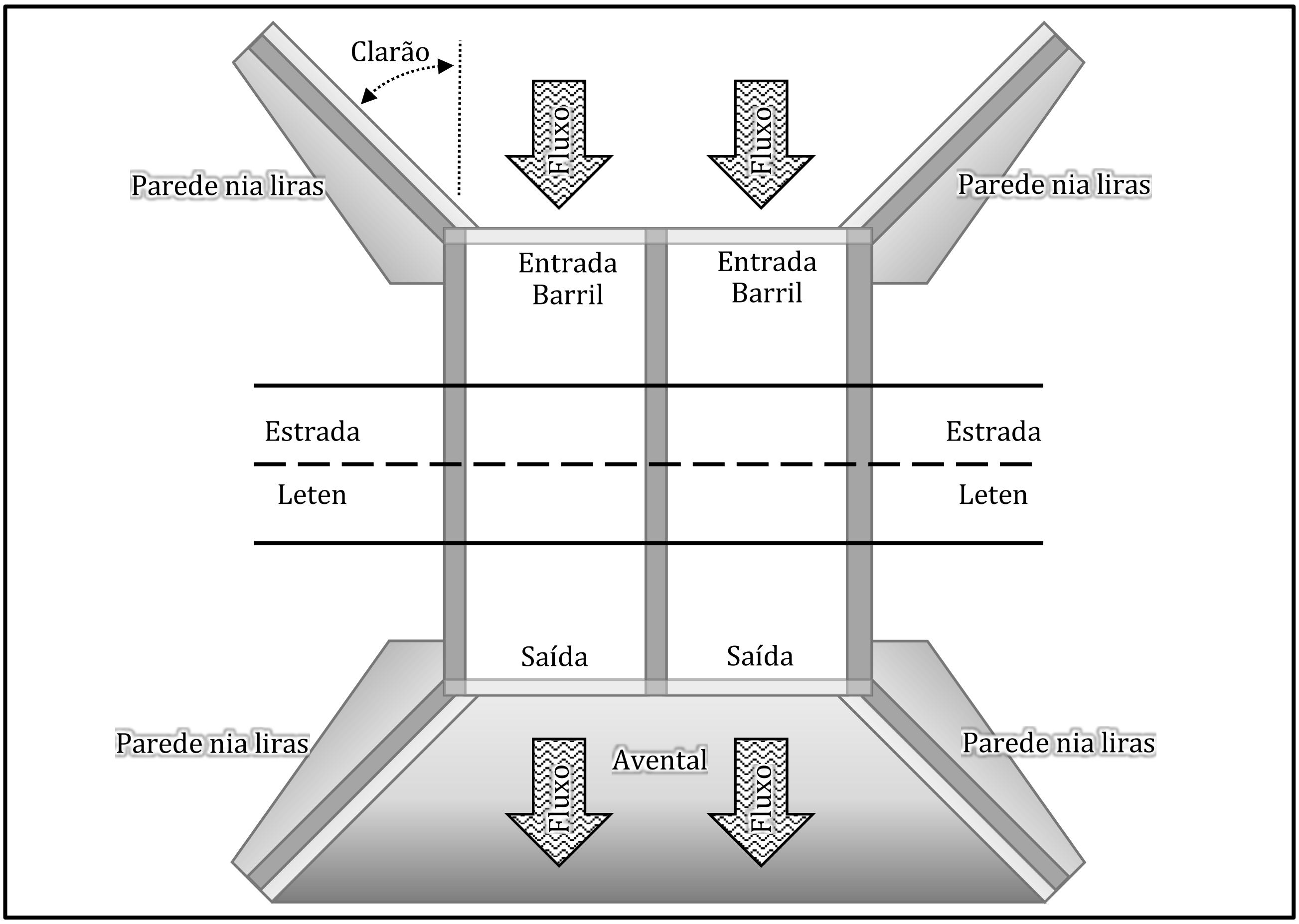


Figura 4.3 — Parte husi culvert nebe planea

4.3 Aplikasaun culvert

Iha limitasaun ba estrutura culvert nia aplikasaun. Nivel ne'ebé rekomenda husi aplikasaun ba kada baril kaixa culvert husi konkretu ida-ne'e hatudu iha Tabela 4.1. Iha posibilidade ba dezeñu liu limitasaun hirak ne'e ho konsiderasaun ne'ebé sufisiente ba dezenu estruktural no trafiku nian todan.

Proporsaun culvert ida (as : largura) ne'e normalmente iha nivel 1 : 1 to'o 1 : 3. Proporsaun hidraulikamente nebe efisiente mak 1 : 2. Maske nune'e, proposaun normal ba culvert mak 1 : 1, tamba nune'e estrutura culvert tenki suporta atu tane trafiku nia todan.

Tabela 4.1 — Limitasaun ne'ebe rekomenda ba kaixa culvert (4) (5)

Propriedade	Minimum	Masimum
As, D	0.75 m (750 mm)	5.0 m (5000 mm)
Largura, B	0.45 m (450 mm)	6.5 m (6500 mm)
Profunidade cobertura (husi material) iha plaka nia leten	0.5 m (500 mm)	—
Proporsaun (as : largura)	1 : 1	1 : 3
Culvert nian gradiente	0.005 m/m (0.5%)	0.100 m/m (10%)

Iha prinsípiu,geometria kaixa culvert ida (largura, gradiente, no elevasaun inferior) tenki hanesan ho aliran be original hodi bele redus sedimentasaun no erosaun. Nia gradiente tenki bo'ot liu 0.5% ka 0.005 m/m, no menus husi 10% ka 0.100 m/m atu garante workability & prevene slippage.

4.4 Alinamen culvert

Aliñamentu culvert importante ba funsaun culvert no aliran be. Karik bele, inlet no outlet culvert tenki lokaliza iha kanal natural iha interseksaun ho estrada nia fill slope.

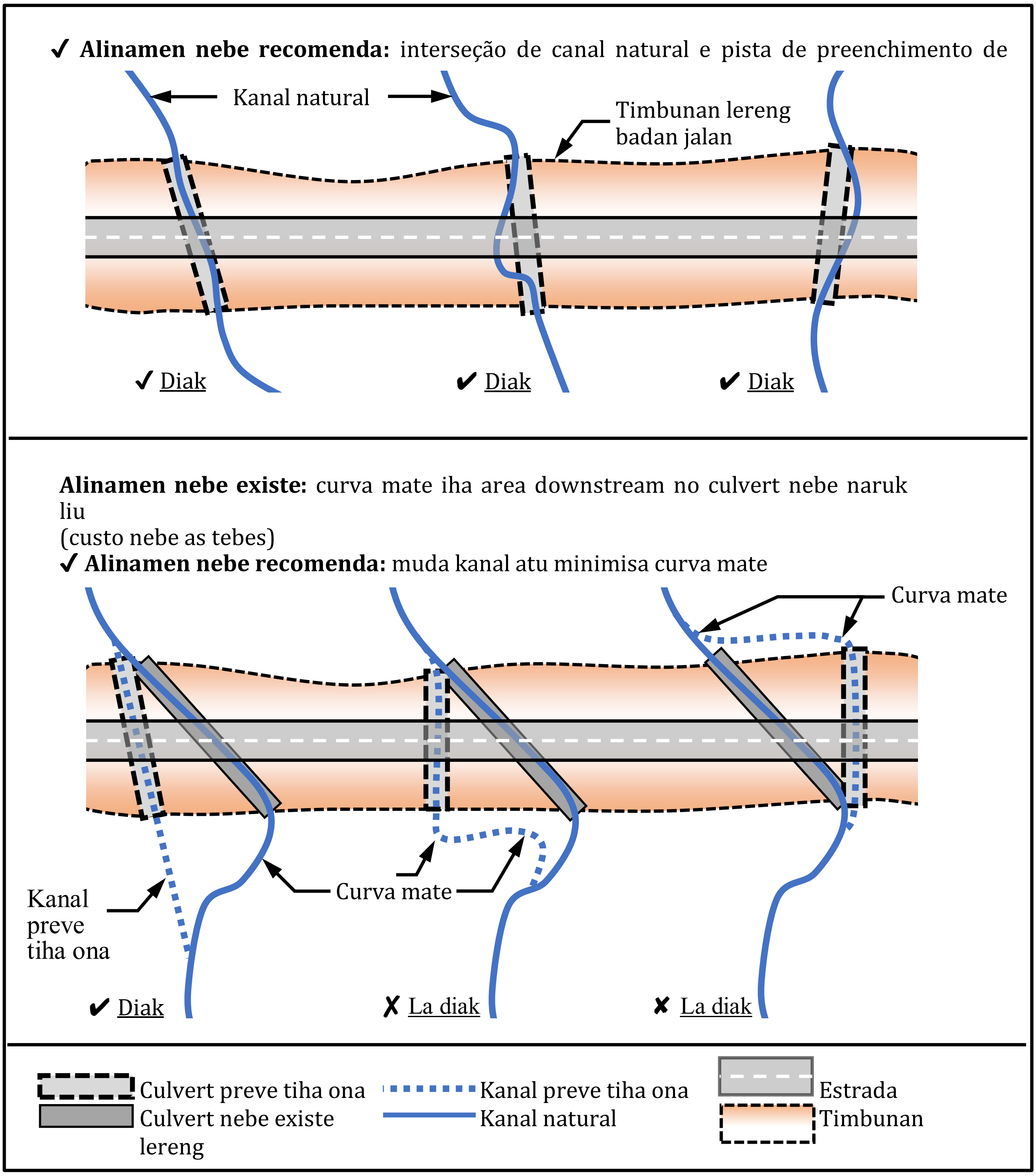


Figura 4.4 — Ezemplu alinamen Culvert

4.5 Prosesu dezenu

Deskrisaun ida kona-ba etapa ba prosesu dezenu hatudu iha Figura 4.5.

Koleta dadus	O Informasaun baziku iha terrenu O Dadus topografia O Dadus kartográfikus (mapa) / dadus geoespacial O Dadus udan ben	Seksaun 5
Analiza udan ben	O Análize frekuénsia O Kalkulasaun udan ben lor-loron ba dezenu	Seksaun 6
Kalkulasaun ba inundasaun	O Kalkulasaun ba area kaptasaun O Kalkulasaun ba konsentrasaun tempu O Kalkulasaun ba Intensidade udan ben O Avaliasaun kona ba cofisiente limpasan O Kalkulasaun kona ba deskarga inundasaun	Seksaun 7
Hidrolika kanak-nakloke	O Seleksaun ba culvert nia dimensaun O Seleksaun kapasidade culvert ba deskarga O Kalkulasaun tipu Inundasaun no velosidade	Seksaun 8
Servisu protesaun	O Seleksaun ba medida protesaun no dimensaun	Seksaun 9

Figura 4.5 — Sumario prosesu dezenu

Iha kazu balun, prosesu simplifikadu ida ba dezeñu bele hetan adota, hanesan hatudu iha Figura 4.6. Prosesu ida ne'e baszea ba adota intensidade udan ben 200 mm/oras husi *Padraun e Manual Dezenu Ponte* (2). Maske nune'e, prosesu ida ne'e bele resulta dezenu hetan excessivos ka la sufisiente no tenki uza ho kuidadu. Prosesu ida ne'e tenki uza deit ba aplikasaun ne'e be kiik iha perkursu kiik, hanesan estrada rural.

Koleta dadus	O Inforasaun baziku iha terrenu O Dadus kartográfikus (mapa) / dadus geoespacial	Seksaun 5
Kalkulasaun ba inundasaun	O Kalkulasaun ba area kaptasaun O Intensidade udan ben = 200 mm/oras O Avaliasaun kona ba kofisiente limpasan O Kalkulasaun kona ba deskarga inundasaun	Seksaun 7
Hidrolika kanak-nakloke	O Seleksaun ba culvert nian dimensaun O Kalkulasaun kapasidade culvert no nia deskarga O Kalkulasaun tipu movimentu no nia velosidade	Seksaun 8
Servisu protesaun	O Seleksaun medida protesaun no nia dimensaun	Seksaun 9

Figura 4.6 — Sumariu simplifikadu prosesu dezenu

5 Koleksaun dadus

Dezeñu culverts presiza komprensaun kona-ba kondisaun iha terrenu. Seksaun tuir mai trasa informasaun oin-oin ne'ebé sei rekolla liu hosi fatin investigasaun no métodu hanesan analiza dokumentu estudu (investigasaun externa).

5.1 Investigasaun baziku iha terrenu

Tenke implementa investigasaun báziku iha terrenu kona-ba dezeñu culvert hotu-hotu. Informasaun ne'e sei fo nesesariu ba planeamentu nomos apoiu desijaun foti iha prosesu dezenu relasiona ho run-off. Ezemplu kona-ba informasaun requere hatudu iha Tabela 5.1 no Figura 5.1.

Tabela 5.1 — Ezemplu checklist ba item investigasaun iha terrenu

☑	Informasaun / Item investigasaun	Fontes ne'ebe posivel
◻	Koordinat lokasi (latitude & longitude)	GNSS (GPS) receiver / smartphone
◻	Medida ba dimensaun husi culvert nebe eziste (m), karik iha	Fita metru
◻	Medida sira kona ba nivel (m) movimentu normal	Fita metru no marka iha strutura nia leten / rai leten
◻	Fotografia fluxo normal	Camera / smartphone / komunidade lokal (populasaun)
◻	Medida sira kona-ba nivel (m) fluxo ne'ebe makas / inundasaun	Fita metru no marka iha strutura nia leten/ rai leten
◻	Fotografia ba fluxo ne'ebe as / inundasaun	Camera / komunidade lokal (populasaun)
◻	Data ba fluxo ne'ebe makas / inundasaun	Komunidade lokal / ofisiál / administrasaun
◻	Fotografia kona ba elevasaun ih terrenu / tuir estrada	Camera / smartphone
◻	Fotografia bes-besik foho / terrenu	Camera / smartphone
◻	Fotografia besik area konstrusaun / rekursu terestres	Camera / smartphone
◻	Fotografia inlet culvert nian (proposta/eziste)	Camera / smartphone
◻	Fotografia iha mota ulun / diresaun ascendente	Camera / smartphone
◻	Fotografia outlet culvert nian (proposta/eziste)	Camera / smartphone
◻	Fotografia iha mota ain / diresaun descendente	Camera / smartphone
◻	Fotografia aérea	UAV (drone) / satellite (Google Earth)

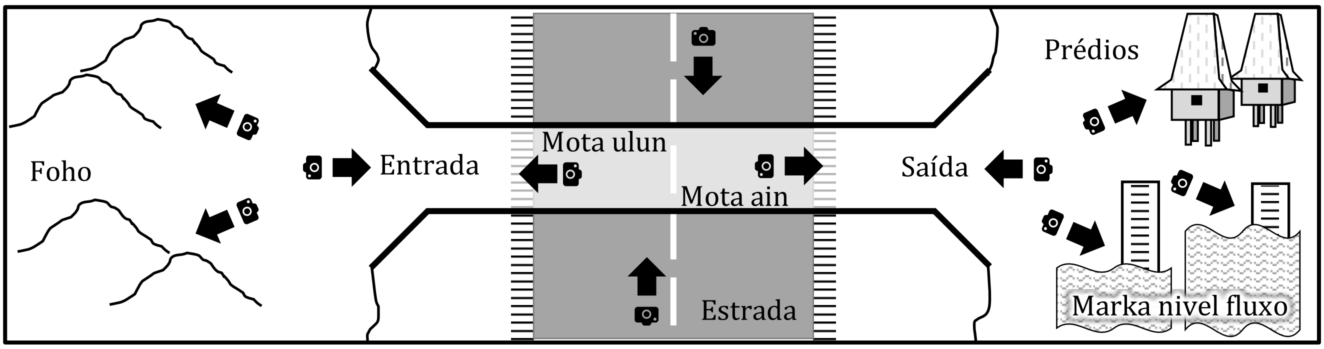


Figura 5.1 — Diagrama fotografia iha terrenu

5.2 Investigasaun topografia

Karik bele,Investigasaun topografikui tenki implementa iha terrrenu. Informasaun ida ne'e sei fo nesesariu ba planeamentu no sei forma parte fundamental ba kalkulasaun dezenu nebe relasiona ho gradiente aliran be. Aleinde ne'e, informasaun ida-ne'e bele hadi'ak presizaun iha dezeñu no fasilita fiskalizasaun kona-ba rezultadu. Informasaun balun ne'ebe requere hatudu ihapossible, Tabela 5.2.

Tabela 5.2 — Ezemplu checklist ba item investigasaun topografiku

☑	Informasaun / Item husi investigasaun	Fontes ne'ebe posivel
◻	Nivel invertidu (m AOD) iha inlet nian proposta/eziste	Total station / theodolite
◻	Nivel invertidu (m AOD) iha outlet propsta/eziste	Total station / theodolite
◻	Nivel Estrada (m AOD)	Total station / theodolite
◻	Perfil aliran air	Total station / theodolite
◻	Cross sections of aliran be (2 / 3 sections in both directions)	Total station / theodolite

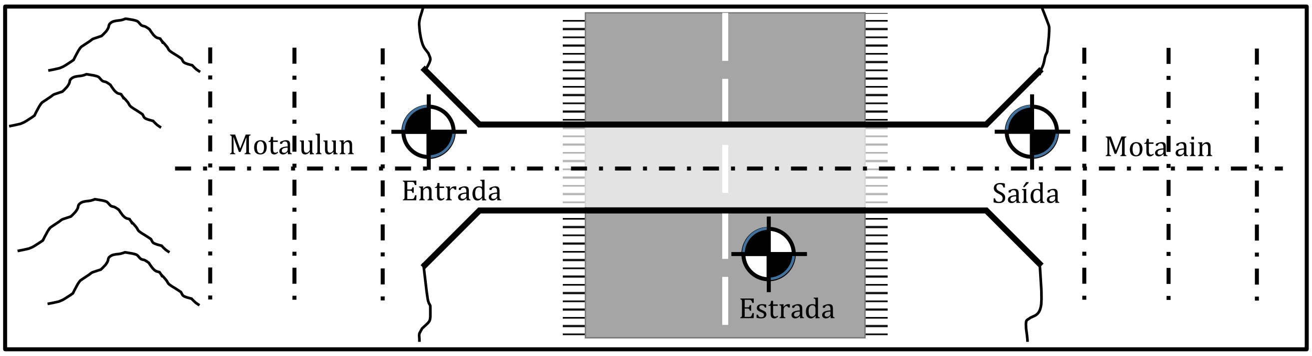


Figura 5.2 — Diagrama levantamentu topográfiku báziku

5.3 Investigasaun kartografiku

Investigasaun kartografiku tenki implementa iha terrenu ba dezenu culvert hotu-hotu. Mapa ida ne'e / informasaun geospasial sei forma fundamento ida que requere parte husi kalkulasaun dezenu relasiona ho kaptasaun. Ezemplu informasaun balun nebe requere hatudu Tabela 5.3.

Tabela 5.3 — Ezemplu checklist husi item ba investigasaun kartografiku

☑	Informasaun / Item husi investigasaun	Fontes ne'ebe posivel
◻	Mapa kartografia (T755 series of 1:50,000 maps, etc.)	Rekursu internu (Mapamentu & GIS)
◻	Modelu elevasaun digital (GIS DEM raster)	Rekursu internu (Mapamentu & GIS)
◻	Garis aliran sungai (GIS vector)	Rekursu internu (Mapamentu & GIS)
◻	Liña estrada (GIS vector)	Rekursu internu (Mapamentu & GIS)

5.4 Dadus udan ben

Investigasaun ida-ne'ebé pluvial tenke implementa iha terrenu ba dezeñu culvert hotu-hotu. Investigasaun ida ne'e sei forma fundamentu ida hanesan parte ida husi kalkulasaun dezenu relasiona ho intensidade udan ben. Ezemplu informasaun balun nebe requere hatudu iha Tabela 5.4.

Tabela 5.4 — Ezemplu checklist husi item ba investigasaun pluvial

☑	Informasaun / Item husi investigasaun	Fontes ne'ebe posivel
◻	Dadus udan ben fulan-fulan	Rekurse internu / autoridade ne'ebe relevante (hare Annexu C)
◻	Dadus udan ben loron-loron	Rekurse internu / autoridade ne'ebe relevante (hare Annexu C)
◻	Intervallu-badak / dadus udan ben kada oras	(Agora dadaun indisponivel iha Timor-Leste)

Disponibilidade dadus udan sei fó influensia ba dezeñu. Tuir mai ne'e hanesan konsiderasaun karakteristiku ideal atu monta dadus udan ben:

- 1+ satasaun iha area kaptasaun ka besik area kaptasaun

- Gravasaun iha minutu-15, minutu-30, oras-1, oras-2, oras-3, oras-6, oras-12 no oras-24 intervallu
- Gravasaun naruk (30+ tinan)

Iha kazu ida ne'e, prosesu dezenu bele utiliza curva *intensidade-durasaun-frekuensia* (IDF), hanesan hatudu iha Figura 5.3. Vantagem husi kurva IDF mak tempetade bele prevee lolos. Nia disvantagem mak atu desenvolve IDF persija dadus udan ben ho montante nebe signifkado.

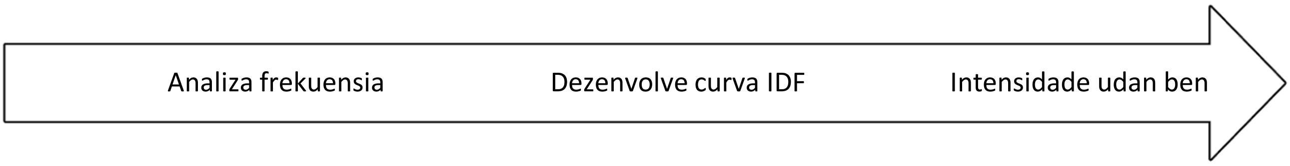


Figura 5.3 — Kurva IDF iha prosesu dezenu

Dadaun ne'e, metodu kurva IDF sedauk bele utiliza ita Timor-Leste, tamba dadus udan ben nia durasaun ne'e limitadu no detaillu ne'ebe limitadu. Tuir mai karakteristika dadus udan ben iha Timor-Leste:

- Estasaun 82 mak oras ne'e dadsun halo operasaun iha Timor-Leste (iha média, 1 ba kada 180 km²)
- Gravasaun ba udan ben mensal eziste kedas husi tinan 1950 (ba estasaun 36 ho gaps)
- Gravasaun udan ben diaria eziste ba estasaun 40 (disponibilidade aproximadu)
- Gravasaun naruk husi tinan 34 ba udan ben diaria iha Dili (ho gaps)
- Gravasaun badak husi tinan 7 – 11 ba udan ben Diaria iha area seluk (aproximadu)

Iha kazu Timor-Leste, udan ben interval-badak la disponivel no disponivel deit dadus udan ben diaria, tan ne'e, fórmula Mononobe tenke utiliza ba prosesu dezeñu hanesan hatudu iha Figura 5.4. Fórmula Mononobe uza atu halo aproximasaun ida ba intensidade udan ben ba durasaun anin ruma husi dadus udan loron-loron. Fó liu vantajen ba fórmula Mononobe ne'e simples. Maibe, iha desvantajen ida-ne'e halo aproximasaun ba tempestade ho durasaun badak (oras 6 ka menus) sei la bele koretu. Fórmula Mononobe ne'e esplika ho detalle liután iha Seksaun 7.4.

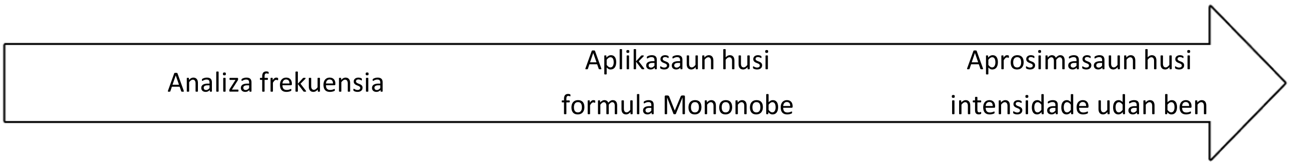


Figura 5.4 — Formula Mononobe iha prosesu dezenu

Udan ben nia Varia depende ba kada regiaaun. Media ba dadus udan ben ful-fulan iha nasaun laran tomak hatudu iha Figura 5.5. Aleinde ne'e, varia entre regiaun indika sumariu tuir mai ne'e:

- Media udan ben tin-tinan aproximamente 1700 mm (nasaun tomak)
- Masimum udan ben tin-tinan aproximamente 3100 mm (Same)
- Minimum udan ben tin-tinan aproximamente 600 mm (Manatuto)

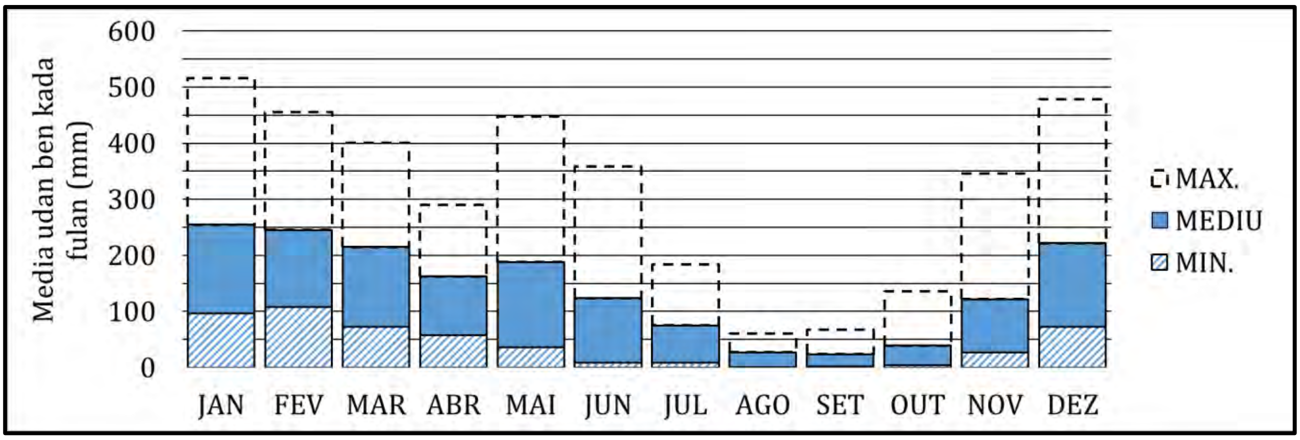


Figura 5.5 — Media udan ben kada fulan iha Timor-Leste

6 Analize udan ben

Analize udan ben refleta risku hidrologikamente ba estrada, no garante protesaun hasoru inundasaun probable. Kontribuisaun ba prosesu ida ne'e mak gravasaun udan ben ne'ebe mak naruk, no rezultadu ida másimu probable udan ben loro-loron, nebe bolu udan ben diaria.

Dezenu ba udan ben diaria determina husi analize husi istoria gravasaun udan ben. Istoriku gravasaun udan ben hatudu relasaun entre akontesimentu tempestade no importasia husi tempestade. Frekuensia akorencia ba tempestade provavel / dezenu tempestade ne'e hanaran 'periodo retornu'. Prediksaun magnetude husi tespestade ba periodu returnu determina dezenu udan ben.

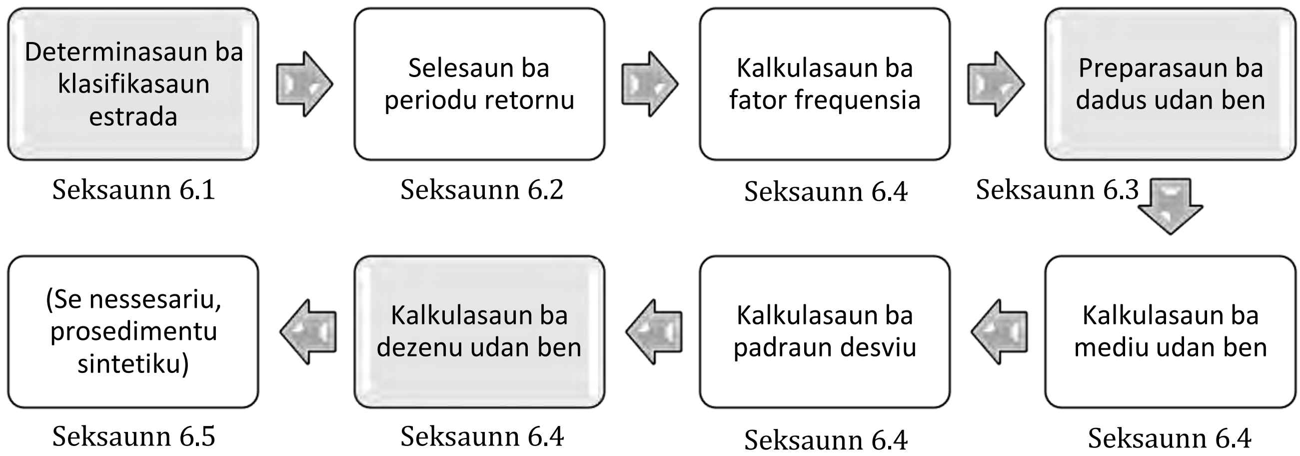


Figura 6.1 — Prosesu analize udan ben

6.1 Klasifikasaun estrada

Tuir *Padraun Dezenu Geometriku Estrada* (3), estrada iha Timor-Leste klasifika hanesan hatudu iha Tabela 6.1.

Tabela 6.1 — Klasifikasaun estrada (3)

Estrada Rural	Estada fora husi vila no cidade
Estrada Nasional	• Estrada arteriais mak hanesan sentru husi importansia nasional no internasional mak estrada ne termina ona no estrada ne'e be termina fronteira liga capital pais no capital regiaun. • Fornese servisu iha nivel altu ba movimentasaun distancia naruk husi sasan no ema ba / husi koridor sentral specialmente ba veículos ne'ebe todan. • Ligasaun estrada sira ne'e sei iha mudansa tuir moda transportasaun ne'ebe posivel.
Estrada Rejional	• Estrada ne'ebe fornese objectivu local, distánsia ne'ebé badak. Serbí tráfiku liu-liu iha rejiaun no distritu sira ne'ebé iha velosidade ne'ebé ki'ik liu no distánsia ne'ebé badak. • Estrada ne'ebe servi hanesan kolektor husi trafiku ba/husi rede lokal ba rede estrada nasional.
Estrada Lokal	• Estrada lokal ne'ebe liga capital sub-distrito ba aldeai no area remotas ne'e ho potensia agrikula ne'ebe b'ot.
Estrada Urbana	Estrada lokal iha vila no cidade laran

Estrada Arterial Urbana	• Estrada arterial urbana hanesan kontinuasaun estrada ho kontrolu asesu parsial atu bele liu husi trafiku area urbanas. Bazikamente transmite trafiku husi area residensia to area vizinhansa husi sentru negosiu distrital ka husi parte ida husi cidade seluk ne'ebe lakoi atu tama ba cidade klaran. Estrada arterial la penetram bairro ne'ebe identifika ona. Movimentu tráfiku kabeer importante tanba ida-ne'e iha volume tráfiku ne'ebé boot.
Estrada Kolektor Urbana	• Estrada kolektor mak estrada ne'ebe ho kontrolu asesu parsial ne'ebe dezenu atu serbi iha kolektor no distribui trafiku entre estrada arterial no sistema estrada lokal. Kolektor mak estrada principal ne'ebe penetra no identifika ona besik iha, area komersial no area industria.
Estrada Lokal Urbana	• Sistema estrada lokal hanesan rede estrada baziku iha bairro ida no fornese asesu diretamente ba fronteira rai. Estrada sira ne'e iha koneksaun ba estrada collector no servi ba viagem badak badak. Liu husi trafiku tenki ho discouraged.

6.2 Periodu retornu

Periodu retornu refleta risku hidrologikamente ba estrada. Selesaun ba mitigasaun ida ne'ebé apropriadu kona-ba risku ne'ebé depende ba valór ekonómiku / importánsia ativu estrada nian ida. Balansu entre kustu ba bens estrada no kustu ba proteje bens estrada mak importante: protesaun ne'ebe la adekuada bele permite bens estrada hetan estraga no lakon valor ekonomikamente. Protesaun excessiva sei hamosu despeza ne'ebe la nessesariu no solusaun ne'ebe antiekonomiku.

Periodu retornu (tinan) representa probabilidade husi occurencia. Periodu retornu la representa periodu garantidu sem inundasaun no ne'e laiha relasaun ho moris dezenu estrada nian. Probabilidade husi occurencia iha relasaun inversu ho magnetude eventu udan ben. Tamba ne'e, periodu retornu ne'ebe naruk hanesan probabilidade ne'ebe badak,ida ne'e signifika katak magnitude ne'ebe as husi eventu udan ben.

Tabela 6.2 — Rekomendasaun periodu retornu husi udan ben ba culvert (4) (6)

Klasse estrada	Nivel husi kapasidade drenajen	Periodu retornu husi udan ben
Estrada Nasional / Estrada Arterial Urbana	As	Tinan 10
Estrada Rejional / Estrada Kolektor Urbana	Mediu	Tinan 7
Estrada Lokal / Estrada Lokal Urbana	Inferior	Tinan 5

Klasifikasaun estrada iha relasaun ho nia valor ekonomiku. Tamba ne'e, seleksaun ba periodu retornu rekomenda tebes bazea ba klasifikasaun husi estrada, hanesan hatudu ona iha Tabela 6.2. Periodu retornu bele modifika husi enginheiru wainhira iha situasaun kapasidade drenajem iha nivel a'as no desajavel. Por ezemplu, estrada ne'ebe dezenu ba servisu bens nasional ne'ebe bo'ot no nia nivel risku tenki sai konkordansia hamutuk ho autoridade nasional sira seluk.

6.3 Preparasaun ba udan ben

Dadus udan ben ba analize frekuensia mak masimum udan ben diaria kada tinan. Preparasaun hus dadus udan ben ba analiza tenki implementa tuir maneira tuir mai ne'e:

1. Aquizisaun husi dadus udan ben
2. Ezaminasaun husi dadus sira hotu (loron 365) iha tinan ne'ebe hanesan (dadus coevus / dadus ne'ebe hanesan)
3. Seleksaun husi valor masimu udan ben (loron 1) kada tinan
4. Repetisaun husi 2 no 3 (iha leten) ba kada tinan

Kompleta gravasaun udan ben nessesariu tebes ba analiza. Komfirmasaun ba dadus intregadu tenki implementa tuir maneira tuir mai ne'e:

- Se dadus contamina nulo ka valor errru (ezemplu, " ** " ka " — " ka " NA " ka " -999.9 "), apaga tiha valor hirak ne'e mak nessesario liu.
- Se dadus ba tinan ida nian lakon besik loron 90 (¼ tinan) dadus, entaun dadus anual ne'e invalido no labele utiliza ba analiza.

6.4 Analiza frekuensia

Analiza frekuensia utiliza distribuisaun probabilidade ba prediksaun dezenu udan ben. Distribuisaun probabilidade mak ralasaun entre frekuensia no magnitude. Distribuisaun probabilidade comforma dadus udan ben, hanesan ho linna tendencia. Ezemplu husi distribuisaun iha diagram forma hanesan sinu ne'ebe hatudu iha Figura 6.2.

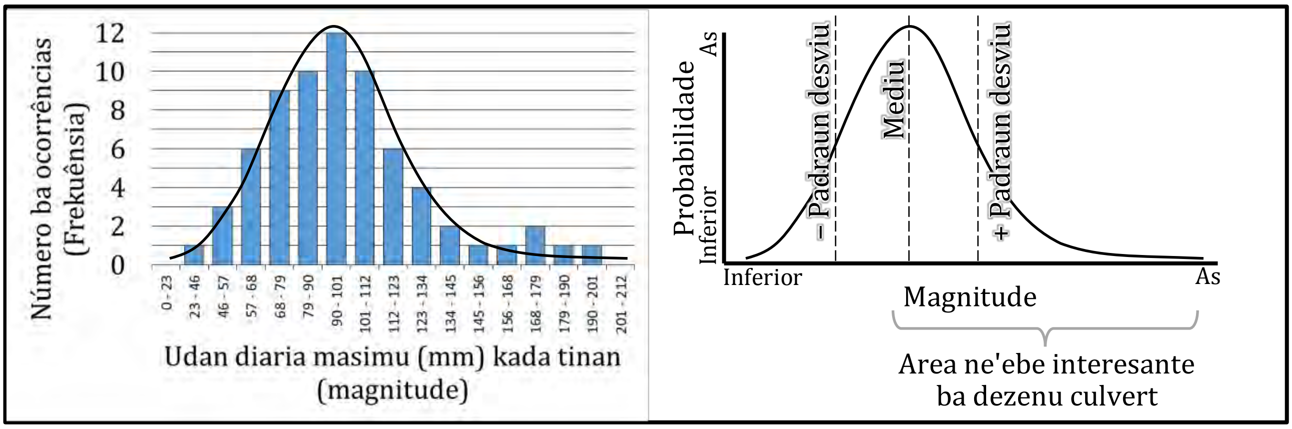


Figura 6.2 — Ezemplu husi distribuisaun probabilidade

Ba dezeñu culvert, nesesariu tebes atu hanoin kona-ba magnetudu ne'ebe as no probabilidade kiik ba dezenu ba udan konsepsaun udan ben. Prosesu ba prediksaun utiliza distrubuisaun "Gumbel" atu repesenta dadus udan ben.

Distribuisaun Gumbel ajusta husi dadus udan ho parametru 2: media no padraun desviu. Periodu retornu inkonpora uja fator frekuensia. Iha esensia, prediksaun distribuisaun Gumbel magnetudu husi dezenu udan ben mai husi meida udan ben. Partida depende ba número padraun dezviu, ne'ebé iha número ne'e fatór frekuénsia (períodu retornu).

Tuir mai ne'e distribuisaun Gumbel ba kalkulasaun dezenu udan ben:

$$R_{24} = \mu + \sigma \times K \quad [1]$$

iha ne'ebe

R_{24} dezenu udan ben ba periodu retornu (mm/loron)
μ gravasaun media husi udan ben (mm/loron), hare equasaun 2
σ padraun desviu husi gravasaun udan ben, hare equasaun 3
K fator frejuensia, hare equasaun 4

Tuir mai ne'e equasaun ba kalkulasaun media husi dadus udan ben:

$$\mu = \frac{\sum X_i}{n} \quad [2]$$

iha ne'ebe

- μ media husi dadus udanben (mm/loron)
- X_i masimu anual ba valor dadus udan ben (mm/loron)
- n numeru husi valor dadus udan ben

[NOTAS: iha spreadsheet software, ida-ne'e bele sai kalkula ho funsaun AVERAGE]

Tuir mai ne'e mak equasaun ba kalkulasaun husi padraun desviu husi dadus udan ben:

$$\sigma = \sqrt{\frac{\sum (X_i - \mu)^2}{n-1}} \quad [3]$$

iha ne'ebe

- σ padraun desviu husi dadus udan ben
- X_i masimu annual husi valor dadus udan ben (mm/loron)
- μ gravasaun husi media dadus udan ben (mm/loron)
- n numeru husi valor dadus udan ben

[NOTAS:iha spreadsheet software, ida ne'e bele kalkula uza funsaun STDEV ka STDEV.S]

Tuir mai ne'e equasaun ba kalkulasaun fatores frekuensia (incorporasaun ba periodu retornu):

$$K = -\frac{\sqrt{6}}{\pi} \times \left(\gamma + ln\left(ln\frac{T}{T-1}\right)\right) \quad [4]$$

iha ne'ebe

- K fatore frekuensia (normalmente entre -1 no 5)
- π Pi mathematical constant = 3.14159
- γ Euler–Mascheroni constant = 0.5772
- T periodu retornu (tinan), hare Tabela 6.2

[NOTAS: iha software spreadsheet, ida ne'e bele kalkula uza funsaun SQRT, PI no LN]

6.5 Prosedimentu sintetika

Iha kazu barak iha Timor-Leste, importante tebes atu implementa prosedimentu sintetiku (compensative) nian. Ho razaun ida katak maioria lokalidade iha diet gravasaun dadus udan ben ne'ebe badak (hare iha Seksaun 5.4). Tan ne'e agora dadaun, Dili hanesan fatin uniko ne'ebe iha dadus udan ben ne'ebe adekuadu ba analiza frekuensia. Uza analiza frekuensia ba dezenu udab ben diaria ba Dili, iha posibilidade atu sintetiza ba fatin seluk ho. Hasae/hatun skala uza rasio husi media anual udan ben ho multiplikador. Prosedimentu atu hetan udan ben diaria iha fatin ne'ebe deit iha Timor-Leste uza Dili hanesan hanesan ninia baze hatudu iha Tabela 6.3.

Tabela 6.3 — Prosedimentu sintetiku atu hatan udan ben diaria iha fatin ne'ebe targetu tiha ona

Periodu retornu husi udan ben	Dezenu udan ben diaria iha Dili, R_{24} (mm/loron)		Rasio husi udan ben anual (multiplikado)
Tinan 10	131.4	×	(Targetu fatin / Dili) (... mm / 940 mm)
Tinan 7	122.3		
Tinan 5	113.6		

Ba referensia, lista targetu fatin no husi dezenu udan ben diaria hanesan hatudu iha Tabela 6.4.

Tabela 6.4 — Lista targetu fatin no simu dezenu udan ben

Targetu fatin	Media annual udan ben (mm/loron)	Multiplikado		Dezenu udan ben, R_{24} (mm/loron) ba periodu retornu Tinan 5	Tinan 7	Tinan 10
Dili	940	1.00		113.6	122.3	131.4
Ainaro	2653	2.82		320.5	345.3	370.8
Alas	1965	2.09		237.4	255.7	274.6
Algarve (Fazenda)	1870	1.99		225.9	243.4	261.3
Atauro (Mau-Meta)	871	0.93		105.2	113.4	121.7
Baguia	2399	2.55		289.8	312.2	335.3
Baucau	1208	1.29		145.9	157.2	168.8
Betano	1298	1.38		156.8	168.9	181.4
Bobonaro	2432	2.59		293.8	316.5	339.9
Dare	1533	1.63		185.2	199.5	214.2
Fatubessi	2929	3.12		353.8	381.2	409.3
Fohorem	1536	1.63		185.6	199.9	214.7
Gleno	1765	1.88		213.2	229.7	246.7
Hato-Builico	2418	2.57		292.1	314.7	337.9
Iliomar	2090	2.22		252.5	272.0	292.1
Laga	770	0.82		93.0	100.2	107.6
Laivai	696	0.74		84.1	90.6	97.3
Lautem	1511	1.61		182.5	196.6	211.2
Liquica	1383	1.47		167.1	180.0	193.3
Lore	1669	1.78		201.6	217.2	233.2
Lospalos	1918	2.04		231.7	249.6	268.0
Luro	1707	1.82		206.2	222.2	238.6
Maliana	2062	2.19		249.1	268.4	288.2
Manatuto	610	0.65		73.7	79.4	85.2
Oecusse	1070	1.14		129.3	139.3	149.5
Ossu	1948	2.07		235.3	253.5	272.2
Quelicai	1728	1.84		208.8	224.9	241.5
Same	3117	3.32		376.5	405.7	435.6
Soibada	2396	2.55		289.4	311.8	334.8
Suai	1355	1.44		163.7	176.3	189.4
Tutuala	1511	1.61		182.5	196.6	211.2
Uatolari	1879	2.00		227.0	244.5	262.6
Vemasse	706	0.75		85.3	91.9	98.7
Venilale	1764	1.88		213.1	229.6	246.5
Viqueque	1577	1.68		190.5	205.2	220.4
Zumalai	1328	1.41		160.4	172.8	185.6

NOTAS Valor udan ben annual foti husi gravasaun dadus husi Ministerio Agrukultura, Floresta no Pescas (MAFP) ba periodu 1950 – 1990. Ida ne'e tenke komplementadu husi dadus udan recentes ne'ebe posivel.

7 Dezenu inundasaun

Kalkulasaun kona ba dezenu inundasaun determina volume be'e ne'ebe sei deskarga husi kaptasaun durante dezenu udan ben. Dezenu ba inundasaun determina kapasidade culvert ne'ebe adequada. Prosedimentu ba kalkulasaun dezenu inundasaun hatudu iha Figura 7.1.

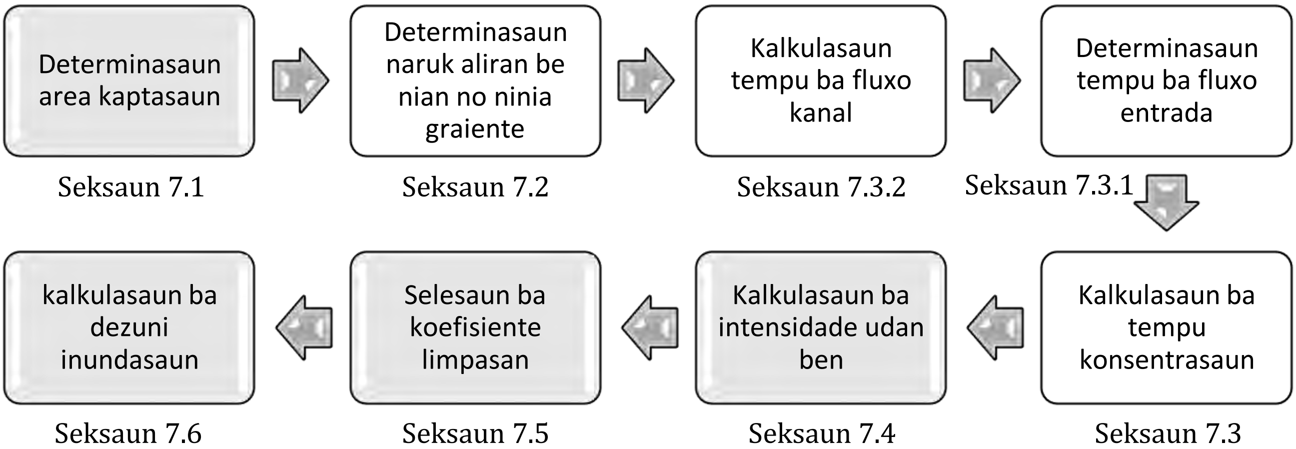


Figura 7.1 — Prosesu husi Kalkulasaun Dezenu Inundasaun

7.1 Area kaptasaun

Kaptasaun mak area husi rai ne'e halo maran to'o ba pontu interese, hanesan culvert, hanesan hatudu iha Figura 7.2. Be'e aliran hotu-hotu ne'ebe sulin husi area kaptasaun sei liu husi pontu interse antes ba iha jusante. *Watershed* mak fronteira entre kaptasaun no kaptasaun seluk ne'ebe besik. Extensaun ba *watershed* (fronteira) bele identifica husi koneksaun ho pontu ne'ebe besik ho elevasaun ne'ebe as, hanesana foho tutun, foho leten, *ridges*, *saddles* no *spurs* hanesan hatudu iha Figura 7.3.

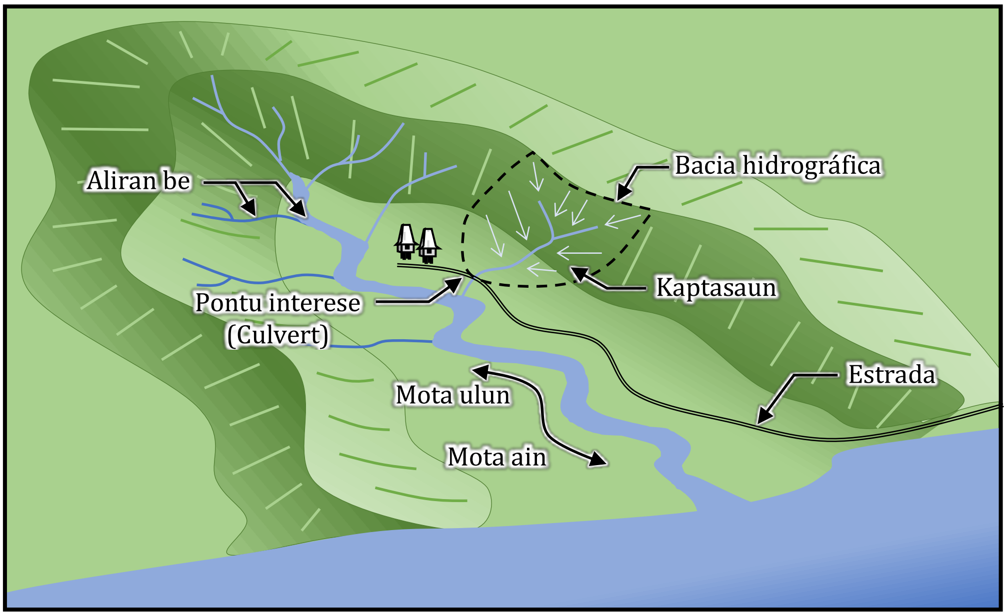


Figura 7.2 — Area kaptasaun iha basia foho nia let

Medida ba kaptasaun iha influensia ne'ebe importante ba kalkulasaun run-off. Ninia medida espressa hanesan area iha termus km^2 ($1\ km^2 = 1{,}000{,}000\ m^2 = 100$ ha). Mapa topografia (1:50,000, hanesan T755 series) bele uza ba determina area kaptasaun. Maske nune'e (1:10,000) ka dadus geographic information system (GIS) rekomenda ba kaptasaun kiik. Ida ne'e importante tebes ba designer atu halo visita iha terrenu atu hetan impresssaun ida kona ba karakteristika kaptasaun.

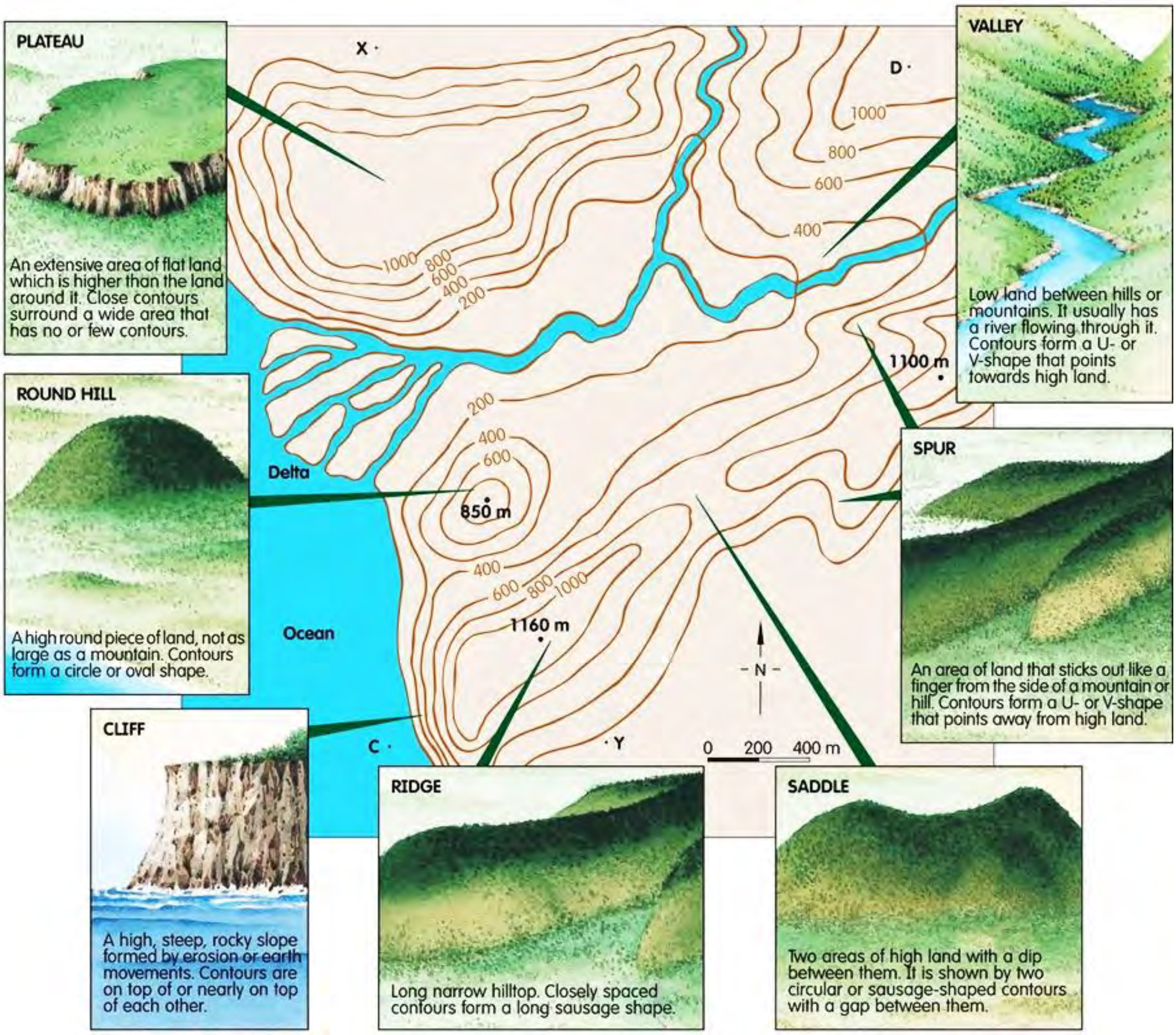


Figura 7.3 — Ezemplu karakteristika topografika

Teknika sukat ba area inclui: transfere kaptasaun ne'ebe deskreve ba iha surat tahan kuadradu ho surat tahan kalkir; importa no hasae diemnsaun mapa nian ba iha software CAD; no uza modelu elevasaun digital (dadus, DEM) no dadus spacial iha *sistema informasaun geografika* (software GIS). Uza GIS mak medida teknika ne'ebe rekomenda ba resultadu ne'ebe koreto. Se bele, pedidu ba informasaun ne'e tenki halo husi seksaun GIS no Mapamentu DNEPCC.

Seksaun GIS no Mapamentu bele analiza kaptasaun liu husi delineating watershed bazea ba contour (ho liafuan seluk, gambar poligon iha shapefile hodi representa area kaptasaun) ka uza algoritma hodi halo watershed husi *modelo elevasaun digital* (DEM). Ezemplu algoritma ba delinea inclui "r.watershed" no "r.water.outlet" iha GRASS Tools QGIS software, no "Watershed" iha Analiza Especial toolbox ArcGIS software. Ezemplu sequensia ida ba delinate watershed husi DEM hanesan tuir mai ne'e:

- Etapa 1) Prense ninia depresaun iha DEM
- Etapa 2) Kalkula diresaun fluxo
- Etapa 3) Delinear area kaptasaun
  - Etapa 3.1) Hili pontu ne'ebe mak ita hakarak ("Outlet" iha QGIS no "Pour Point" iha ArcGIS)
  - Etapa 3.2) Delinear ba watershed
  - Etapa 3.3) Kalkula nia luan

Aleinde total area kaptasaun, kalkulasaun ba area sub-kaptasaun nessesario local iha tipu terrenu ne'ebe distintamente diferente. Fronteira husi tipu terrenu bele analiza husi investigasaun iha terrenu, husi satelite imagery ka hu dadus kobre terrenu.

7.2 Propriedade aliran be

Hanesan ho Seksaun 7.1, propriedade aliran be bele sukat ho mapa topografika, software CAD ka GIS. Karik bele, pedidu ba inforasaun tenki halo husi seksaun GIS no Mapping DNEPCC.

Propriedade aliran be presija tebes ba kalkulasaun konsentrasaun tempu iha gradiente nia naruk. Naruk husi gradeinte aliran be (L) tenki sukat husi komesa aliran beba to'o pontu intere, hanesan hatudu iha Figura 7.4.

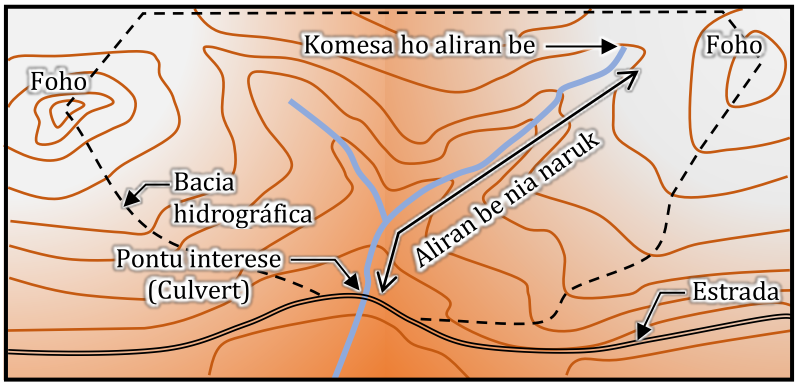


Figura 7.4 — Medida aliran be nia naruk

Media gradiente tenki uza ba gradiente aliran be (G), hanesan hatudu ona iha Figura 7.5. Kalkulasaun media gradiente ne'ebe presiza naruk (valor L) no as (valor H) iha pontu oioin ne'ebe tuir perfil aliran be. Iha maioria spreadsheet software, media gradiente bele kalkulu utiliza funsaun LINEST: *LINEST([H values] , [L values] , FALSE)* fo resultado ho m/m ka *LINEST([H values] , [L values] , FALSE)*100* fo resultado ho persentagem (%).

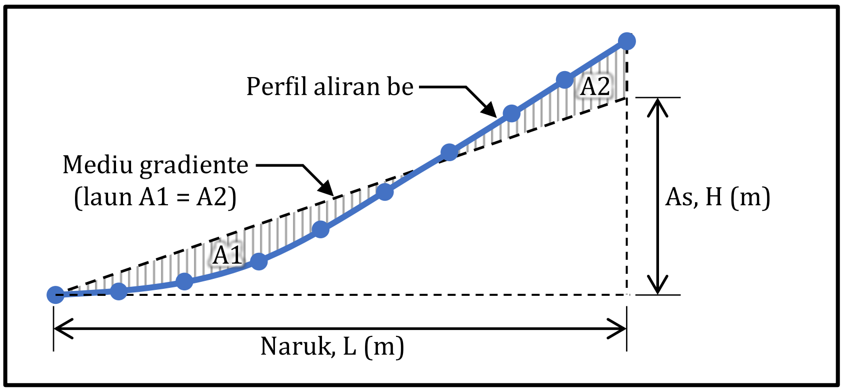


Figura 7.5 — Kalkulasaun media gradiente aliran be

7.3 Konsentrasau tempu

Tempu konsentrasaun presiz tebes ba kalkulasaun intensidade udan ben. Tempu konsentrasaun mak tempu ba be atu sulin husi pontu inisiu husi watershed (i.e. foho) to'o ba pontu interese (i.e. culvert). Area ne'ebe diferrente husi watershed bele contribui run-off iha tempu ne'ebe diferente depois hahu udan. Tempu iha ne'ebe parte hotu-hotu husi watershed hahu kontribui ba run-off husi basin, hanesan hatudu iha Figura 7.6. Tempu konsentrasaun kalkula ho equasaun 5.

Tuir mai ne'e equasaun ba kalkulasaun konsentrasaun tempu:

$$t_c = t_e + t_f \quad [5]$$

iha ne'ebe

- t_c konsentrasaun tempu (oras)
- t_e tempu fluxo husi watershed ba to'o aliran be (oras), hare iha Tabela 7.1
- t_f tempu fluxo husi inisiu aliran be to pontu deskarga (oras), hare equasaun 6

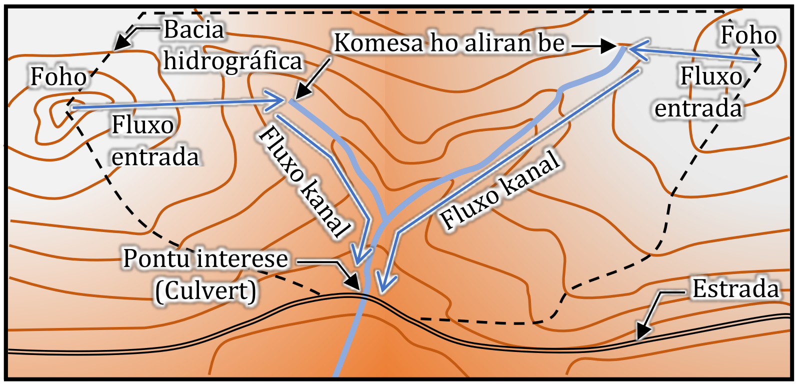


Figura 7.6 — Tempu ba konsentrasaun

7.3.1 Tempu ba fluxo inlet

Tempu ba fluxo iha inlet mak tempu ba superficie fluxo ne'ebe lao husi watershed to ba iha inisiu aliran be.

Tabela 7.1 — Tempu fluxo entrada (4)

Tipu kaptasaun	Tempu ba inlet (minutus)	Tempu ba inlet (oras)
Foho	15.0 – 30.0	0.25 – 0.50
Potongan lereng	3.0 – 5.0	0.05 – 0.083
Area urbana	5.0	0.083

7.3.2 Tempu ba fluxo kanal

Tempu ba fluxo ba kanal mak tempu ba superfice fluxo lao husi hahu aliran be ba to'o pontu interese (Culvert). Formula Kraven mak equasaun emperikal baze ba dadus bain.

Tuir mai formula Kraven ba kalkulasaun templu fluxo ba kanal:

$$t_f = \frac{L}{3600 \times W} \quad [6]$$

iha ne'ebe

- t_f tempu ba fluxo husi inisiu aliran be ba to'o pontu deskarga (oras)
- L naruk aliran be (m)
- W velosidade limpasan (m/s), hare iha Tabela 7.2

Tabela 7.2 — Velosidade limpasan (4)

Aliran be nia Gradiente, G			Velosidade limpasan, W (m/s)
> 1 / 100	> 1.0%	> 0.010 m/m	3.5
1 / 200 – 1 / 100	0.5% – 1.0%	0.005 – 0.010 m/m	3.0
< 1 / 200	< 0.5%	< 0.005 m/m	2.1

7.4 Intensidade udan ben

Generalidade, intensidade tempestade mak inversamente proporsional ba durasaun tempestade ba klima maioria. Relasaun inverse ida ne'e signifika katak durasaun tempestade badak iha intensidade udan ben ne'ebe as no durasaun tempestade ne'ebe naruk iha intensidade udan ben ne'ebe badak, hanesan hatudu iha Figura 7.7.

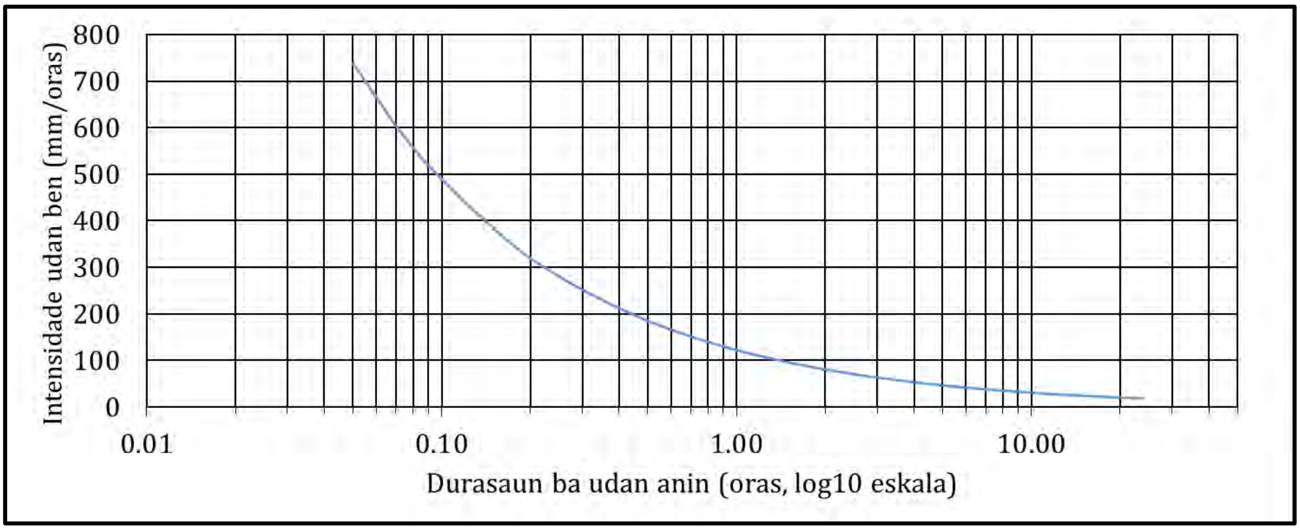


Figura 7.7 — Ezemplu relasaun inverse husi kurva intensidade-durasaun

Dezenu intensidade udan ben mak wainhira durasaun husi tempestade hanesan ho konsentrasaun tempu, hanesan hatudu husi (b) iha Figura 7.8. Hanesan hatudu iha (a), wainhira durasaun tempestade menus liu tempu konsentrasaun, entaun area kaptasaun hotu la deskarga ba culvert, tan ne'e laos maksimu deskarga hanesan hatudu iha (c), wainhira durasaun tempestade mak bo'ot liu konsentasaun tempu, nune'e intensdade udan ben sei kiik liu, tan ne'e mos laos deskarga maksimu. Konsentrasaun tempu mak wainhira parte hotu-hotu husi watershed hahu contribui ba run-off husi basin no ida ne'e wainhira hasoru dezenu intensidade udan ben.

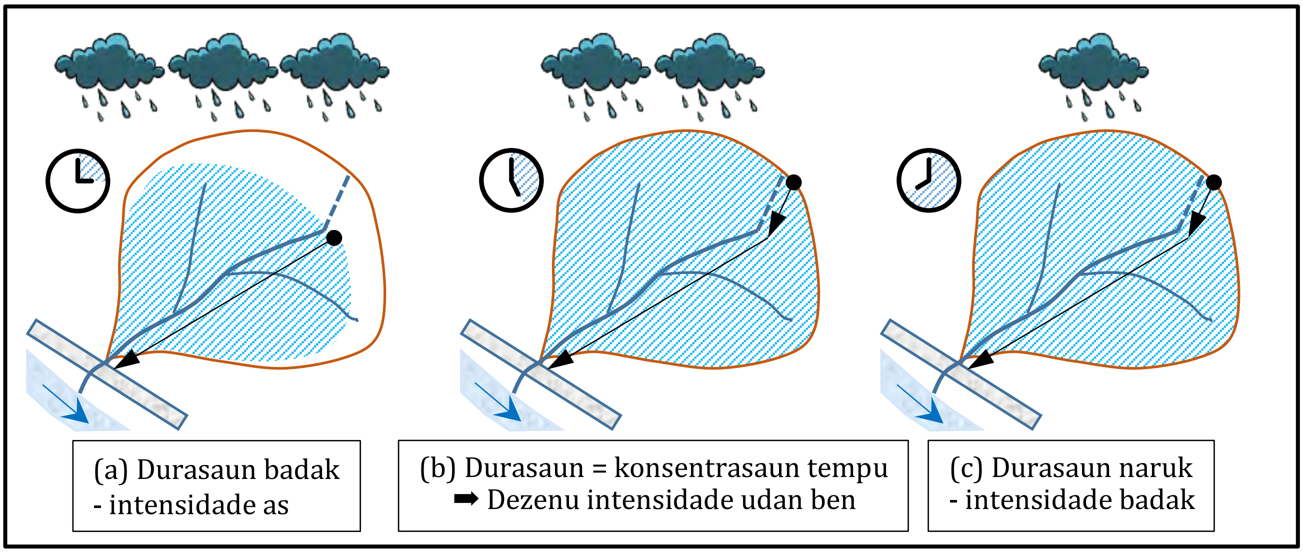


Figura 7.8 — Dezenu Intensidade udan ben ba maksimu deskarga provavel

Hanesan temi tiha ona iha Seksaun 5.4, iha ne'ebe iha dadus udan ben ne'ebe la suficiente iha Timor-Leste ba kria kurva durasaun intensidade, hanesan Figura 7.7. Mononobe Fórmula mak equation empíriku ida ba estimativa intensidade udan ben. ida ne'e solusaun ba pratika aplikasaun ho dadus udan ben ne'ebe oituan.

Tuir mai ne'e mak Mononobe Formula ba kalkulasaun intensidade udan ben:

$$i = \frac{R_{24}}{24} \times \left(\frac{24}{t_c}\right)^{0.6} \qquad [7]$$

iha ne'ebe

- i intensidade udan ben (mm/oras)
- R_{24} dezenu udan ben diaria (mm/loron), hare Seksaun 6
- t_c konsentrasaun tempu (oras), hare equasaun 5

Desvantagem husi formula Mononobe mak nia prediksaun bele mos la akuransia ba intensidade udan ben ba tempestade ho durasaun ne'ebe badak (<6). Rekomenda ba Timor-Leste halibur dadus udan ben iha intervallu minutu-15, minutu-30, oras-1, oras-2, oras-3, oras-6, oras-12 no 24-oras nia laran kada stasaun. Fornesementu dadus ida ne'e bele kobra, *intensidade-durasaun-frekuensia* (IDF) grafiku ne'e bele. Dezenvolve 2050 no dezenu hidrological teknika bele hadia.

7.5 Kofisiente limpasan

Run-off mak be husi udan ben ne'ebe suli iha superfice (iha liafuan seluk superfice sulin). Montante husi udan ben sai fali run-off ne'ebe sulin depende iha montante be'e ne'ebe lakon husi infiltrasaun no evaporasaun. Be'e ne'ebe lakon tamba infiltrasaun no evaporasi representa husi kofisiente run-off. Tamba ne'e, kofisient run-off mak proporsional udan ben ne'ebe sai run-off.

Ekomendasaun ba kofisien run-off, C, mak hatudu iha Tabela 7.3. Koefisien run-off ne'ebe as indika katak udan ne'ebe barak liu tan bele sai run-off, no hanesan koefisien run-off ne'ebe menus ne'ebe indika menus udan ben bele sai run-off.

Se imi nia area kaptasaun iha typu terrenu,tan ne'e rekomenda aplikasaun weighted koefisien. Koefisien weighted tenki kalkula hanesan hatudu iha equasaun 8.

Tabela 7.3 — Koefisiente limpasan (4)

Tipu terrenu	Kofisiente ba limpasan	Valor medio
Superficie estrada nian no superficie rai halis	0.70 – 1.00	0.85
Foho lolon	0.75 – 0.90	0.83
Rai foho ho suave	0.70 – 0.80	0.75
Rai ondulante no ai horis	0.50 – 0.75	0.63
Area agrikula ne'ebe tetuk	0.45 – 0.60	0.53
Natar	0.70 – 0.80	0.75
Area urbana	0.60 – 0.90	0.75
Zona florestál	0.20 – 0.40	0.30
Area kaptasaun husi foho leten	0.75 – 0.85	0.80
Area kaptasaun ba mota kiik oan iha rai tetuk	0.45 – 0.75	0.60
Area kaptasaun husi mota bo'ot ne'ebe nia parte balun halai iha rai	0.50 – 0.75	0.63

Tuir mai ne'e equasaun ba kalkulasaun husi todan kofisiente limpsan:

$$C = \frac{(C_1 \times A_1 + C_2 \times A_2 + \cdots + C_n \times A_n)}{(A_1 + A_2 + \cdots + A_n)} \qquad [8]$$

iha ne'ebe

- C kofisiente limpasan ne'ebe tetu tiha ona (adimensional)
- $C_{1,2,n}$ kofisiente limpasan ba terrenu ne'ebe la han (adimensional), hare Tabela 7.3
- $A_{1,2,n}$ area kaptasaun ho tipu terrenu ne'ebe diferente (m^2), hare Seksaun 7.1

7.6 Metodu Rasional

Metodu Rasional tenki aplika ba kalkulasaun dezenu inundasaun. Ida ne'e hanesan proposta dahuluk in tinan 1851 husi Enginheiru Irlandes ne'ebe hanaran Mulvaney. Ida ne'e bazea ba relasaun simplista entre dadus udan ben no run-off ba prediksaun empiriku deskarga husi kaptasaun. Metodu ida ne'e apropriadu ba kondisaun dezenu tuir mai ne'e:

- Kalkulasaun ba pico deskarga
- Terrenu ne'ebe la iha gauge (sem aliran fluxo / dadus mota) / terrenu ne'ebe gauge atu sukar fluxo mota nian
- Analiza deterministika bazea ba udan ben
- Kaptasaun la ho armajem be nian ne'ebe signifikado (sem lagos, sem lagoas, sem zonas húmidas)
- Aplicável < 15.0 km^2 (5)
- Metodu rasional ne'ebe adequadu ba kaptasaun kiik liu ≤ 0.8 km^2 (7)

Limitasaun ba aplikasasun kaptasaun < 15.0 km^2 tamba koefisien run-off labele precisamente representa water storage (ka kaptasaun ne'ebe hidrolikamente complexu). Metodu ne'e asume katak intensidade udan ben mak uniforme ba kaptasaun hotu-hotu; Intensidade udan mak area kaptasaun hotu ne'ebe uniforme. Portanto, pico husi limpasan ne'ebe presume mosu wainhira durasaun tempestade hanesan ho konsentrasaun tempu.

Tuir mai equasaun Metodu Rasional ba kalkulasaun pico descarga:

$$Q_P = \frac{1}{3.6} \times C \times i \times A \qquad [9]$$

iha ne'ebe

- Q_P pico deskarga ka dezenu inundasaun iha aliran be (m^3/s)
- C kofisiente limpasan, hare iha Tabela 7.3
- i intensidade udan (mm/oras), hare equasaun 7
- A area kaptasaun aliran be (km^2)

Hanesan mensiona tiha ona iha Seksaun 4.5, prosesu ida ne'e simplifikadu tiha ona ba dezenu bazea ba adosaun intensidade udan ben 200 mm/oras husi *Padraun e Manual Dezenu Ponte* (2) be uza ba aplikasaun kiik ona iha route minor, hanesan estrada rural lokal. Ba referensia, prosesu simplifikadu dezenu inundasaun hanesan hatudu iha Tabela 7.4.

Tabela 7.4 — Ezemplu dezenu inundasaun ba aplikasaun kiik utiliza proaeau simplifikadu

Koefi-siente limpa-san, C	Dezenu inundasaun, Q_P, (m^3/s) ba area kaptasaun husi									
	0.1 km^2	0.2 km^2	0.3 km^2	0.4 km^2	0.5 km^2	0.6 km^2	0.7 km^2	0.8 km^2	0.9 km^2	1.0 km^2
0.20	1.2	2.3	3.4	4.5	5.6	6.7	7.8	8.9	10.0	11.2
0.30	1.7	3.4	5.0	6.7	8.4	10.0	11.7	13.4	15.0	16.7
0.40	2.3	4.5	6.7	8.9	11.2	13.4	15.6	17.8	20.0	22.3
0.45	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0
0.50	2.8	5.6	8.4	11.2	13.9	16.7	19.5	22.3	25.0	27.8
0.55	3.1	6.2	9.2	12.3	15.3	18.4	21.4	24.5	27.5	30.6
0.60	3.4	6.7	10.0	13.4	16.7	20.0	23.4	26.7	30.0	33.4
0.65	3.7	7.3	10.9	14.5	18.1	21.7	25.3	28.9	32.5	36.2
0.70	3.9	7.8	11.7	15.6	19.5	23.4	27.3	31.2	35.0	38.9
0.75	4.2	8.4	12.5	16.7	20.9	25.0	29.2	33.4	37.5	41.7
0.80	4.5	8.9	13.4	17.8	22.3	26.7	31.2	35.6	40.0	44.5
0.85	4.8	9.5	14.2	18.9	23.7	28.4	33.1	37.8	42.5	47.3
0.90	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0
NOTAS: Valor sira iha leten ne'e mai husi prosesu simplifikadu ne'ebe adpta husi intensidade udan 200 mm/oras. Valor hirak ne'e tenki uza ho kuidadu. Karik bele, tenki uza prosesu tomak no tenki kalkula intensidade udan ben.										

8 Hidrolika kanal-nakloke

Open-channel hydraulics mak karakteristika husi be ne'ebe sulin iha gravidade nia okos no presaun iha atmosferika nia okos relasiona ho superficie be nian ne'e iha relasaun ho ar (superficie ne'ebe livre). Prosesu dezenu eskritu iha Figura 8.1

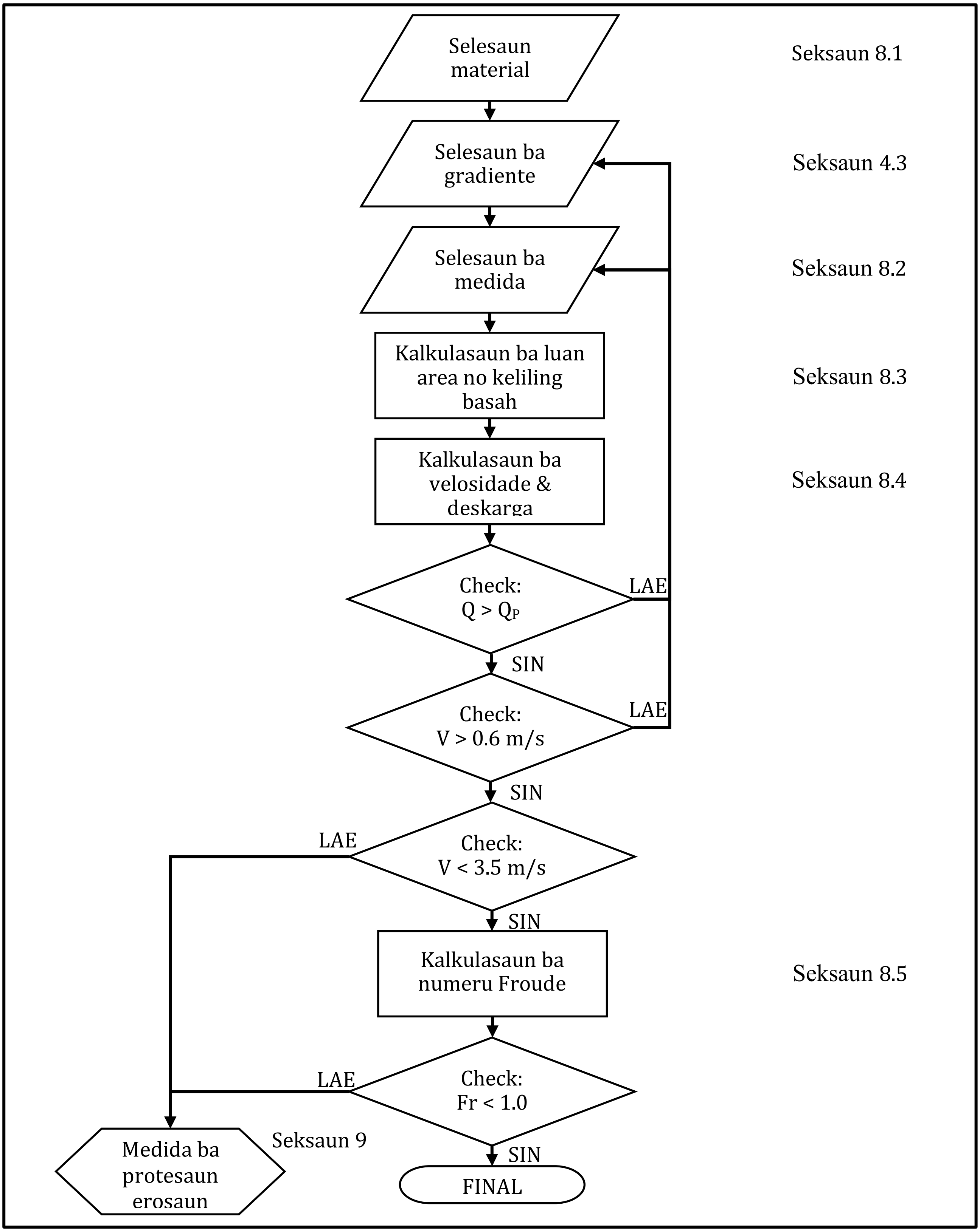


Figura 8.1 — Prosesu kalkulasaun fluxo kanal-nakloke

8.1 Material culvert nian

Material (no kondisaun) husi kanal mak determina ninia kekasaran. Kekasaran mak representante husi frictional resistance batas kuat geser. Ba kalkulasaun ne'ebe uniforme, gaya gravitasi tenki balansu ho resistance force nebe mak hanesan batas gaya geser (τ). Konseptu ida ne'e deskritu tiha ona iha Figura 8.2.

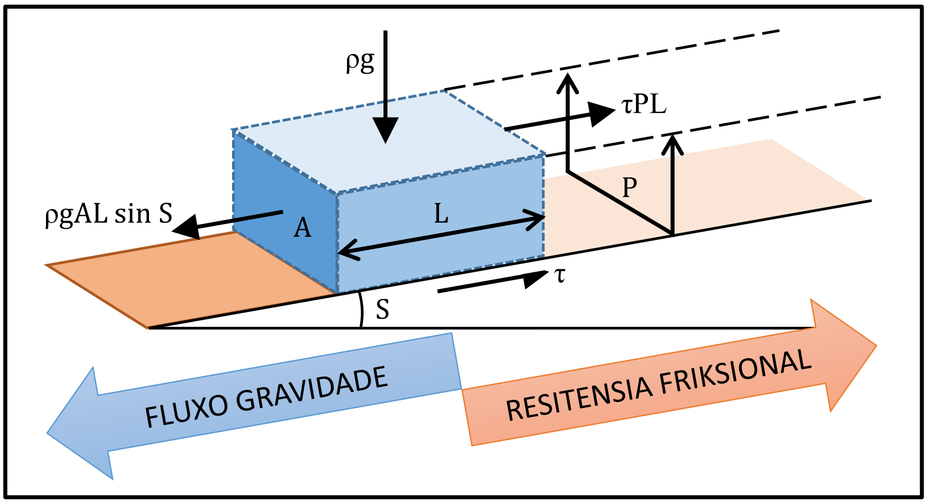


Figura 8.2 — Konseptu fluxo uniforme

Roughness mak representa iha kalkulasaun be sulin husi numeru Manning, *n*. Material ne'ebe babain ba konstrui box culvert mak konkretu. Valor numeru Manning ne'ebe rekomenda ba konkretu mak hanesn hatudu iha Tabela 8.1.

Tabela 8.1 — Valor numeru Manning ne'ebe rekomenda (4)

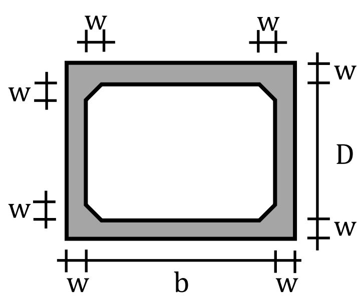
Material ba culvert	Numeru Manning, *n*
Konkretu:	
beton ne'ebe halo iha terrenu	0.015
beton ne'ebe produto fabrika nian	0.013

8.2 Medida culvert

Iha rekomendasaun ba selesaun ba medida culvert ne'ebe mak relevante ho padraun dezenu strutural. Ba referensia, medida ba culvert mak hanesan hatudu iha Tabela 8.2, Tabela 8.3 no Tabela 8.4.

Tabela 8.2 — Padraun dimensaun ba single culvert (8)

Largura, b (mm)	As, D (mm)	Didin lolon nia mahar & fillets, w (mm)
1000	1000	160
1000	1500	170
1000	2000	180
2000	1000	220
2000	1500	230
2000	2000	250
2000	2500	260
2000	3000	280



3000	1500	280	
3000	2000	300	
3000	2500	300	
3000	3000	300	

Tabela 8.3 — Padraun dimensaun ba culvert duplu (9)

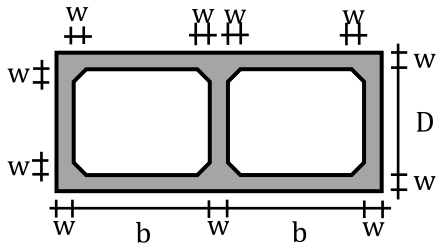
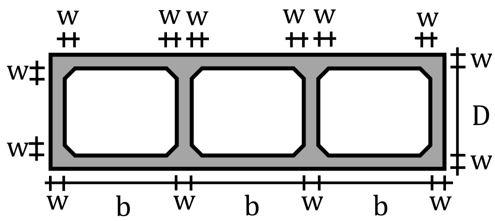
Largura, b (mm)	As, D (mm)	Didin lolon nia mahar & fillets, w (mm)	
1500	1000	200	
2000	1000	240	
2000	1500	240	
2000	2000	240	
2000	2500	250	
2000	3000	260	
2500	1500	260	
2500	2000	260	
2500	2500	260	
2500	3000	280	
3000	1500	300	
3000	2000	300	
3000	2500	300	
3000	3000	300	

Tabela 8.4 — Padraun dimensaun ba triplu culvert (10)

Largura, b (mm)	As, D (mm)	Didin lolon nia mahar & fillets, w (mm)	
1500	1000	160	
1500	1500	170	
1500	2000	180	
1500	2500	220	
1500	3000	260	
2000	1000	200	
2000	1500	220	
2000	2000	250	
2000	2500	260	
2000	3000	300	
2500	1500	280	
2500	2000	280	
2500	2500	280	
2500	3000	300	
3000	1500	300	
3000	2000	300	
3000	2500	300	
3000	3000	300	

8.3 Geometria culvert

Geometria culvert afeita resistensia friksional. Aleinde batas kekasaran, frictional resistance sei sae hanesan medida husi batas sae nian. Medida husi batas ne'e. Dimensaun husi fronteira mak hanesan kalkulasaun tuir mai ne'e.

Area ne'e mak area cross sectional fluxo iha diresaun normal (prependicular) ba diresaun fluxo. Wetted perimeter mak naruk husi perimetru ne'ebe mak kontaktu ho sasukat iha diresaun normal (perpendicular) ba to'o iha diresaun husi be sulin ba. Radius hidrolika mak rasio husi area ba wetted perimeter, hanesan hatudu iha equasaun 10. Largura superficie mak largura kanal ho superficie livre.

Tuir mai ne'e mak equasaun geral kona ba kalkulasaun radius hidrolika:

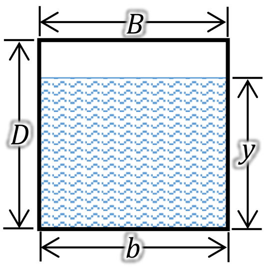
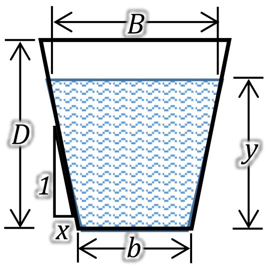
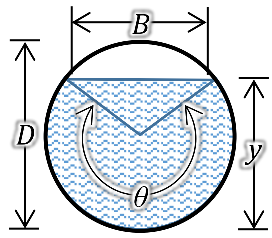
$$R = \frac{A}{P} \qquad [10]$$

iha ne'ebe

- R radius hidrolika (m)
- A luas penampang melintang (m^2)
- P keliling basah (m)

Equasaun ba kalkulasaun propriedade ba geometrika husi kanal balun mak hatudu iha Tabela 8.5. Matadalan ida ne'e kona ba box culvert, tan ne'e euasaun ba geometria rectagular tenki aplika. Equasaun geometria kona ba trapezional no circular fornese mos hanesan refensia deit.

Tabela 8.5 — Propriedade geometri ba kanal

Geometria	 **Rektangulu (Kaixa)**	 **Trapeziu**	 **Sirkula (Kanu)**
Area fluxo nian, A (m^2)	$b \times y$	$(b + x \times y) \times y$	$\frac{1}{8} \times (\theta - \sin\theta) \times D^2$
Keliling basah, P (m)	$b + 2 \times y$	$b + 2 \times y \times \sqrt{1 + x^2}$	$\frac{1}{2} \times \theta \times D$
Radius hidrolik, R (m)	$\frac{b \times y}{b + 2 \times y}$	$\frac{(b + x \times y) \times y}{b + 2 \times y \times \sqrt{1 + x^2}}$	$\frac{1}{4} \times \left(1 - \frac{\sin\theta}{\theta}\right) \times D$
Largura superficie, B (m)	b	$b + 2 \times x \times y$	$\left(\sin\frac{\theta}{2}\right) \times D$
Angulo fluxo, θ (radians)			$2 \times \cos^{-1}\left(1 - 2 \times \frac{y}{D}\right)$

iha ne'ebe

- b largura iha baze (m)
- y profunidade fluxo (m)
- D as interna ka diametru (m)
- x largura ba kada metru 1 husi as parte ne'ebe declive (m)
- θ angulo fluxo (radians)

8.4 Dezenu kapasidade culvert

Dezenu kapasidade descarga ba culvert mak kalkulasaun ho equasaun 11. Kapasidade dezenu teki bo'ot liu dezenu inundasaun, ($Q > Q_P$).

Tuir mai ne'e mak equasaun ba kalkulasaun dezenu kapasidade ba culvert:

$$Q = \frac{A^{5/3} \times S_0^{1/2}}{P^{2/3} \times n} \quad [11]$$

iha ne'ebe

- Q dezenu capacidade culvert (m^3/s)
- A area fluxo nian (m^2)
- P keliling basah (m)
- S_0 gradiente culvert (m/m)

Hanesan referensia, presiza nota katak equasaun 11 mak kombinasaun equasaun ba descarga no numeru Manning, hanesan hatudu iha equasaun iha okos ne'e equasaun 12 no 13, respetivamente.

Tuir mai ne'e mak equasaun geral ba kalkulasaun descarga:

$$Q = A \times V \quad [12]$$

iha ne'ebe

- Q dezenu capacidade fluxo (m^3/s)
- A area fluxo nian (m^2)
- V velocidade Fluxo (m/s), hare equasaun 13

Sedimentasaun no debris afeta dezmpenu hidrauliku husi culvert. Marjin 20% husi area cross-sectional (A) mak rekomenda atu antisipa sedimentasaun. Ho liafuan seluk, profunidade fluxo tenki dezenu menus husi ou hanesan 80% husi box culvert nia as internal ($y \leq 0.8 \times D$).

Tuir mai ne'e mak equasaun Manning ba kalkulasaun velocidade ba culvert:

$$V = \frac{1}{n} \times R^{2/3} \times S_0^{1/2} \quad [13]$$

iha ne'ebe

- V velocidade fluxo (m/s)
- n koefisient kekasaran /manning, hare iha Tabela 8.1
- R radius hidrolika (m), hare Seksaun 8.3
- S_0 gradiente culvert (m/m)

Velocidade fluxo be'e affeta erosaun no sedimentasaun ba culvert. Velocidade normal ne'ebe alcansa fluxo mak $0.6 \text{ m/s} \leq V < 3.5 \text{ m/s}$. Nune'e bele redus montante sedimentasaun, rekomenda katak velocidade fluxobo'ot liu 0.6 m/s. Se lae, tenki konsidera manutensaun regular. Nune'e atu redus montante husi erosaun, rekomenda velocidade fluxo tenki menus husi 3.5 m/s. Se lae, tenki konsidera medida protesaun ba erosaun.

Ezemplu husi dezenu capacidade culvert iha various gradiente mak hatudu iha Tabela 8.6.

Tabela 8.6 — Dezenu capacidade ezemplu hanesan culvert

Dimensaun culvert			Dezenu kapasidade, Q (m^3/s) ba gradiente							
b (m)	D (m)	y (m)	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	5.0%	7.0%
1.0	1.0	0.8	1.72	2.43	2.98	3.44	3.84	4.21	5.44	6.43
1.0	1.5	1.2	2.83	4.00	4.89	5.65	6.32	6.92	8.93	10.57
1.0	2.0	1.6	3.96	5.61	6.87	7.93	8.86	9.71	12.53	14.83
1.5	1.0	0.8	3.00	4.25	5.20	6.01	6.72	7.36	9.50	11.24

Dimensaun culvert			**Dezenu kapasidade, Q (m^3/s) ba gradiente**							
b (m)	**D (m)**	**y (m)**	**0.5%**	**1.0%**	**1.5%**	**2.0%**	**2.5%**	**3.0%**	**5.0%**	**7.0%**
1.5	1.5	1.2	5.07	7.17	8.78	10.14	11.33	12.41	16.03	18.96
1.5	2.0	1.6	7.23	10.22	12.52	14.46	16.16	17.70	22.86	27.04
1.5	2.5	2.0	9.44	13.35	16.35	18.88	21.11	23.13	29.86	35.33
1.5	3.0	2.4	11.69	16.53	20.24	23.37	26.13	28.63	36.95	43.73
2.0	1.0	0.8	4.39	6.21	7.61	8.79	9.82	10.76	13.89	16.44
2.0	1.5	1.2	7.55	10.68	13.08	15.11	16.89	18.50	23.88	28.26
2.0	2.0	1.6	10.91	15.43	18.90	21.83	24.40	26.73	34.51	40.84
2.0	2.5	2.0	14.39	20.35	24.92	28.78	32.18	35.25	45.51	53.84
2.0	3.0	2.4	17.94	25.37	31.07	35.88	40.11	43.94	56.73	67.12
2.5	1.5	1.2	10.20	14.42	17.66	20.39	22.80	24.98	32.25	38.15
2.5	2.0	1.6	14.89	21.06	25.79	29.78	33.30	36.47	47.09	55.72
2.5	2.5	2.0	19.79	27.98	34.27	39.58	44.25	48.47	62.58	74.04
2.5	3.0	2.4	24.82	35.10	42.99	49.64	55.49	60.79	78.48	92.86
3.0	1.5	1.2	12.95	18.32	22.43	25.90	28.96	31.72	40.95	48.46
3.0	2.0	1.6	19.08	26.98	33.04	38.16	42.66	46.73	60.33	71.38
3.0	2.5	2.0	25.52	36.09	44.21	51.04	57.07	62.52	80.71	95.49
3.0	3.0	2.4	32.18	45.51	55.73	64.35	71.95	78.82	101.75	120.40

8.5 Tipu fluxo

Aleinde fluxo velocidade, tipu fluxo tenki konsidera wainhira avaliasaunse medida protesaun ba erosaun nessesario. tipu fluxo bele konsidera ho numeru Froude, hanesan, as hatudu iha Figura 8.3. Numeru Froude indika tipu fluxo hanesan tuir mai ne'e:

- $Fr > 1$: Fluxo supercritical (lalais)
- $Fr = 1$: Fluxo critical (change point)
- $Fr < 1$: Fluxo subcritical (neneik)

Tuir mai ne'e mak equasaun ba kalkulasaun numero Froude no simplifikasaun ba caix rektangulu culvert:

$$Fr = \frac{V}{(g \times y)^{0.5}} = \left(\frac{{Q_P}^2 \times b}{g \times (y_n \times b)^3}\right)^{0.5} \qquad [14]$$

iha ne'ebe

Fr numeru Froude (la ho dimensaun)
V velocidade fluxo (m/s)
g akselarasaun gravitasional (m/s^2) = 9.81 m/s^2
y profunidade fluxo (m)
Q_P pico deskarga ka dezenu inundasaun iha aliran be (m^3/s)
y_n profunidade fluxo normal (m)
b largura baze culvert nian (m)
g akselarasaun gravitasonal (m/s^2) = 9.81 m/s^2

Profunidade fluxo normal, y_n, bele kalkula ho troka profunidade fluxo, y, no hetan kalkula fila fali area, A, no wetted perimeter, P, ba equasaun 11 to'o dezenu capacidade hanesan ho dezenu inundasaun (Q =

Q_P). Alternativamente, Métodu Newton-Raphson bele mós uza ba konverjénsia ne'ebé efisiente ba Q = Q_P.

Aleinde fluxo velocidade ne'ebe as, medida protesaun ba erosaun iha outlets tenki konsidera ba fluxo supercritical iha ne'ebe Fr > 1. Rekomendasaun ba selksaun no dimensaun husi medida protesaun ba erosaun mak deskritu iha Seksaun 9.

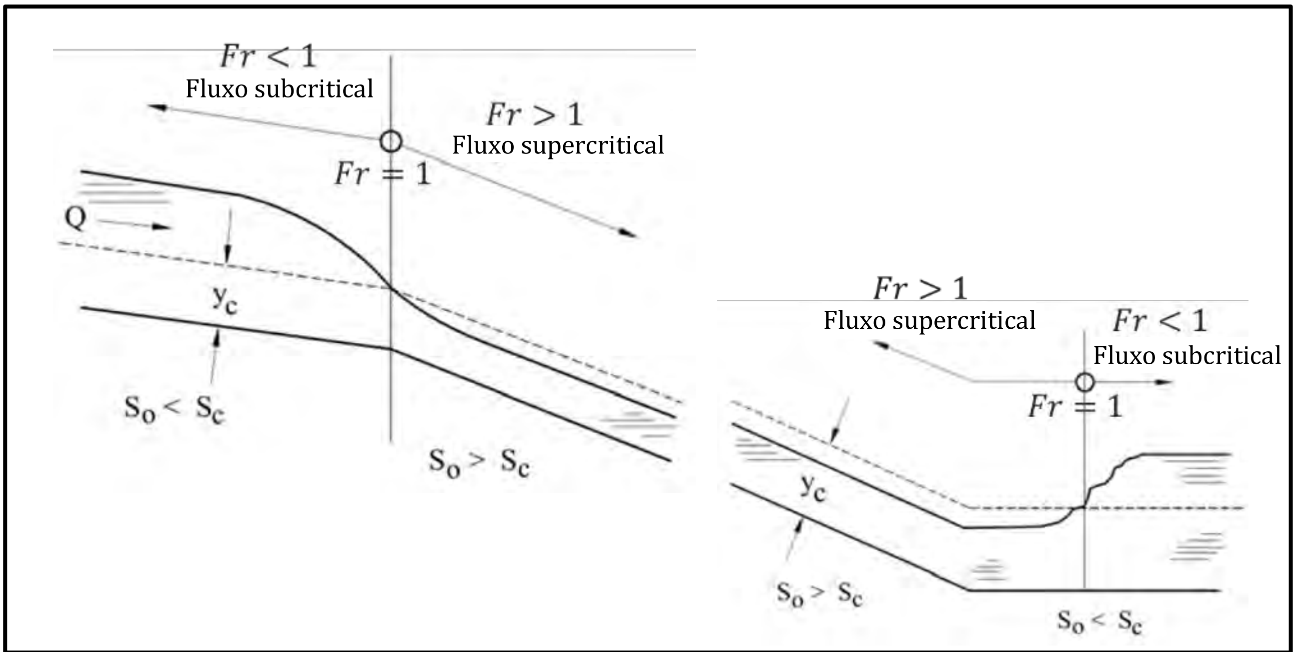


Figura 8.3 — Konseptu numeru Froude ne'ebe indika tipu fluxo (5)

9 Servisu protesaun

Medida ba protesaun mak nessesariu wainhira erosaun akontese. Outlet husi culverts mak problematika liu no ezemplu husi erosaun hatudu iha Figura 9.1. Generalidade,erosaun akontese wainhira:

- velocidade fluxo as / fluxo supercritical, hare Seksaun 8.4 no 8.5
- diresaun fluxo nian hetan mudansa ho lalais (i.e. kurva mate), hare Seksaun 4.4

Figura 9.1 — Ezemplu erosaun iha culvert nia outlet (7)

9.1 Protesaun iha inlet

Erosaun iha upstream husi culvert ladun iha problema se wainhira inlet wing walls tuir padraun. Iha kazu erosaun, provizaun husi stone pitching ka rede gabion, ka kontrusaun apron ho konkretu entre wing wall mak baibain suficiente liu. Stone pitching ho medida 200 mm no nia as hanesan ho culvert normal nia as dala rua, hansan hatudu iha Figura 9.2. Apron konkretu iha inlet hanesan hatudu iha Figura 9.3.

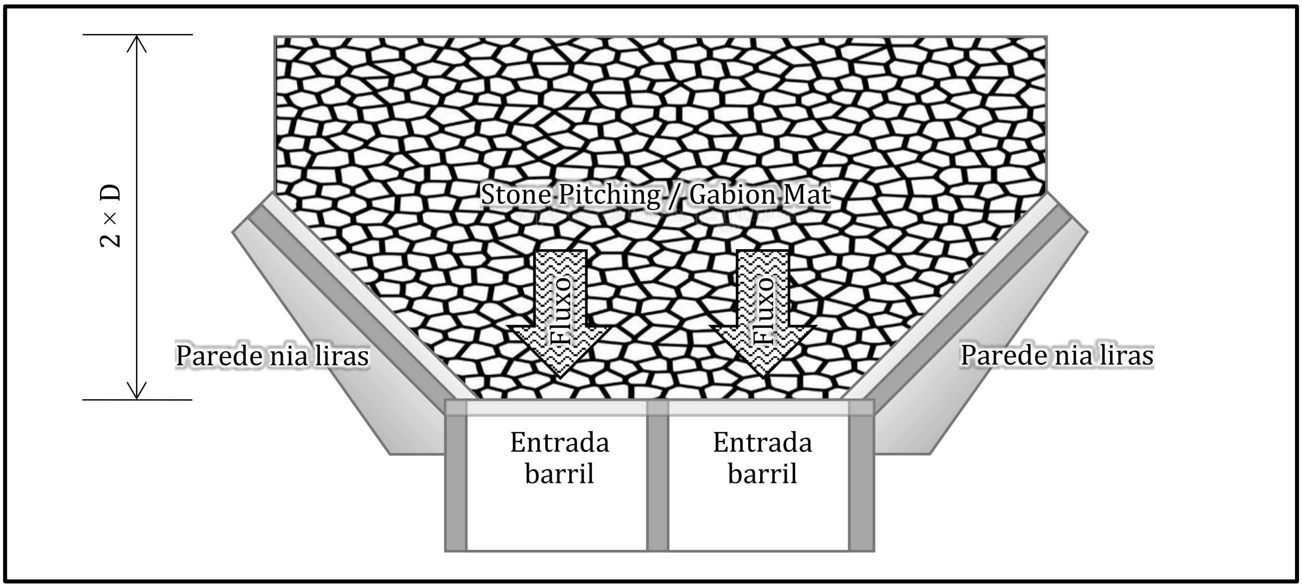


Figura 9.2 — Protesaun ba inlet utiliza stone pitching / rede gabion

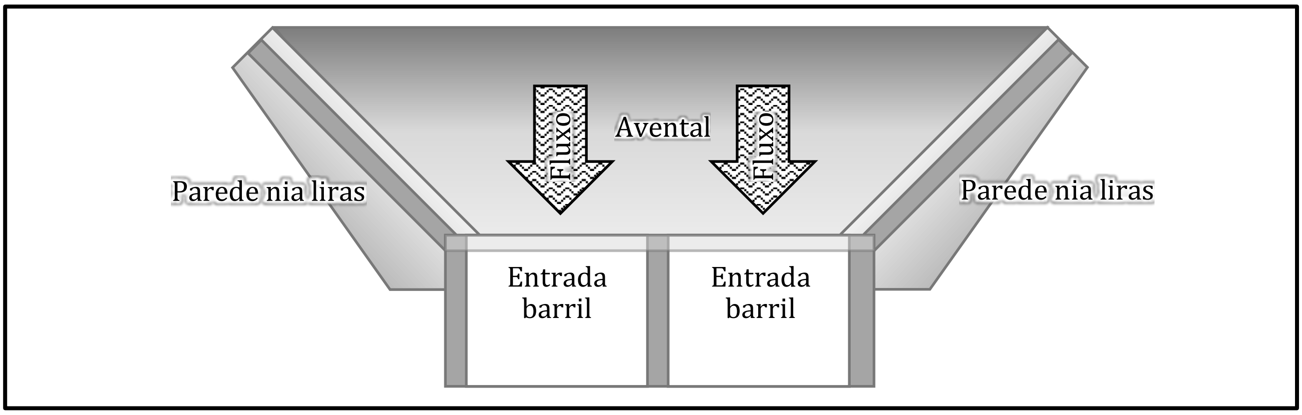


Figura 9.3 — Protesaun inlet utiliza apron konkretu

9.2 Protesaun outlet

Erosaun iha downstream husi culvert akontese bebeik tanba fluxo velocidade ne'ebe muda an. Mudansa iha fluxo velocidade tanba diferensa iha cross-secional no kanal nia roughness. Objectivu husi medida protesaun ida ne'e mak atu redus velocidade to'o nia hanesan ho fluxo natural iha kanal.

Medida protesaun ba erosun mak hanesan parte ida husi padraun kontrusaun ba outlet. Ba aplikasaun normal, medida ba outlet atu hanesan ho inlet,hanesan hatudu iha Figura 9.2 no Figura 9.3. Iha kazu ne'ebe erosaun hanesan prekupasaun ida, rekomenda strutura ba enejia dissipasaun. Strutura tuir mai mak solusaun ne'ebe posibel ba protesaun erosaun iha outlet:

- Tipu diagrma 1 stilling basin ho fatuk, hare Figura 9.5
- Tipu diagrma 2 stilling basin ho fatuk, hare Figura 9.6
- Tipu diagrma 3(a) no 3(b) stilling basin ho fatuk, hare Figura 9.7 no Figura 9.8
- Tipu diagrama 5 stilling basin ho konkretu, hare Figura 9.9

9.2.1 Seleksaun medida protesaun

Etodu ba seleksaun meidda protesaun ba erosaun ne'ebe apropriado mak hatudu iha Figura 9.4. Lina 2 tenki trasa perpendicular ba iha axes. Interseksaun husi lina 2 ne'e hatudu medida ne'ebe rekomenda.

Profunidade fluxo normal iha outlet no numeru Froude mak presiza ba seleksaun metodu ida ne'e. Profunidade fluxo normal no subsquentemente numeru Froude ba caixa culvert bele kalkula bazeia ba Seksaun 8.5. Y-axis mak rasio profunidade fluxo normal ba to iha culvert nia as, y_n / D, no X-axis mak numeru Froude, *Fr*.

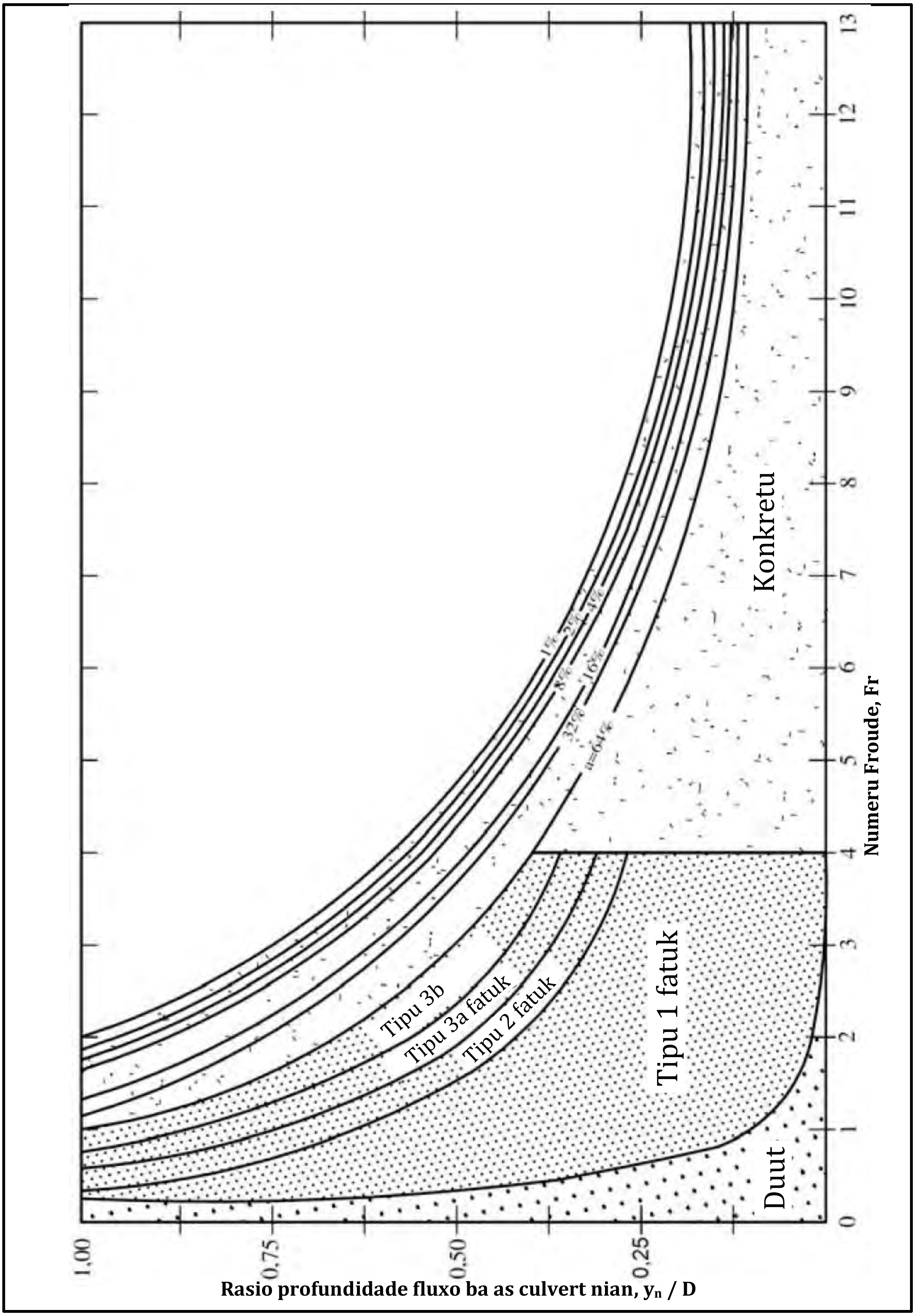
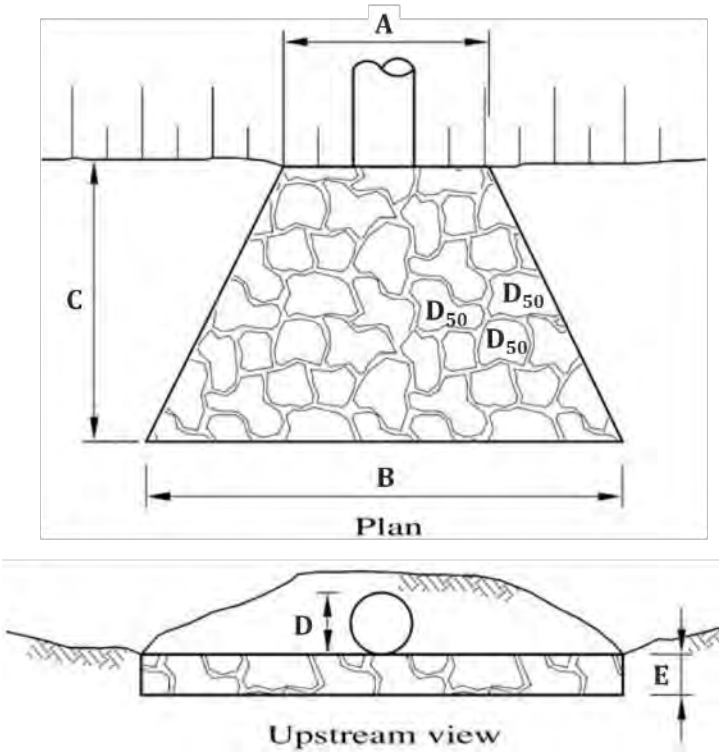


Figura 9.4 — Metodu Seleksaun medida protesaun b erosaun (5)

9.2.2 Detaillamentu ba medida protesaun

Dimensaun ne'ebe rekomenda no konstrusaun medida protesaun ba erosaun mak hanesan hatudu iha Figura 9.5, Figura 9.6, Figura 9.7, Figura 9.8 no Figura 9.9.



D = culvert nian as (m)

$A = 3 \times D$
= largura fatuk basin iha parte saida (m)

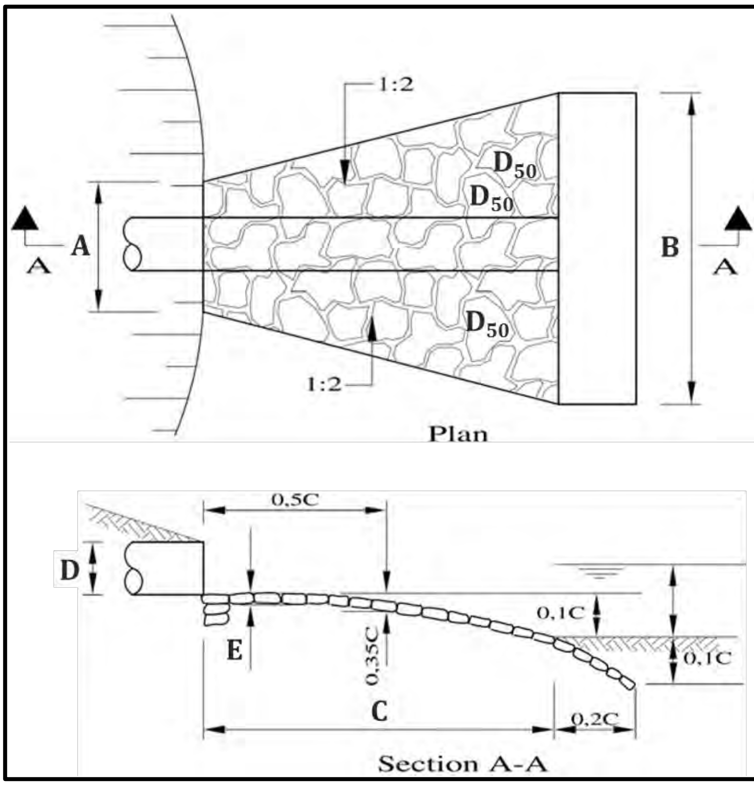
$B = A + C$
= largura mota ain (m)

$$C = 3.0792 \times \frac{Q}{D^{1.6}} + 2.4384$$
= fatuk basin nia naruk (m)

$E = 0.5 \times D \times Fr$
= fatuk basin nia mahar (m)

$$D_{50} = 0.0883 \times \frac{Q^{1.333}}{D^{2.333}}$$
= medida minimu husi fatuk iha 50% husi material basin (m)

Figura 9.5 — Tipu diagrma 1 stilling basin ho fatuk (5)



D = culvert nian as (m)

$A = 3 \times D$
= largura fatuk basin iha parte saida (m)

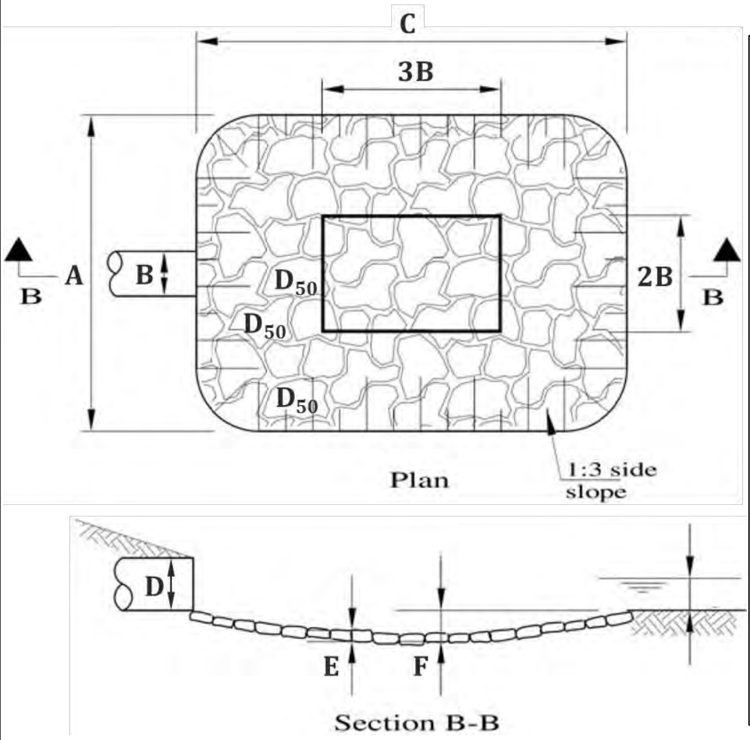
$B = 5 \times D$
= largura mota ain (m)

$C = 5 \times D$
= fatuk basin nia naruk (m)

$E = 2 \times D_{50}$
= fatuk basin nia mahar (m)

$$D_{50} = 0.0707 \times \frac{Q^{1.333}}{D^{2.333}}$$
= medida minimu husi fatuk iha 50% husi material basin (m)

Figura 9.6 — Tipu diagrma 2 stilling basin ho fatuk (5)



D = culvert nian as (m)

B = culvert nian largura (m)

$A = 2 \times D + 6 \times F$
= largura fatuk basin iha parte saida (m)

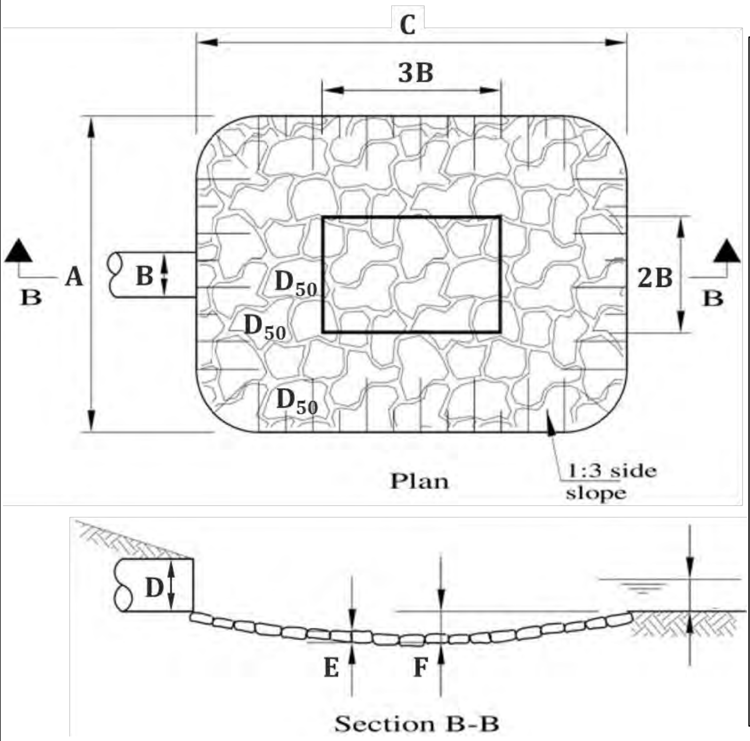
$C = 3 \times D + 6 \times F$
= fatuk basin nia naruk (m)

$F = 0.5 \times D$
= profundidade fatuk basin (m)

$E = 2 \times D_{50}$
= fatuk basin nia mahar (m)

$D_{50} = 0.0552 \times \frac{Q^{1.333}}{D^{2.333}}$
= medida minimu husi fatuk iha 50%

Figura 9.7 — Tipu diagrma 3a stilling basin ho fatuk (5)



D = culvert nian as (m)

B = culvert nian largura (m)

$A = 2 \times D + 6 \times F$
= largura fatuk basin iha parte saida (m)

$C = 3 \times D + 6 \times F$
= fatuk basin nia naruk (m)

$F = D$
= profundidade fatuk basin (m)

$E = 2 \times D_{50}$
= fatuk basin nia mahar (m)

$D_{50} = 0.0362 \times \frac{Q^{1.333}}{D^{2.333}}$
= medida minimu husi fatuk iha 50%

Figura 9.8 — Tipu diagrma 3b stilling basin ho fatuk (5)

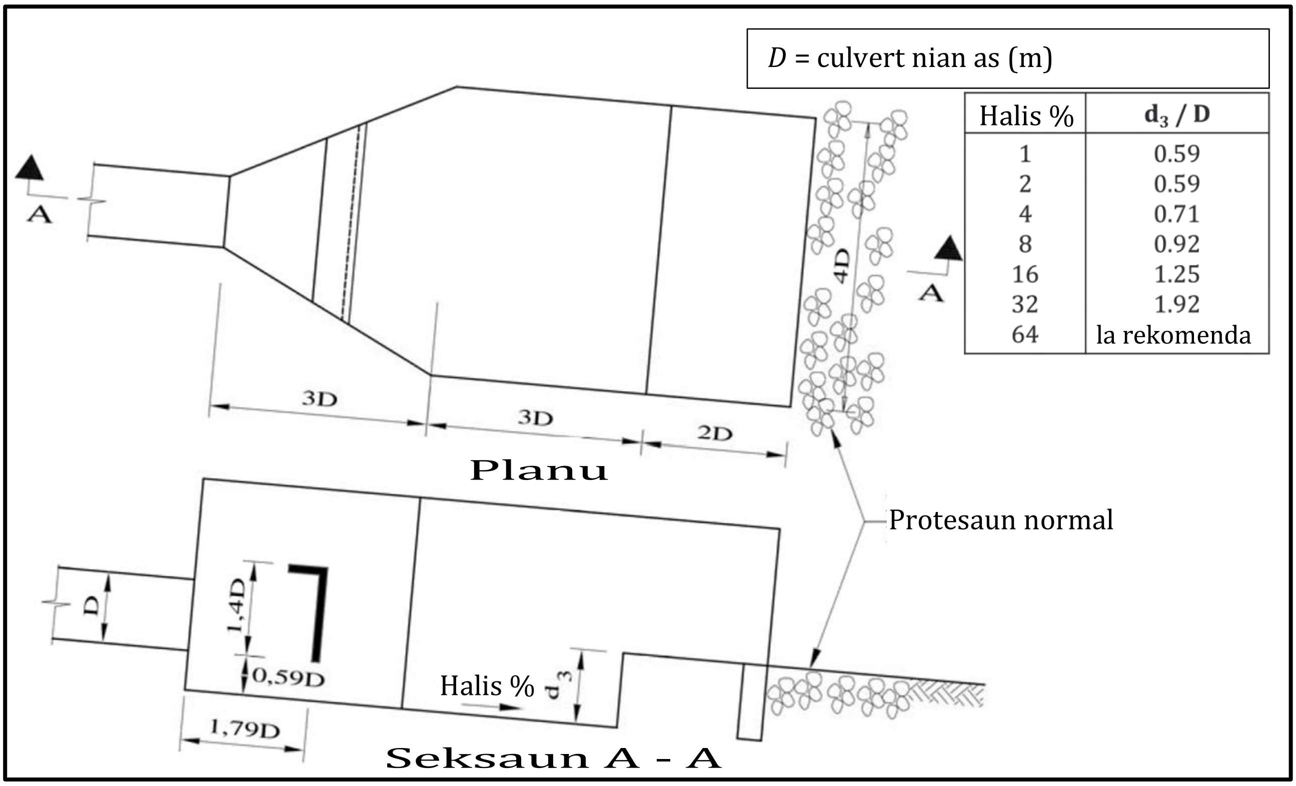


Figura 9.9 — Tipu diagrama 5 stilling basin ho konkretu (5)

Glossário

English	Tetun / Portuguese / Indonesian	Japanese
Alignment	Alinhamento / Penjajaran	線型
Allowance height	Altura / Tunjangan tinggi	余裕高
Annual maximum daily rainfall	Chuva diária máxima anual	年最大日降雨量
Annual rainfall	Chuvas anuais	年間降雨量
Area (cross-section of flow)	Área (seção transversal do fluxo)	通水断面積
Artificial channel	Canal artificial / Saluran buatan	人工水路
Basin	Bacia / Baskom	流域
Catastrophe	Catastrophe / Malapetaka	災害
Catchment area	Área de captação / Area tangkapan	集水地域
Channel profile	Perfil do canal	溝形断面
Coefficient	Coeficiente	係数
Critical depth	Profundidade crítica / Kedalaman kritis	臨界深度
Critical flow	Fluxo crítico / Aliran kritis	限界の流れ
Departure	Partida	偏差計算
Depth (of flow)	Profundidade (do fluxo) / Kedalaman (arus)	水深
Discharge	Descarga	排水
Discharge capacity	Capacidade de descarga / Merancang kapasitas debit	通水量
Duration	Duração	期間
Elongated	Alongada / Memanjang	伸びた
Empirical	Empírico	経験的
Erosion protection measure	Medida oinsa atu prvene erosaun	浸食防止工法
Evaporation	Evaporação	蒸発
Extrapolation	Extrapolação	外挿
Factor	Fator	因子
Flood hazard	Perigo de inundação / Bahaya banjir	洪水の危険
Flow	Aliran / Fluxo / Mengalir	流れ
Frequency	Freqüência	周波数
Friction	Atrito / Gesekan	摩擦
Frictional resistance	Resistência à fricção / Resistensi gesekan	きしみ反応
Froude number	Numeru Froude / Nural Froude	フルード数
Gradient	Gradiente/Kemiringan	流路勾配
Gradient / bed slope	Gradiente / Encosta do rio / lereng sungai	勾配
Gravitational acceleration	Aceleração gravitacional / Percepatan gravitasi	重力加速度
Headwater	Kedalaman air di Upstream	上流
Height of culvert (internal)	Altura do cais (interno) / Tinggi gorong-gorong (internal)	高さ
Hydraulic jump	Salto hidráulico / Lompatan hidrolik	跳水
Hydraulic mean depth	Profundidade média hidráulica	流体平均深さ
Hydraulic radius	Raio hidráulico / Radius hidrolik	径深
Infiltration	Infiltração	浸潤
Influence	Influência	影響
Interpolation	Interpolação	内挿
Lag	Atraso / Ketinggalan	時差（遅れ）
Limitation	Limitasaun / Limitação	制限
Longitudinal section	Seção longitudinal	縦断面
Magnitude	Magnitude	マグニチュード

English	Tetun / Portuguese / Indonesian	Japanese
Manning's roughness coefficient	Coeficiente de rugosidade de Manning / Koefisien kekasaran Manning	粗度係数
Maximum 24-hour rainfall / Probable daily rainfall	Chuva máxima de 24 horas / Chuva diária provável	確率日降雨量
Mean	Média	平均
Natural channel	Canal natural / Saluran alami	自然水路
Newton-Raphson method	Metodo Newthon-Rapshon	ニュートン・ラプソン法
Normal depth	Kedalaman normal	等流水深
Normal flow	Aliran normal	等流の流れ
Occurrence	Ocorrência / Kejadian	発生
Peak	Pico / Puncak	ピーク（最大）
Ponding	Ponding / Kolam	たん水
Prediction	Predição	予測
Probability	Probabilidade	確率
Probability distribution	Distribuição de probabilidade	確率分布
Rainfall	Udan / Chuva / Precipitação	降雨
Rainfall intensity	Intensidade da chuva	降雨強度
Rational Method	Método Racional (hidrología)	合理式
Return period	Período de retorno	確率年
Riprap	Riprap (Fatuk kasar nebe usa ba protesaun ba erosaun)	護床工
Runoff	Escoamento / Limpasan	流出
Sedimentation	Sedimentação / Pengendapan	堆積
Sharp bend	Curva acentuada / Tikungan tajam	急カーブ
Standard deviation	Desvio padrão	標準偏差（SD）
Stilling basin	Posisi cekungan	減勢池
Storage	Armazenamento	貯水池
Subcritical flow	Fluxo subcrítico / Aliran subkritis	常流
Supercritical flow	Fluxo supercrítico / Aliran supercritical	射流
Tailwater	Kedalaman air di Downstream	下流
Time of concentration	Tempo de concentração	洪水到達時間
Trial-and-error method	Metodo trial no error	試行錯誤手法
Uniform	Uniforme	均一
Urbanised	Urbanizado	都市化された
Velocity	Velocidade / Kecepatan	洪水速度
Watercourse	Aliran be / Curso de água / Anak sungai	水路
Watershed	Bacias hidrográficas / Batas air	分水地点
Weighted average	Média ponderada	加重平均
Wetted perimeter	Perímetro molhado / Perimeter terbasah / Keliling basah	潤辺
Width (internal)	Largura (interna) / Lebar (internal)	幅

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Democratic Republic of Timor-Leste

Ministry of Public Works

Directorate General of Public Works

National Directorate of Roads, Bridges and Flood Control

Road Guidelines — Slope Protection — Retaining Wall & Slope Collapse

Guia de Estrada — Proteção de Taludes — Muro de Contenção e Colapso de Inclinação

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Contents

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REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTÉRIO DAS OBRAS PÚBLICAS
GABINETE DO VICE-MINISTRO
Av. Nicolau Lobato, Mandarin, Dili, Timor-Leste

Foreword

In the interest of constructing high quality and economically viable government infrastructure to serve the nation, these guidelines for optimal design of slope protection components were prepared by the JICA Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste (CDRS) in collaboration with the *Direcção Nacional de Estradas, Pontes e Controlo de Cheia*s (DNEPCC, 'National Directorate of Roads, Bridges and Flood Control') of the *Ministério das Obras Públicas* ('Ministry of Public Works'). We would like to thank JICA for their continuing support.

September, 2019

Eng. Nicolau Lino Freitas Belo
Vice Minister for Public Works
Ministry of Public Works

Foreword by JICA

Japan International Cooperation Agency (JICA) has been conducting a technical cooperation project for development of capacity regarding road services, which is called CDRS, in order to facilitate the DNEPCC in properly managing and maintaining the road infrastructure that is the basis of social and economic activities. To this end, JICA has been dispatching a team of experts from March 2016 to December 2019. As a result of collaborative work with counterparts of the DNEPCC, these guidelines for slope protection have been finalized. I hope that these guidelines will contribute to infrastructure development and maintenance, and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials of the Government of the Democratic Republic of Timor-Leste for their close cooperation with the expert team.

September, 2019

Masafumi NAGAISHI
Chief Representative of JICA Timor-Leste Office
Japan International Cooperation Agency

Acknowledgements

The Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste wishes to thank all parties involved in preparing and revising these Slope Protection guidelines.

In support of the project, the officials of the (former) Ministry of Development and Institutional Reform: M. R. M. Cruz, J. L. C. C. P. Mestre and J. Santos; and the officials of the Ministry of Public Works: C. M. Henrique and especially R. H. F. Guterres; are hereby acknowledged.

In contributing to the preparation of this document, the officials of the DNEPCC: M. R. C. Monteiro, J. P. Amaral, J. M. G. Sousa, J. G. Carlvalho, I. M. L. Gutteres, N. Lobato, L. Luis, M. Soares and J. L. Kehy; and the International Labour Organization's (ILO) technical assistance team of the Roads for Development Support Program (R4D-SP): A. O. Asare, K. H. Myaing, S. Done, U. Yat and L. Thakuri; are hereby acknowledged.

Feedback:

Any positive feedback for possible incorporation into future editions would be appreciated. Please send such comments or feedback to the below address.

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Introduction

These guidelines were developed by JICA Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste in collaboration with the *Direcção Nacional de Estradas, Pontes e Controlo de Cheias* (DNEPCC, 'National Directorate of Roads, Bridges and Flood Control') for the purpose of developing institutional capacity regarding slope protection.

Generally speaking, design in civil engineering must stands on geological information and survey drawings instead of impression at the site. Therefore, these guidelines start with "Minimum Required Information for Design".

Most of all projects use the common drawings in Timor-Leste. However how many in-house engineers are conscience backgrounds of them, in other words their original design. These guidelines treat stability calculations of gravity retaining walls in the common drawings in order to present hints for better user of the common drawings. On the other hand, stability calculation of gravity retaining wall is front door for other structures design. Master of the calculation has got a step to higher level.

Existing countermeasures against slope collapse in Timor-Leste are mainly re-cutting. And existing slope protection methods are vegetation and cover sheet. These means must face limit in many cases of shallow slope collapse. Combination of sewing bar and surface cover structure seems one of most adequate countermeasure against shallow slope collapse. Therefore this method shall be introduced into Timor-Leste to control shallow slope collapse.

There are other types of slope disaster such as rock fall, rock mass failure, mass movement (land slide), debris flow and embankment collapse. These guidelines focus on slope collapse on cut or natural slope because of secure capacity development. The CDRS project provides other guidelines entitled Landslide Investigation.

Road Guidelines — Slope Protection — Retaining Wall & Slope Collapse

1 Scope

The scope of these guidelines is gravity retaining wall and shallow (depth is smaller than about 2m) slope collapse on cut or natural slope.

These guidelines consist of three themes, investigation, gravity retaining wall and slope protection.

When some problem in civil engineering occurs the first step of procedure shall be scientific investigation. The investigation must include ground shape and substance. Clause 4 presents minimum required information for design.

Clause 5 to 7 treat gravity retaining wall. Clause 5 shows design procedure of gravity retaining wall. Clause 6 aims to support users of the common drawing in case of selection. Characteristics of Type1 and Type2 are shown. Most of all failed retaining walls are due to shortage of bearing capacity of foundation ground. Clause 7 handles this matter.

Clause 8 to 12 treat slope stability. Clause 8 and 9 present general information of slope and slope disaster as background knowledge of slope stability. Clause 10 introduces a method of slope stability calculation. Clause 11 is influence analysis on safety factor of slope by surface gradient, shear strength and ground water. Clause 12 is design example of combination of sewing bar and surface cover structure against shallow slope collapse on a cut slope.

These guidelines focus on slope collapse on cut or natural slope because of secure capacity development.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO maintains terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
retaining wall
wall supporting backfill soil, embankment soil or a cut slope

[SOURCE:ISO 23469:2005(en),3.46]

3.2
earth pressure
pressure from soil on a wall or an embedded portion of a structure

[SOURCE:ISO 23469:2005(en),3.11]

3.3
bearing capacity of the soil
maximum permissible stress on the foundation soil that provides adequate safety against bearing failure of the soil, or settlement of the foundation of such magnitude as to impair the structure

[SOURCE:ISO 28842:2013(en),3.9]

4 Investigation (Minimum Required Information for Design)

Phenomenon of slope disaster is that ground moves downward by gravity force under influence of water. Therefore Information of ground shape and content, water condition just at disaster occurring can be said the minimum required information for countermeasure design. In many cases water condition is unknown because of no observation so estimation is alternative for it. Survey gives information of ground shape. Geological investigation gives information of ground content.

4.1 Ground Shape

Representative cross section is vital for countermeasure basic design. We can get it easily by cross section survey at the site.

In detail design plan with contour map, longitudinal section and cross sections are necessary as ground shape information. We can study placement, coverage and matching with surrounding land on the plan. And plan must have bench mark which can be found in-situ by peg or pin. Longitudinal section fulfils the function to show road longitudinal gradient and elevation and location of survey point. Cross sections of survey point present working area and construction quantity.

4.2 Geological Information

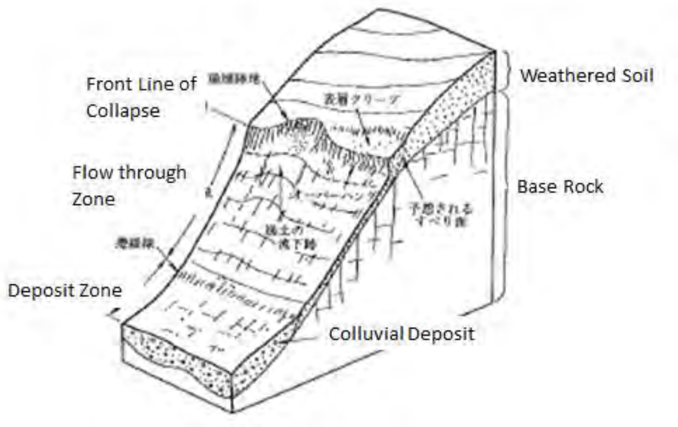
Basically geologist is in charge of geological investigation and civil engineer is a user of geological information however the civil engineer should approach actively geological knowledge to become a smart user. If there is no geologist in the project civil engineer must get geological information by himself.

(1) Geomorphologic approach

Ground shape reflexes ground content. Geomorphologic approach is the first step of geological investigation. We can get aerial or satellite photo through the internet easily. The photo teaches us ground shape around the target point. Geologist figures out detail geomorphic characteristics such as colluvial deposit, alluvial fan, mass movement fluvial terrace and so on from aerial stereo photograph.

Figure 4.1 Birds-eye view of satellite photo

Typical geological contests of mountainside is shown in next figure. When road goes near ridge line weathered soil often appears on cut slope, and near bottom of valley we often face colluvial deposit. These two have potential of collapse because of unconsolidated layers



Adapted from bibl. [1]

Figure 4.2 Typical mountainside structure

(2) Surficial geological observation

Surficial geological observation targets; to collect geological information at exposure which can be found cut slope and gully sides, to observe ground water condition through gully stream, trace of flow, spring, and to confirm site-scale geomorphic impression.

(3) Mechanical boring and standard penetration test

Most popular mean of geological investigation is mechanical boring and standard penetration test for soil layer. Of course it takes cost and time however there is no other choice to get clear evidence of ground content. N-value since standard penetration test is linked evaluation of bearing capacity and shear strength. Therefore it can be said that N-value is like a common ruler of soil layer. There is a weak point of N-value when a layer has rich gravel, the gravel messes N-value too much bigger.

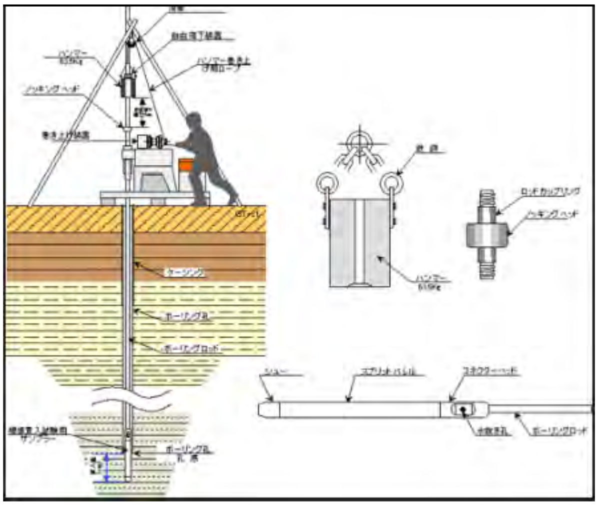


Figure 4.3 Mechanical boring and SPT

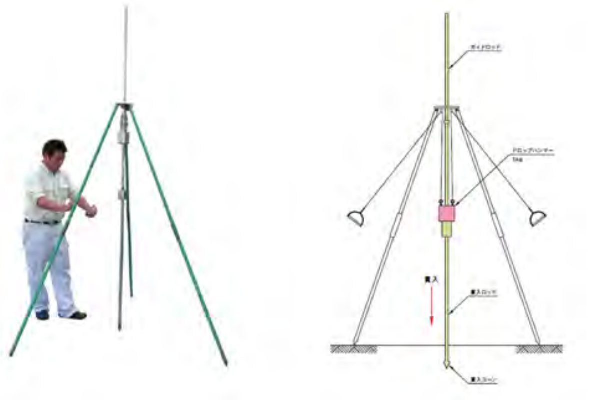
(4) Other penetration tests

There are some types of penetration test by man power as shown in figure 4.4. These test can execute far cheaper than mechanical boring but have limits in allowable layer and depth. In the project one Dokenbo is provided to DRBFC for simple geological investigation. Usage manual is compiled as Annex A.

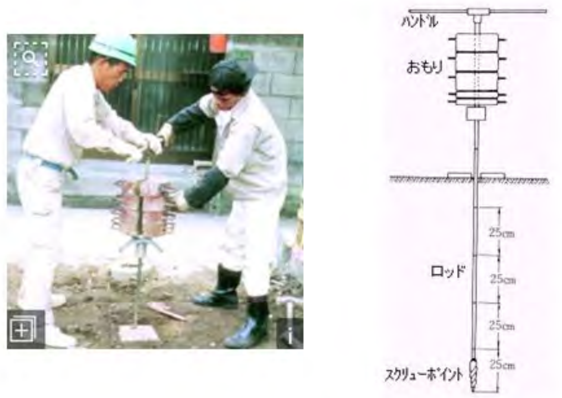
Table 4.1 Characteristics of penetration tests

	Standard Penetration Test SPT	Simplified Dynamic Cone Penetration Test	Swedish Sounding Test	Portable Cone Penetration Test	Prospect Rod for Soil Layer Strength Cone Penetration Test Dokenbo
Driving Method	Dynamic Hammering by Weight	Dynamic Hammering by Weight	Static Pushing by Weight and Turning by Hand	Static Pushing by Hand	Static Pushing by Hand
Power	Mechanical Power	Man power	Man power	Man power	Man power
Portability	Un-portable	16kgf / 1set	More than 100kgf		4.5kgf / 1set
Penetrator	Sampler ϕ51mm	Cone ϕ25mm	Screw-point ϕ33.3mm	Cone ϕ28.6mm	Cone ϕ15mm
Rod Diameter	ϕ40.5mm	ϕ16mm	ϕ19mm	ϕ16mm	ϕ10mm
Weight and Stroke	63.5kgf, 760mm	5kgf, 500mm	5,15,25,50,75,100kgf		
Unit testing Length	30cm, Pre-Blow 15cm	10cm	25cm	Every 10cm	At the Point
Allowable Layer	All Soil Layer Except Gravel Layer	All Soil Layer Except Gravel Layer	All Soil Layer Except Gravel Layer	Clayey Layer	Soil Layer except Dense Sandy Layer
Maximum Depth	Limitless	15m	15m	5m	5m
Outcome	SPT- N: Number of hammering per 30cm penetration	N_d: Number of hammering per 10cm penetration	N_{sw}: Number of half revolution per 1m penetration	D: Pushing Load q_c: Penetration resistance	W: Pushing Load q_{dk}: Penetration strength
Characteristics	King of penetration test So many past results Established outcome usage With boring	Downsized SPT	Common test for house foundation in Japan	Test only for soft soil layer	Good for slope investigation Multi use for Soil depth prospection Penetration test Shear strength test

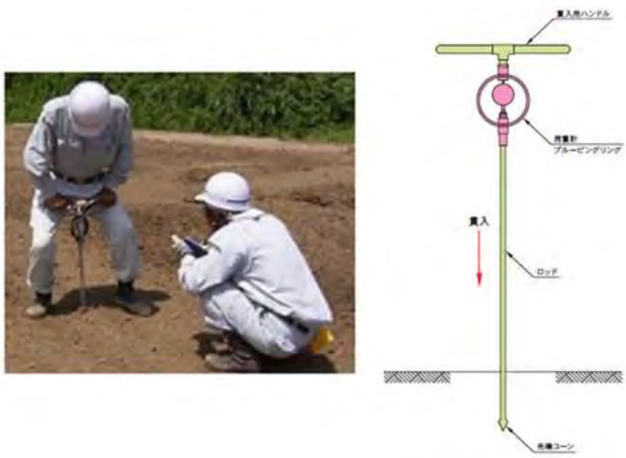
Simplified dynamic cone penetration test



Swedish sounding test



Portable cone penetration test



Prospect rod for soil layer strength

Dokenbo

Figure 4.4 Penetration tests by man power

5 Design of Gravity Retaining Wall

Design of gravity retaining wall seems an entrance door of civil engineering design. It is simple but included a useful method. If you understand it then you have easier way to approach other structures such as gabion wall, bridge abutment, debris flow barrier dam, gravity concrete dam and so on. That is why these guidelines treat this theme.

5.1 Design Procedure

Gravity retaining wall often applies as stop of embankment. Design procedure of gravity retaining wall is shown in Figure 5.1. The procedure mainly consist of stability calculation. Self-standing structures such as bridge abutment and gravity dam take similar procedure therefore understanding the procedure is good for first step of youth civil engineers.

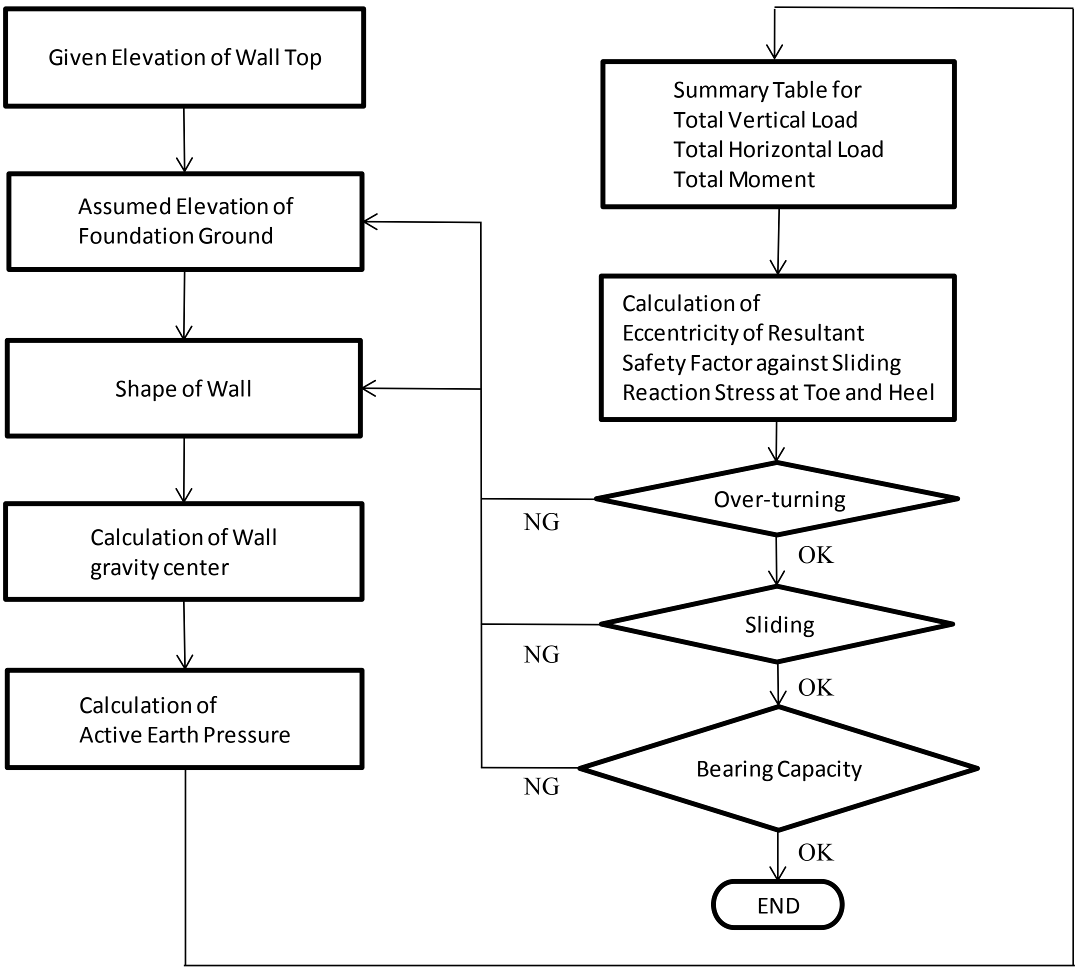


Figure 5.1 Design procedure of gravity retaining wall

5.2 Each step of the procedure

Each step of the procedure will describe along an example as below.

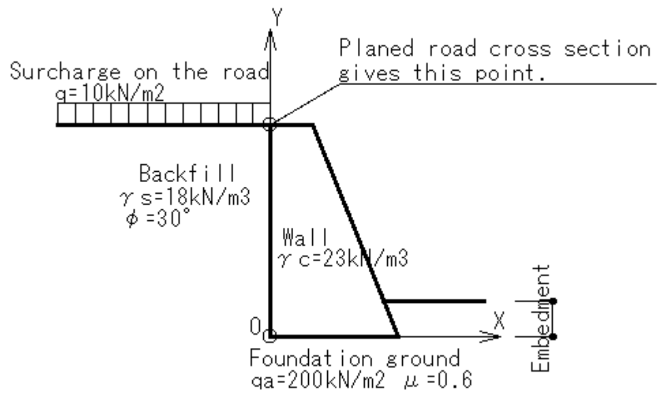


Figure 5.2 Example gravity retaining wall

(1) Given position of roadside wall top

Planed road cross section usually gives position of roadside wall top.

(2) Assumed elevation of wall bottom

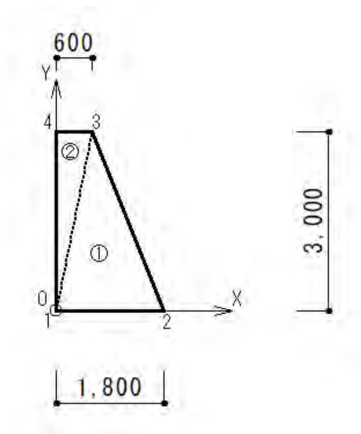
Elevation of wall bottom depends on foundation ground condition because the ground must bear the wall. Embedment depth which is distance between ground surface and wall bottom shall be larger than 0.5m.

(3) Shape of wall

You can select shape of wall from the common drawings. You also can set up an original shape. In this example type 1 H=3m is selected.

(4) Calculation of wall gravity center

The wall is divided into some simple figure such as triangle to calculate gravity center easily. The excel worksheet can calculate gravity center when you give coordinates of divided triangles with horizontal bases.

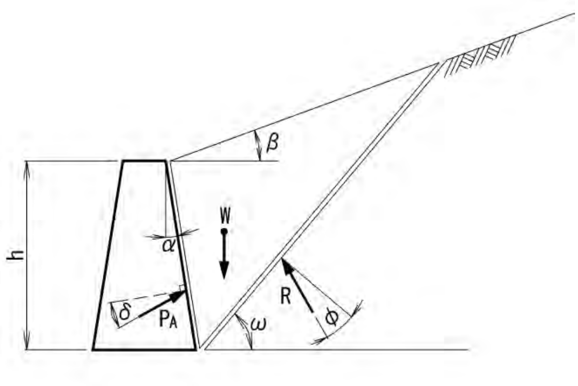


Element	Area A (m2)	Weight V (kN)	Arm length x (m)	Moment M (kNm)
1	2.70	62.1	0.800	49.7
2	0.90	20.7	0.200	4.1
Total		82.8		53.8

(5) Calculation of active earth pressure

Retaining wall folds backfill soil then backfill soil gives active earth pressure to the retaining wall. There are some methods to calculate active earth pressure, here we use Coulomb's formula.

$$K_A = \frac{\cos^2(\varphi-\alpha)}{\cos^2\alpha\cos(\alpha+\delta)\left\{1+\sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\beta)}{\cos(\alpha+\delta)\cos(\alpha-\beta)}}\right\}^2}$$



K_A: Active earth pressure coefficient

α: Angle between back surface of the wall and vertical line

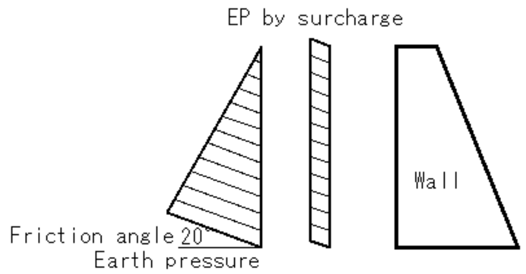
β: Angle between ground surface and horizontal line

φ: Internal friction angle

δ: Friction angle between back surface of the wall and the soil

α degree	β degree	φ degree	δ degree	KA
0.0	0.0	30.0	20.000	0.297

$$P_A = K_A\left(\frac{1}{2}\gamma h^2 + qh\right)$$



P_A: Active earth pressure acting on the wall

γ: Unit weight of the backfill

h: Height of the wall

q: Surchargeload on the road

Active Earth Pressure Coefficient	Backfill Unit Weight	Wall Height	Surcharge on the Road	Load Name	Load	Friction Angle of Wallback	Vertical Load	Arm Length	Moment	Horizontal Load	Arm Length	Moment
KA	γ kN/m3	h m	q kN/m2		PA kN	δ degree	V kN	x m	M kNm	H kN	y m	M kNm
0.297	19	3.000		Earth Pressure	25.4	20.000	8.7	0.000	0.0	23.9	1.000	23.9
0.297		3.000	10	EP by Surcharge	8.9	20.000	3.0	0.000	0.0	8.4	1.500	12.6
						Total	11.7		0.0	32.3		36.5
											ΣM=	36.5

(6) Summary table for loads and moments

Each load and moment are summarized into total vertical load, total horizontal load and total moment in the summary table as below.

Load Name	Vertical Load kN	Horizontal Load kN	Moment kNm
Wall Weight	82.8		53.8
Earth Pressure	11.7	32.3	36.5
Total	94.5	32.3	90.3

(7) Three check points of stability index

Retaining wall must pass three check points of stability index. They are over-turning, sliding and bearing capacity of foundation ground. They are checked by eccentricity of resultant, safety factor against sliding and reaction stress at wall toe and heel.

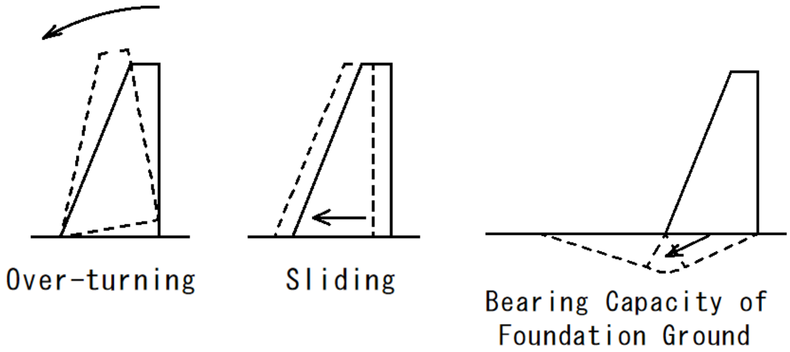


Figure 5.3 Three check points of stability index

(8) Calculation of eccentricity of resultant

X-coordinate of resultant is given as below.

$$\mathrm{X} = \frac{\sum M}{\sum V} = \frac{90.3}{94.5} = 0.956m$$

Eccentricity of the resultant is given as below.

$$\mathrm{e} = \mathrm{X} - \frac{B}{2} = 0.956 - 0.900 = 0.056m$$

Allowable eccentricity is B/6=0.300m, therefore the resultant drops within the middle third. Check point against over-turning is passed.

$$\mathrm{e} = 0.056\mathrm{m} < \frac{B}{6} = 0.300m \quad \mathrm{OK}$$

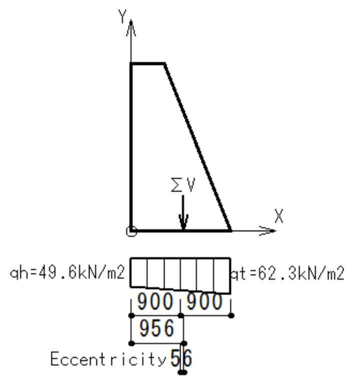
(9) Calculation of safety factor against sliding

Safety factor against sliding is given as below. The factor is bigger than 1.5 then check point against sliding is passed.

$$F_S = \frac{\mu \sum V}{\sum H} = \frac{0.6 \times 94.5}{32.3} = 1.76 > 1.5 \ \ \mathrm{OK}$$

(10) Calculation of reaction stresses at wall toe and heel

Reaction stresses at wall toe and heel are given as below.



$$q_t = \frac{\sum V}{B}\left(1 + \frac{6e}{B}\right) = \frac{94.5}{1.800} \times \left(1 + \frac{6 \times 0.056}{1.800}\right) = 62.3\ kN/m^2$$

$$q_h = \frac{\sum V}{B}\left(1 - \frac{6e}{B}\right) = \frac{94.5}{1.800} \times \left(1 - \frac{6 \times 0.056}{1.800}\right) = 49.6\ kN/m^2$$

The stresses are smaller than allowable stress 200kN/m2 then check point against bearing capacity is passed.

5.3 Active Earth Pressure by Backfill

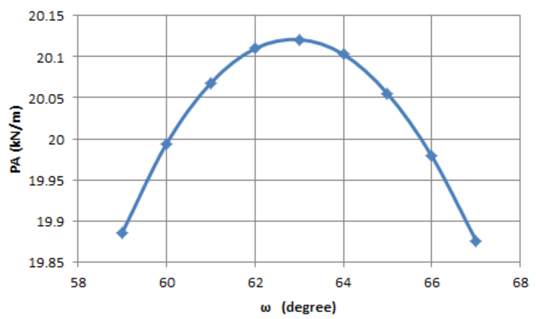
When a slope stands just behind of the wall trial wage method is applied for active earth pressure calculation instead of Coulomb's equation. The earth pressure is presented as next equation. W is weight of the wage, when sliding angle ω is assigned then W can be calculated. Maximum value of PA is targeted earth pressure value.

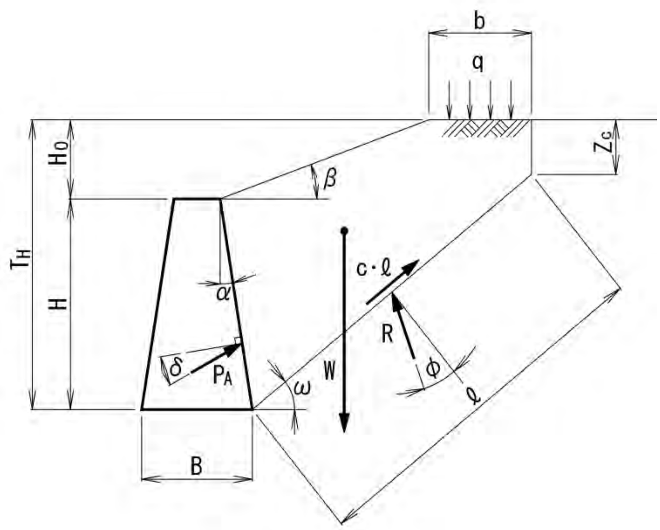
$$P_A = \frac{W sin(\omega - \varphi)}{cos(\omega - \varphi - \alpha - \delta)}$$

P_A: Active earth pressure

W: Weight of soil wedge

ω : Sliding angle of the wedge





We must determine unit weight and shear strength of backfill for earth pressure calculation. We can refer next table for it.

Table 5.1 Unit weight and shear strength of backfill

Type of Soil	Unit weight	Internal friction angle	Cohesion
	(kN/m³)	(degree)	(kN/m²)
Gravelly soil	20	35	0
Sandy soil	19	30	0
Clayey soil	18	25	0

Adapted from bibl. [5]

Technical Memorandum of PWRI No.3924-2 (2004.1) (Public Works Research Institute)

5.4 Foundation Ground

We also need to determine allowable bearing capacity and friction coefficient between wall and foundation ground. We can refer table 5.2 for it. If you face more weak ground then you can refer Table 5.3 and 5.4.

Most of all failed retaining walls are due to shortage of bearing capacity of foundation ground. Estimating bearing capacity is one of the most difficult matter for engineer. Durable ground such as base rock layer or diluvium layer has no problem. In contrast weak ground such as colluvium or heavily weathered rock requires us correct evaluation. Geological information through investigation help us to evaluate the ground. Classification, oldness and SPT-N (Standard penetration test N-value) are reliable information. Direct observation of foundation ground during working is last chance for evaluation.

Table 5.2 Allowable bearing capacity and friction coefficient of foundation ground

Type of foundation ground		Allowable bearing capacity	Friction coefficient between wall and foundation	Remarks	
				Unconfined compressive strength	SPT N vale
		(kN/m²)	-	(kN/m²)	-
Base rock layer	Homogeneous hard rock with few cracks	1,000	0.7	10,000 and up	-
	Hard rock with a lot of cracks	600		10,000 and up	-
	Soft rock, Mudstone	300		1,000 and up	-
Gravel layer	Dense one	600	0.6	-	-
	Not dense one	300		-	-
Sandy layer	Dense one	300	0.6	-	30 to 50
	Medium one	200		-	20 to 30
Clayey layer	Very stiff one	200	0.5	200 to 400	15 to 30
	Stiff one	100		100 to 200	10 to 15

Adapted from bibl. [5]

Technical Memorandum of PWRI No.3924-2 (2004.1) (Public Works Research Institute)

Table 5.3 Index on site to estimate bearing capacity for sandy layer

Type	Condition	Index on Site	Allowable Bearing Capacity kN/m²	SPT N-value
Sandy Layer	Very loose	Reinforcement bar ϕ13mm easily penetrates by the hand.	0	Less than 4
	Loose	Scoop-able by the hand with shovel	50	4 to 10
	Medium	Reinforcement bar ϕ13mm easily penetrates by the hand with 2.2kgf hammer.	100	10 to 15
		Same as above Some effort is required.	200	15 to 30
	Dense	Same as above Depth reaches approx. 30cm.	300	30 to 50
	Very dense	Same as above Emitting metallic sound Depth reaches approx. 5cm.	300	Greater than 50

Table 5.4 Index on site to estimate bearing capacity for clayey layer

Type	Condition	Index on Site	Allowable Bearing Capacity kN/m²	SPT N-value
Clayey Layer	Very soft	Fist easily penetrates about 10cm depth.	0	Less than 2
	Soft	Thumb easily penetrates about 10cm depth	20	2 to 4
	Medium	Thumb penetrates about 10cm with medium effort.	50	4 to 8
	Stiff	Thumb dents the surface with normal effort and penetrates with much effort	100	8 to 15
	Very stiff	Remove-able with spade	200	15 to 30
	Hard	Removing requires pickax	200	Greater than 30

6 Gravity Retaining Wall in the Common drawings

DRBFC has the common drawings which frequently appear in many projects for labor-saving about drainage, cross culvert, retaining wall, gabion, pavement and so on. This chapter treats gravity retaining wall in the common drawings.

6.1 Shape of the Walls

There are two types of gravity retaining wall in the common drawings, these shapes are shown as below. Type1 has vertical backside and around 1:0.4 gradient on front side. In contrast Type 2 has inverse 1:0.45 to 0.49 gradient on back side and 1:0.1 gradient on front side. Width of top is 0.6 m for both type.

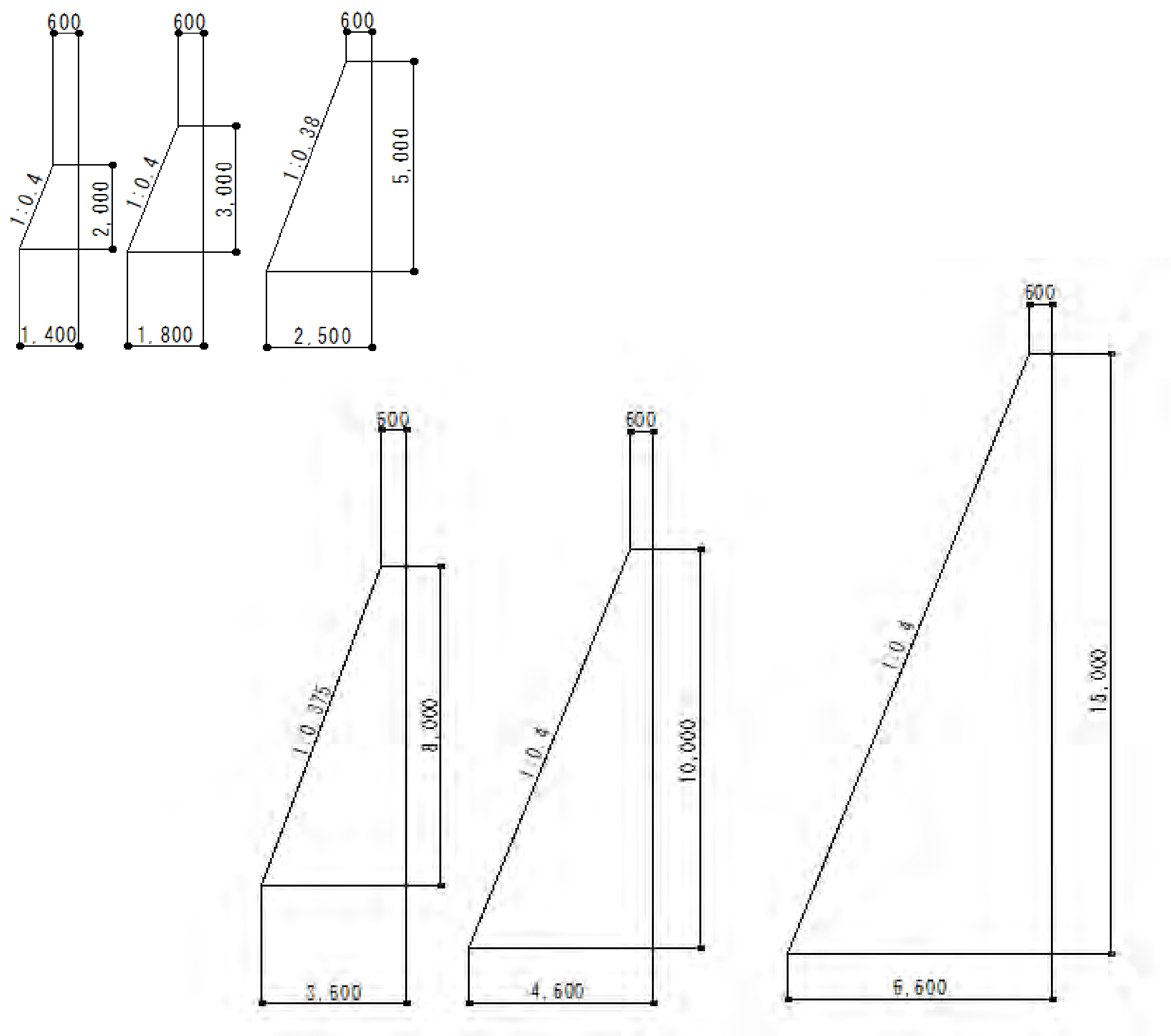


Figure 6.1 Shape of the Type 1 walls

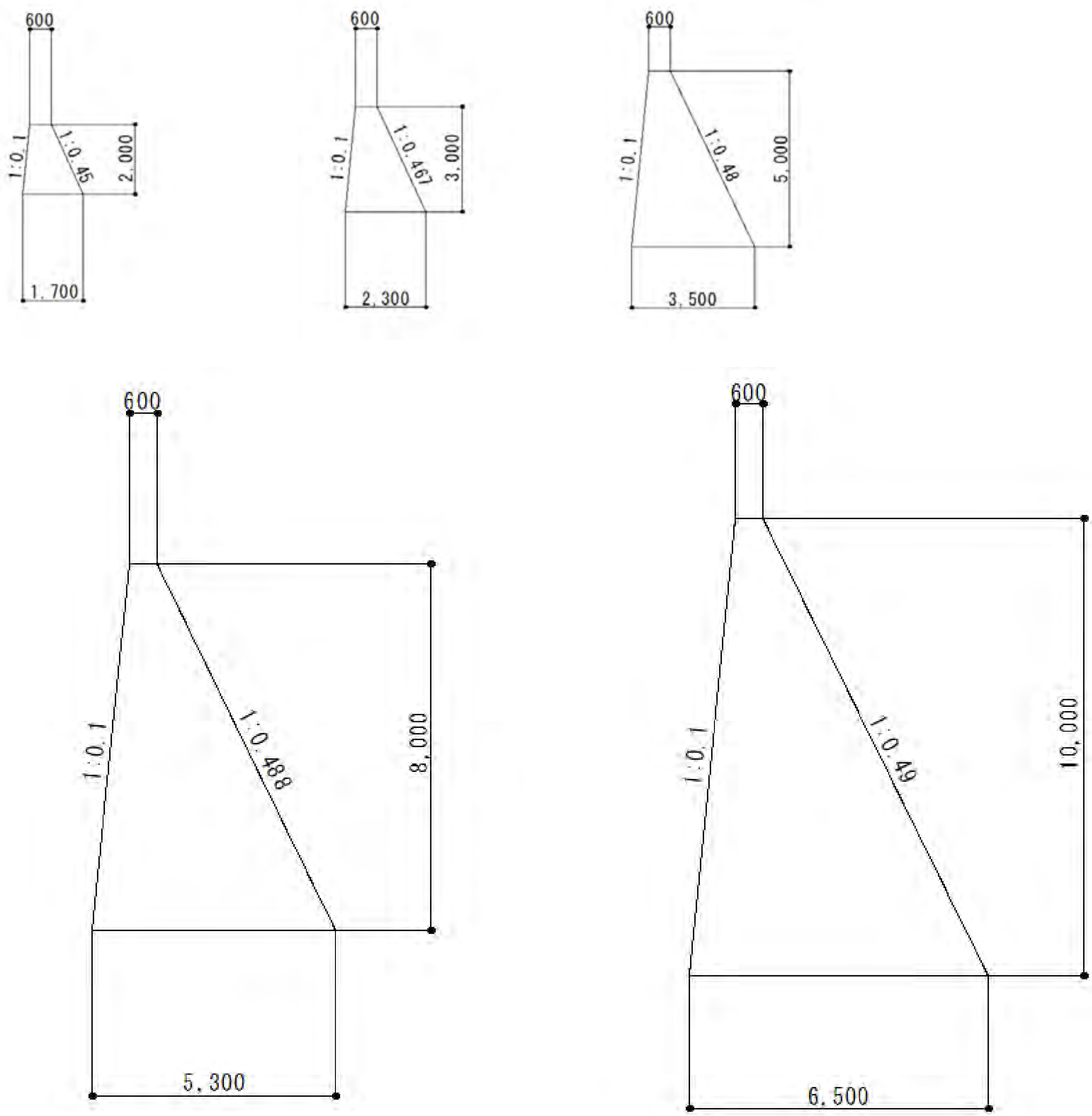


Figure 6.2 Shape of the Type2 walls

6.2 Result of stability calculation

These tables show the results of stability calculations on the Type1 and Type2. Calculation conditions are; backfill height is as same as wall top, backfill surface is horizon, earth pressure is calculated under backfill unit weight 19kN/m^3 and friction angle 30deg, road surcharge 10kN/m^2 on road surface.

Table 6.1 Result of Type1 stability calculation

Wall Body			Earth Pressure			Load Summary			Eccentricity		Bearing Capacity
Wall Height	Base Width	CS_Area	Total EP	Vertical EP	Horizontal EP	Siguma_V	Sigma_H	Siguma_ Moment	Eccentric Length	6e/B	Max Reaction Stress
H	B	A	PA	PAV	PAH	ΣV	ΣH	ΣM	e		qmax
m	m	m2	kN/m	kN/m	kN/m	kN	kN	kNm	m		kN/m2
2	1.40	2.00	17.24	5.90	16.20	51.90	16.20	37.43	-0.021	-0.09	40.4
3	1.80	3.60	34.34	11.74	32.27	94.54	32.27	84.08	0.011	0.04	54.5
5	2.50	7.75	85.48	29.24	80.32	207.54	80.32	229.60	0.144	0.35	111.7
8	3.60	16.80	204.55	69.96	192.22	456.36	192.22	654.39	0.366	0.61	204.1
10	4.60	26.00	312.18	106.77	293.35	704.77	293.35	1,332.20	0.410	0.53	235.2
15	6.60	54.00	680.11	232.61	639.09	1,474.61	639.09	3,779.74	0.737	0.67	373.1

Table 6.2 Result of Type2 stability calculation

Wall Body			Earth Pressure			Load Summary			Eccentricity		Bearing Capacity
Wall Height	Base Width	CS_Area	Total EP	Vertical EP	Horizontal EP	Siguma_V	Sigma_H	Siguma_ Moment	Eccentric Length	6e/B	Max Reaction Stress
H	B	A	PA	PAV	PAH	ΣV	ΣH	ΣM	e		qmax
m	m	m2	kN/m	kN/m	kN/m	kN	kN	kNm	m		kN/m2
2	1.70	2.30	30.90	21.56	22.15	74.46	22.15	52.37	0.147	0.52	66.5
3	2.30	4.35	62.80	44.42	44.39	144.52	44.39	129.99	0.251	0.66	104.0
5	3.50	10.25	158.85	113.57	111.06	349.37	111.06	448.93	0.465	0.80	179.4
8	5.30	23.60	383.56	275.86	266.50	818.66	266.50	1,520.90	0.792	0.90	293.0
10	6.50	35.50	587.13	423.09	407.08	1,239.59	407.08	2,786.94	1.002	0.93	367.1

6.3 Over-turning Condition

Safety against over-turning is evaluated that resultant force drops within the middle third area of the wall bottom base. This criterion means that there is no tension zone in the base as shown in Figure 6.3.

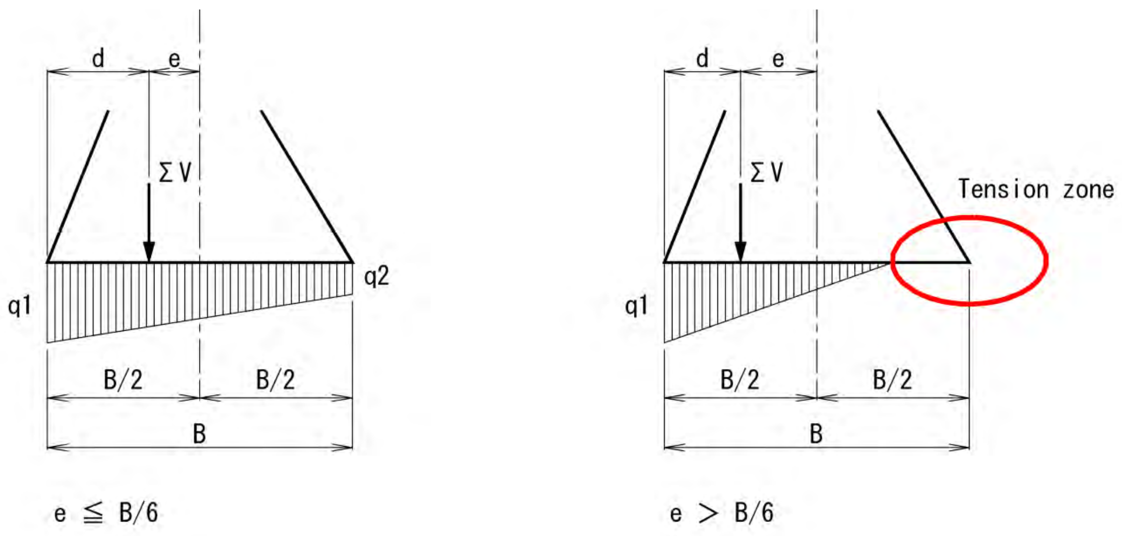


Figure 6.3 Correlation between eccentricity and distribution of ground reaction stress

It can be given by next equation.

$e \leq \frac{B}{6}$ $\frac{6e}{B} \leq 1$

6e/B which should be called ratio of eccentricity is shown in next figure. All walls pass check point for middle third. This check point does not relate foundation ground but shape of wall and backfill earth pressure. Minus zone of the ratio means that the resultant force drops within heel half side of the wall base.

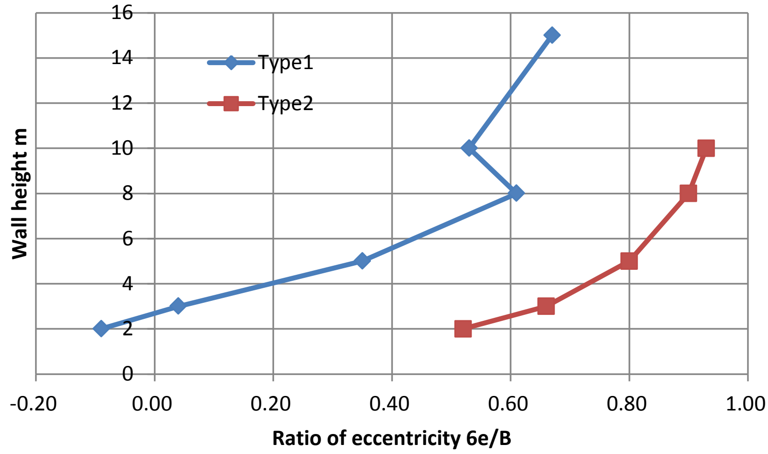


Figure 6.4 Over-turning condition of the walls

6.4 Sliding Condition

Safety factor against sliding is given by next equation.

$F_S = \frac{\mu \sum V}{\sum H} \geq 1.5$ $\mu \geq \frac{1.5 \sum H}{\sum V}$

Requested friction coefficient between wall and foundation can be calculated by the equation as below figure. Refer table 5.2 friction coefficients are; base rock layer 0.7, gravel and sandy layer 0.6, clayey layer 0.5. Therefore Type1 with over 7m height must stand on base rock layer, with 3m to 6m height must stand on more than sandy layer and with 2m height can stand on even clayey layer. In contrast Type2 with all height has no problem about sliding condition.

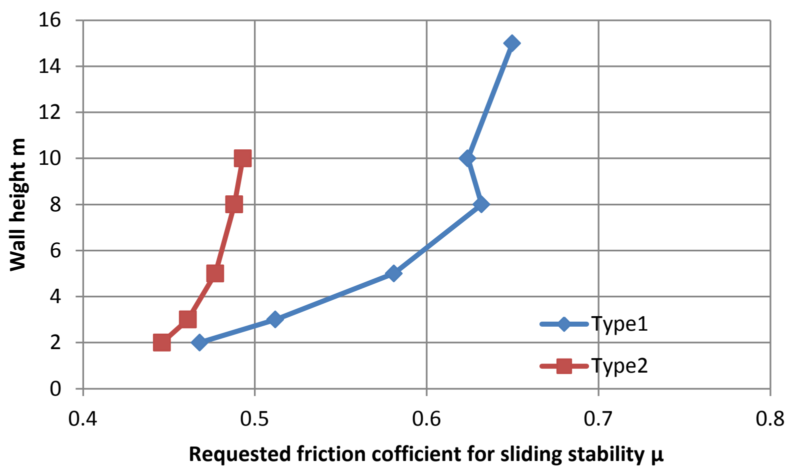


Figure 6.5 Sliding condition of the walls

6.5 Bearing Capacity Condition

Reaction stress must be smaller than allowable bearing capacity of foundation ground. Maximum reaction stress of foundation ground usually arises at wall toe. It can calculated by next equation.

$$q_t = \frac{\sum V}{B}\left(1 + \frac{6e}{B}\right)$$

Type1 has an advantage in this point because the stress is smaller than Type2 at the same wall height. Refer table 5.2 to 5.4 allowable bearing capacities are; base rock layer 300 to 1,000kN/m², gravel layer 300 to 600kN/m², sandy layer 0 to 300kN/m² and clayey layer 0 to 200kN/m². In mountain area we very often meet colluvial deposit which consists of clayey matrix and gravel. Clayey matrix can reach to stiff stage at the best condition so that bearing capacity stays around 100kN/m². We can roughly say that soil ground in mountain area can bear Type1 H≦4m and Type2 H≦2m only. Therefor high wall H>5m in mountain area should stand on base rock layer because of bearing capacity.

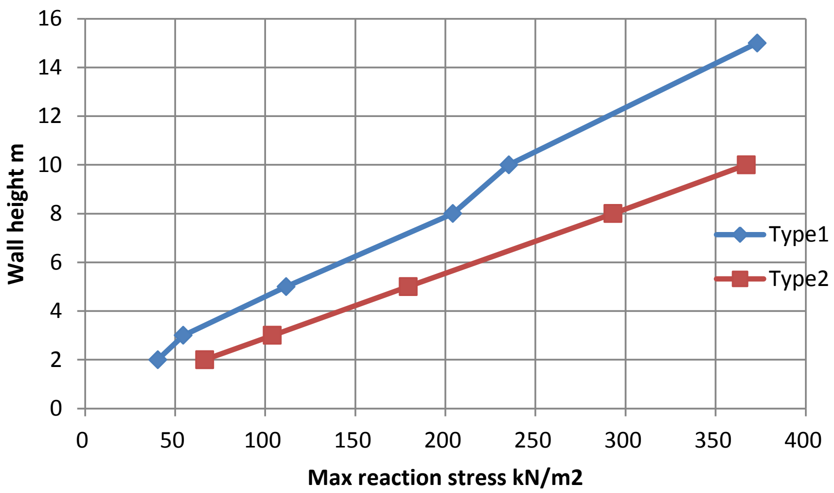


Figure 6.6 Bearing capacity condition of the walls

6.6 Adequacy of the Types

When you choose the type of gravity wall you shall pay attention below items about adequacy of the types.

(1) Cross section area

Next figure presents comparison of cross section area between Type1 and Type2. Type1 has advantage in this point, more specifically Type1 is cheaper than Type2 at the same wall height.

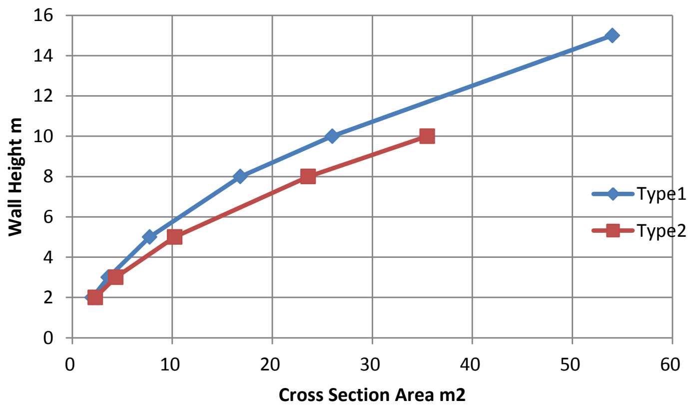


Figure 6.7 Comparison of cross section area

(2) Foundation ground

Type2 has advantage on sliding condition as we studied in section 6.4 but Type1 has advantage on bearing capacity condition as section 6.5. These two conditions are trade off relation. Type1 has smaller ΣV than Type2, it can be advantage because of smaller reaction stress qt against bearing capacity and can be disadvantage because of smaller resistance force against sliding.

(3) Land form

Figure 6.7 presents adequacy for slope ground. When wall is on horizontal ground necessary wall height is 5m same for both types. For instance how about on 30deg slope? Type1 needs additional 1.952m to touch the ground at the toe. Type2 can touch the ground with 0.647m addition. Therefore Type2 has adequacy for slope ground.

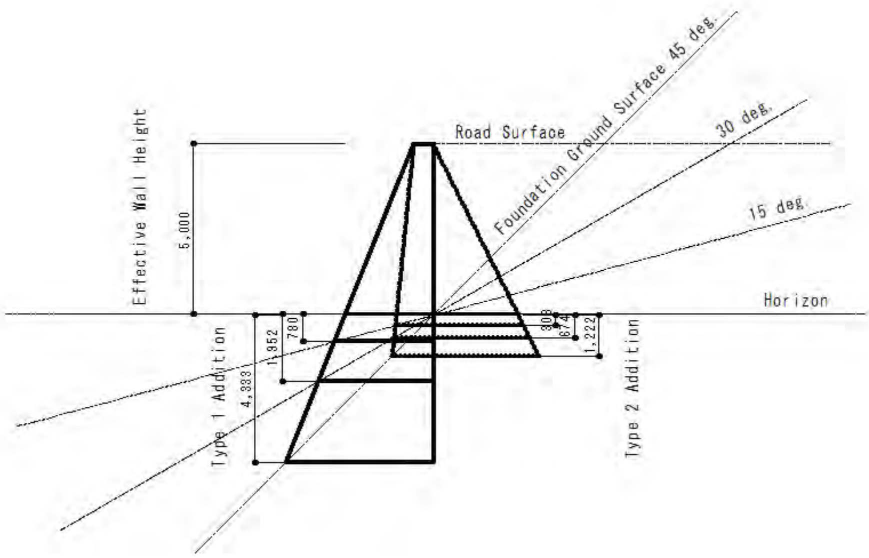


Figure 6.8 Adequacy for slope ground

7 Bearing Capacity

As described in section 5.4 estimation of bearing capacity of foundation ground is one of the most difficult matter for engineer. Reference values are given in table 5.2 to 5.4 in section 5.4. This chapter presents another approach for bearing capacity.

7.1 Terzaghi's Ultimate Bearing Capacity

When a load is applied to a horizontal ground there are two type of load-settlement relationships as show next figure. Ground which has middle level strength such as dense sandy layer or stiff clayey layer performs "General shear failure". Ultimate bearing capacity can be identified on this failure relationship.

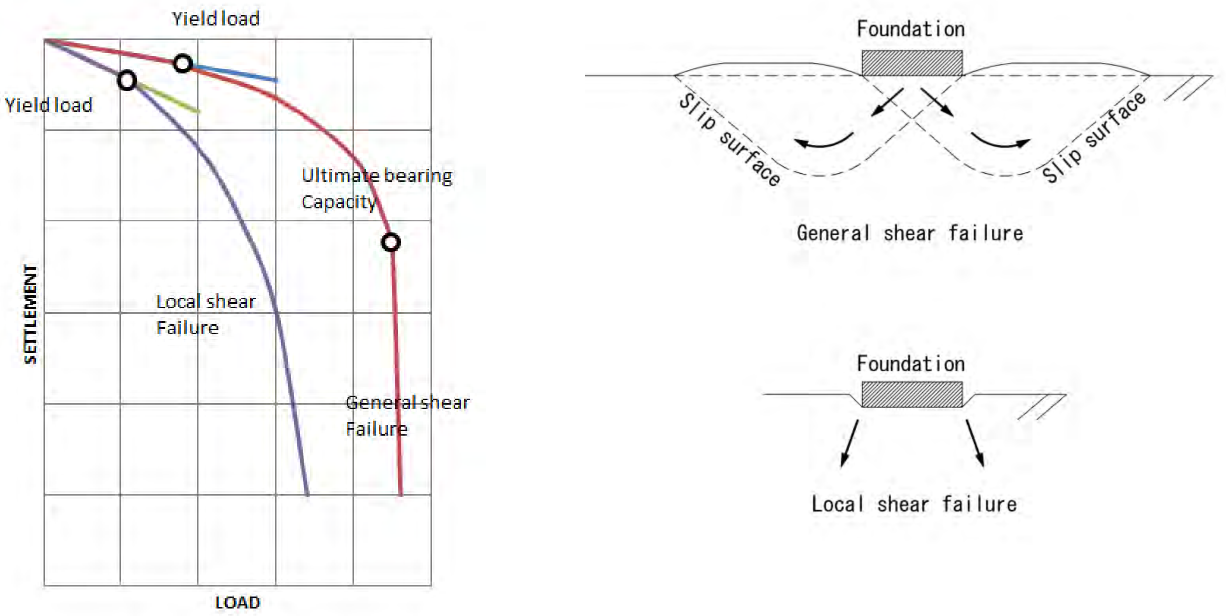


Figure 7.1 Load-settlement relationship

Terzaghi who seems the father of soil mechanics made up an equation for ultimate baring capacity as below.

$$\frac{Q}{B} = cN_c + q_s N_q + \frac{1}{2}\gamma_t B N_\gamma$$

Q: Ultimate bearing capacity of the foundation ground
B: Width of Base
c: Cohesion of the foundation ground
qs: Uniform load on the foundation ground (Surcharge loads)
γt: Unit weight of the foundation ground
Nc, Nq, Nγ: Coefficient of bearing capacity

$$N_c = 2\left(K_p^{1.5} + K_p^{0.5}\right) \qquad N_q = K_p^2 \qquad N_\gamma = \frac{1}{2}\left(K_p^{2.5} - K_p^{0.5}\right)$$

$$K_p = tan^2\left(\frac{\pi}{4} + \frac{\varphi}{2}\right)$$

7.2 Influence of shear strength for ultimate bearing capacity

When we calculate ultimate bearing capacity by Tergaghi's equation we need to set unit weight, cohesion and internal friction angle of the ground. Here we try to know how these values influence the result on two example.

Example1; Type1, H=2m, ΣV=51.90kN, ΣH=16.20kN, e=-0.021m   Result Figure 7.2

Example2; Type1, H=3m, ΣV=94.54kN, ΣH=32.27kN, e=-0.011m   Result Figure 7.3

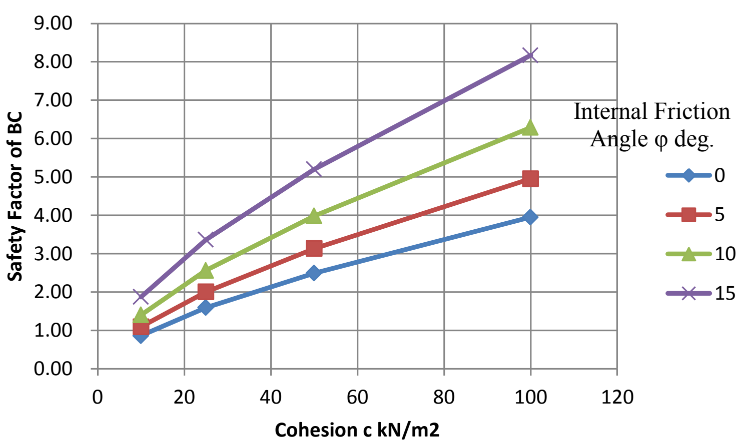
$$F_s = \frac{Q_u}{\Sigma V} \geq 3$$

Fs: Safety factor of bearing capacity

Qu: Ultimate bearing capacity

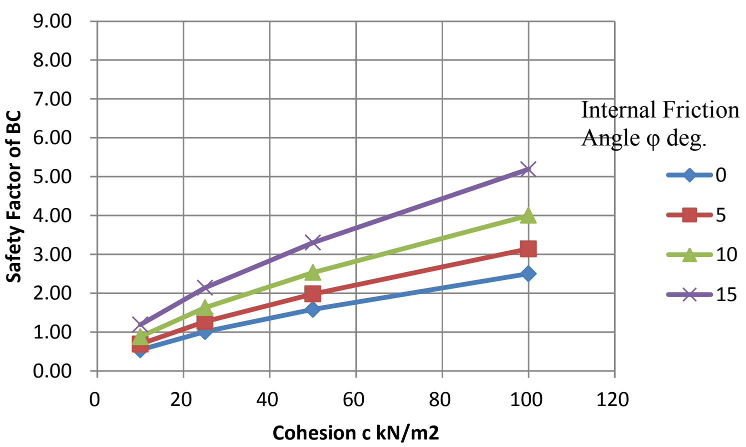
ΣV: Total vertical load

Influence of ground shear strength values is big. Therefore we should be careful for setting the values. If the ground allows Dokenbo shear strength test, we can get some hint from the test result.



Foundation Ground			Result	
Internal Friction Angle φ degree	Cohesion c kN/m2	Unit Weight γ kN/m3	Ultimate Bearing Capacity Qu kN	Safty Factor Fs -
0	10	18	445	0.86
	25		824	1.59
	50		1,292	2.49
	100		2,049	3.95
5	10		564	1.09
	25		1,037	2.00
	50		1,622	3.13
	100		2,568	4.95
10	10		728	1.40
	25		1,328	2.56
	50		2,068	3.98
	100		3,267	6.29
15	10		971	1.87
	25		1,743	3.36
	50		2,697	5.20
	100		4,241	8.17

Figure 7.2 Influence of c and ϕ for Qu Type1 H=2m



Foundation Ground			Result	
Internal Friction Angle φ degree	Cohesion c kN/m2	Unit Weight γ kN/m3	Ultimate Bearing Capacity Qu kN	Safty Factor Fs -
0	10	18	515	0.54
	25		952	1.01
	50		1,493	1.58
	100		2,368	2.50
5	10		651	0.69
	25		1,199	1.27
	50		1,876	1.98
	100		2,971	3.14
10	10		835	0.88
	25		1,539	1.63
	50		2,396	2.53
	100		3,784	4.00
15	10		1,127	1.19
	25		2,020	2.14
	50		3,124	3.30
	100		4,911	5.19

Figure 7.3 Influence of c and ϕ for Qu Type1 H=3m

7.3 Influence of front side slope for ultimate bearing capacity

In mountain area we often have no other choice but setting wall near slope. Here we try to know how front side slope influence the bearing capacity on two example.

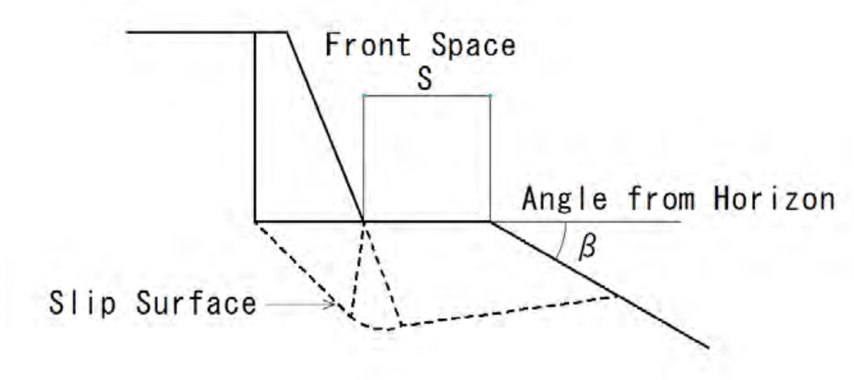


Figure 7.4 Front space and slope angle in case of wall stands near slope

[Calculation conditions]

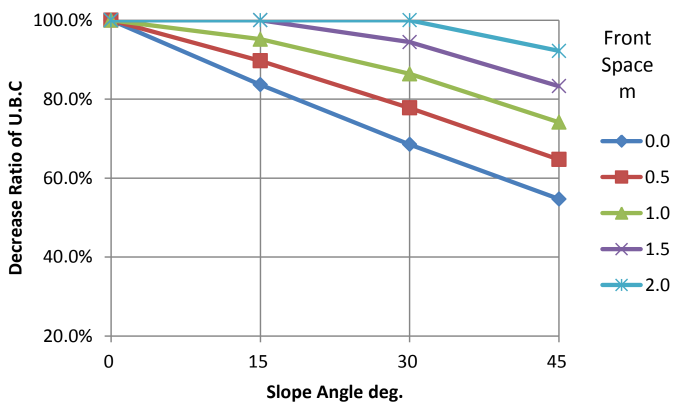
Resultant forces and eccentricity come from Type1 H=3m

Example1; Clayey foundation ground, φ=15deg, c=50kN/m^2, γ=18kN/m^3

Example2; Sandy foundation ground, φ=30deg, c=10kN/m^2, γ=19kN/m^3

(1) Case of clayey foundation ground

Under S=0m and β=45deg ultimate bearing capacity decreases 55% of horizontal ground in case of clayey ground. Under S=2m Qu stays over 90% therefore we can say 2m front space is effective against influence of front slope in case of clayey ground.

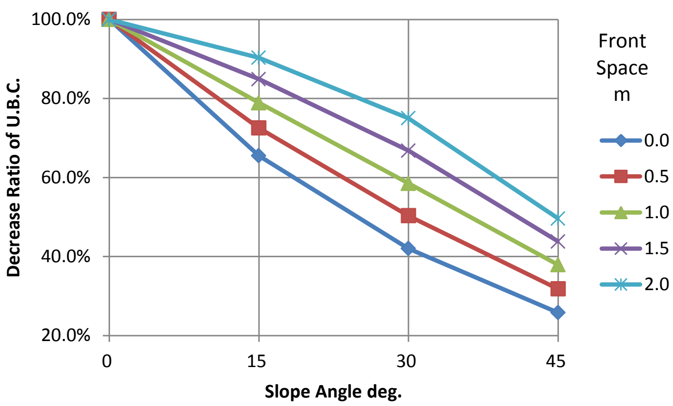


Slope Shape		Result		
Front Space S m	Angle from Horizon β degree	Ultimate Bearing Capacity Qu kN	Decrease Ratio of U.B.C %	Safty Factor Fs -
0.0	0	3,193.0	100.0	3.38
	15	2,670.8	83.6	2.83
	30	2,187.6	68.5	2.31
	45	1,746.2	54.7	1.85
0.5	0	3,193.0	100.0	3.38
	15	2,864.5	89.7	3.03
	30	2,483.9	77.8	2.63
	45	2,066.0	64.7	2.19
1.0	0	3,193.0	100.0	3.38
	15	3,038.9	95.2	3.21
	30	2,758.8	86.4	2.92
	45	2,367.8	74.2	2.50
1.5	0	3,193.0	100.0	3.38
	15	3,193.0	100.0	3.38
	30	3,016.0	94.5	3.19
	45	2,659.3	83.3	2.81
2.0	0	3,193.0	100.0	3.38
	15	3,193.0	100.0	3.38
	30	3,193.0	100.0	3.38
	45	2,943.9	92.2	3.11

Figure 7.5 Influence of front side slope on clayey foundation ground

(2) Case of sandy foundation ground

Under S=0m and β=45deg ultimate bearing capacity decreases 26% of horizontal ground in case of sandy ground. Under S=2m and β=45deg Qu still decreases 50%. Sandy ground is more sensitive to the influence of front side slope than clayey ground. Therefore we should pay more attention to this case.

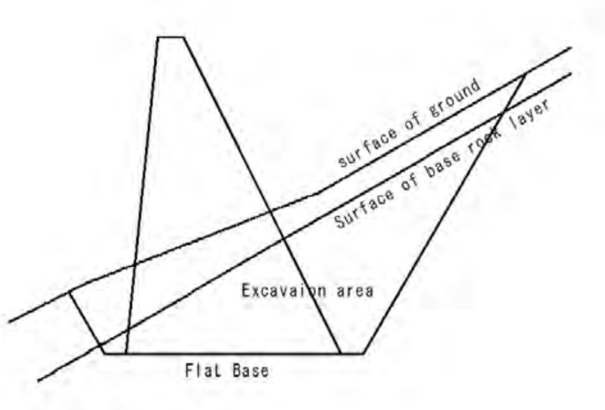


Slope Shape		Result		
Front Space S m	Angle from Horizon β degree	Ultimate Bearing Capacity Qu kN	Decrease Ratio of U.B.C %	Safty Factor Fs -
0.0	0	4,115.0	100.0	4.35
	15	2,696.1	65.5	2.85
	30	1,726.3	42.0	1.83
	45	1,060.5	25.8	1.12
0.5	0	4,115.0	100.0	4.35
	15	2,981.8	72.5	3.15
	30	2,068.4	50.3	2.19
	45	1,310.6	31.8	1.39
1.0	0	4,115.0	100.0	4.35
	15	3,247.6	78.9	3.44
	30	2,409.1	58.5	2.55
	45	1,559.0	37.9	1.65
1.5	0	4,115.0	100.0	4.35
	15	3,492.5	84.9	3.69
	30	2,748.4	66.8	2.91
	45	1,803.6	43.8	1.91
2.0	0	4,115.0	100.0	4.35
	15	3,714.2	90.3	3.93
	30	3,085.2	75.0	3.26
	45	2,039.3	49.6	2.16

Figure 7.6 Influence of front side slope on sandy foundation ground

7.4 Step Cut Foundation

As described in section 6.5 High wall H>5m in mountain area should stand on base rock layer because of bearing capacity. In such case flat foundation requires huge excavation as show right.



Step cut foundation can solve this problem. Examples are shown in figure 7.7.

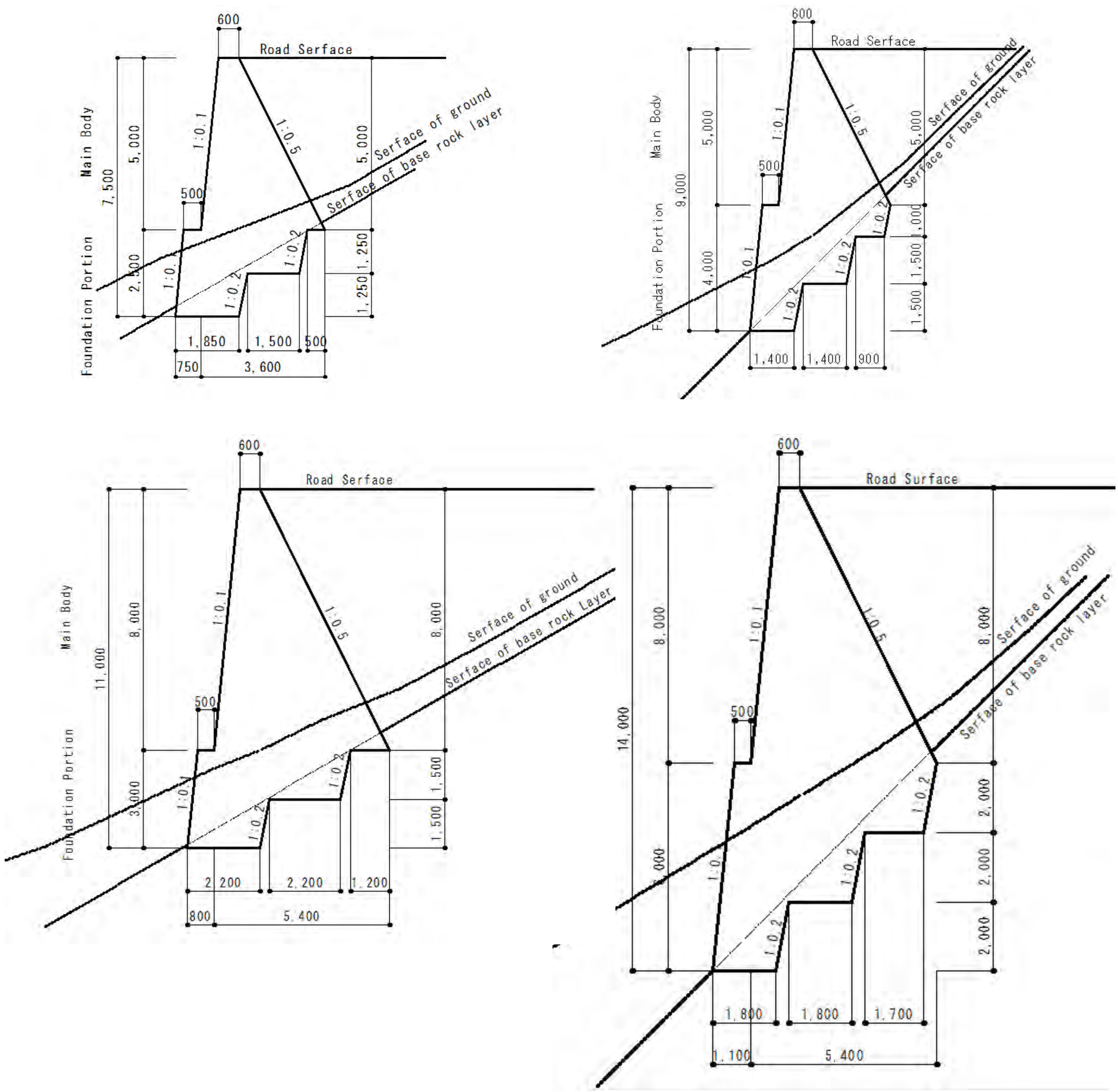


Figure 7.7 Examples of step cut foundation

8 Slope

8.1 Classification of Slope

What is a slope? Slope is not flat but inclined plane. Land in mountain area consists of a lot of slopes. In contrast water surface is not inclined but flat plane. What is the difference between land and water? Water has no shear strength. Land, it means soil and rock mass, can keep its sloped shape against gravity tangential force by its own shear strength. In other word, land bears gravity at all times.

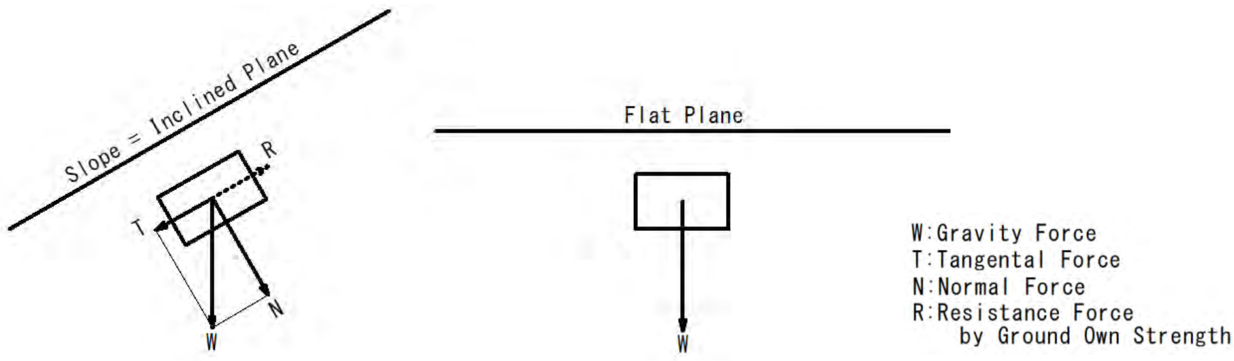


Figure 8.1 Difference between slope and flat plane

Slope primarily can be classified natural slope and embankment slope. Natural slope can be divided original, collapsed and cut slopes. The table shows characteristics of slopes. Only embankment slope consists of banking material therefore we can control its strength in construction.

Table 8.1 Slope classification and characteristics

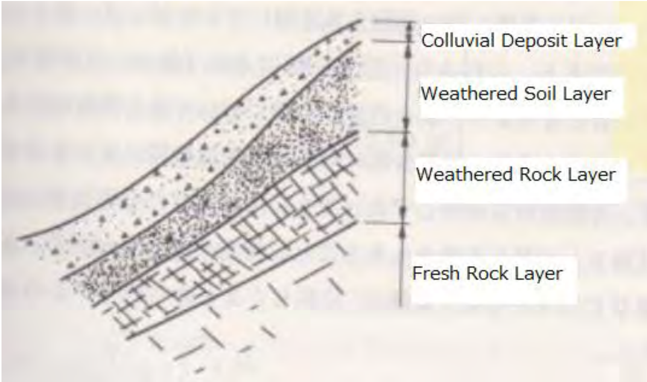
Classification	Shape	Geology	
Natural Slope	Natural Terrain	Natural Ground	Complexity Inhomogeneous
Collapsed Slope	Collapsed Gradient		
Cut Slope	Cut Gradient		
Embankment Slope	Embankment Gradient	Banking Material	Random –Selected material Homogeneous

8.2 Natural Slope

Mountain is ordinary made of rock mass except thin soil surface layers. In contrast alluvial plane has thick soil layers. Typical natural slope surface composition is shown in Figure 8.2. Colluvial deposit and weathered soil are surface soil layers. Colluvial deposit has moved by collapse in the past however weathered soil stays on the original position. Collapse often occurs within soil layers because of its weakness.

When collapse occurs in rock layer rock mass almost always brakes along cracks. Strength along the cracks dominate over rock layer collapse.

Ground water stays in void of soil layers and cracks of rock layers. Increase of ground water very often triggers collapse.



Adapted from bibl. [2]

Figure 8.2 Natural slope surface composition

8.3 Cut Slope

Cut slope is weaker than original slope because of below reasons. Frist, cutting makes ground stress condition change. Compression stress sometimes changes into tension stress. This phenomenon is called as stress-release. Another, cut gradient must be steeper than original natural slope.

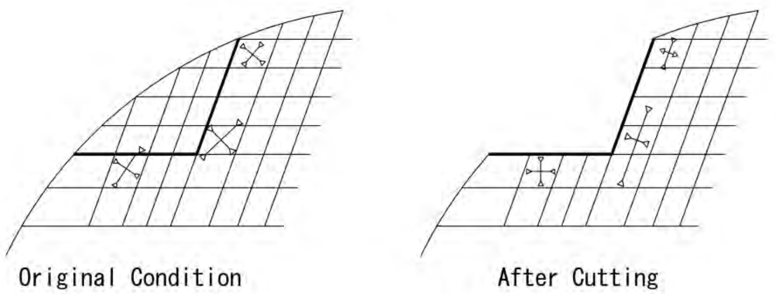


Figure 8.3 Stress release on the cut slope

Cut slope is exposed to the air as naked. Rain run off erodes and weathering goes on little by little. Slaking makes mudstone be broken into pieces. Drainage and slope protection are countermeasures against them.

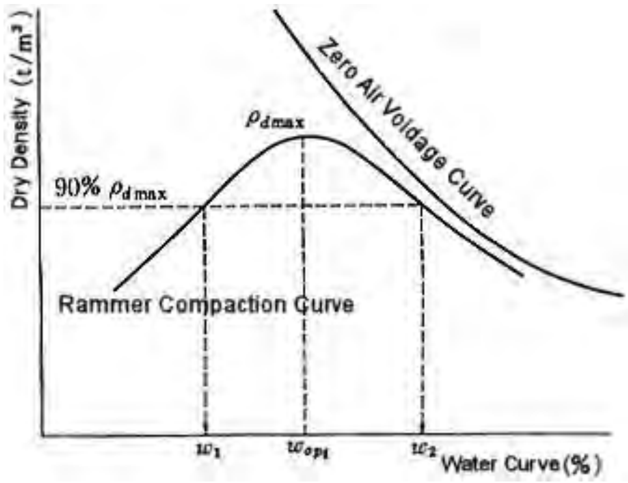
Erosion **Slaking**

Figure 8.4 Erosion and weathering on the cut slope

8.4 Embankment Slope

8.4.1 Embankment Body

We can select embankment material and compaction procedure. Necessary conditions for strong embankment are; material has good grain size distribution, water content is near the optimum water content and compaction energy is suitable. Then embankment can get high density near maximum dry density. It means the embankment has high shear strength near maximum strength.



Adapted from bibl. [5]

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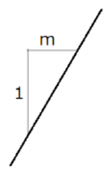
Figure 8.5 Curve of soil compaction

Adequate gradients for embankment are shown in table 8.2. Erosion and weathering occur on embankment slope as same as cut slope.

Table 8.2 Adequate gradients for embankment

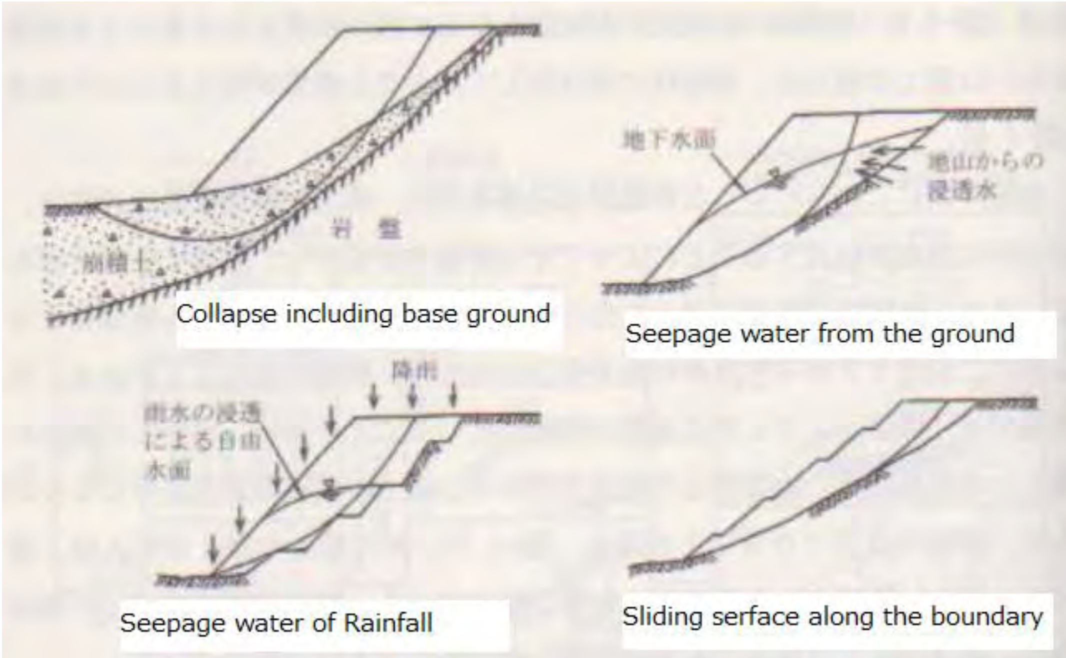
Banking materials	Height of embankment (m)	Standard gradient	Remarks
Well-graded Sand (S), gravel, and sand mixed with gravel (G)	Less than 5m	1:1.5 to 1: .8	To be applied to embankments with sufficient bearing capacity at foundation ground, which is not affected by inundation. Typical unified soil classification are shown in ( ) for reference. In case of exception of standard slope is needed the stability calculation.
	5m to 15m	1:1.8 to 1:2.0	
Poorly-graded Sand (SG)	Less than 10m	1:1.8 to 1:2.0	
Rock masses (including muck)	Less than 10m	1:1.5 to 1:1.8	
	10m to 20m	1:1.8 to 1:2.0	
Sandy soil (SF), hard clayey soils and hard clay (hard clayey soils and clay of alluvium, loam, etc.)	Less than 5m	1:1.5 to 1:1.8	
	5m to 10m	1:1.8 to 1:2.0	
Volcanic cohesive soils (V)	Less than 5m	1:1.8 to 1:2.0	



Adapted from bibl. [5]
Technical Memorandum of PWRI No.3924-2 (2004.1) (Public Works Research Institute)

8.4.2 Boundary between embankment and foundation ground

Cause for collapse on embankment slope very often come from boundary between embankment and foundation ground. Typical collapses on embankment are shown in figure 8.6. Key points against the collapses are bench cut (step cut), underground drainage and surface drainage.



Adapted from bibl. [2]

Figure 8.6 Typical collapse on the embankment slope

9 Slope Disaster

9.1 Classification of Slope Disaster

Figure 9.1shows one of classification on slope disaster. Classification gives you first step to understand what happing at the disaster site. Table 9.1 gives characteristics of each types. The main subject of these guidelines is T1 slope collapse.

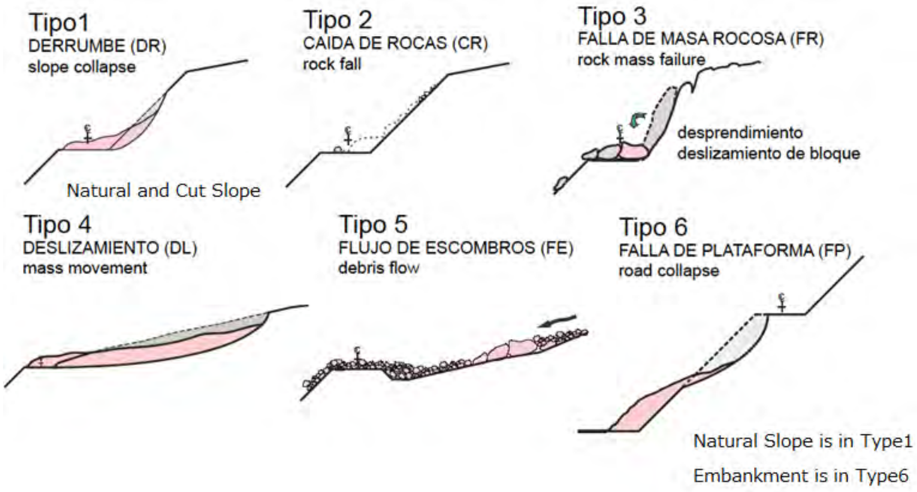


Figure 9.1 Classification on slope disaster

Table 9.1 Characteristics of each disaster

Disaster Type		Move -ment	Topography	Moving Material	Moisture	Scale	Speed
T 1	Slope collapse	Slide	Mild - Steep, Low - High slope	Weathered Rock, Soil	Moist	Small-Medium (<5,000m^3)	Rapid
T 2	Rock fall	Fall	Steep, High slope	Rock	Dry	Very Small (<5m^3)	Extremely rapid
T 3	Rock mass failure	Topple, Slide, Fall	Steep, Very high slope	Rock	Dry	Medium-Large (>100m^3)	Rapid
T 4	Mass movement	Slide	Gentle slope with characteristic landform	Soil, Debris, Rock	Moist	Large (>5,000m^3)	Slow
T 5	Debris flow	Flow	Stream Mountainside	Debris, Mud	Liquid form	Medium-Large (>1,000m^3)	Rapid
T 6	Road collapse	Slide	Embankment slope	Fill material	Moist-Wet	Small (<1,000m^3)	Rapid

T2 rock fall is common phenomena you have seen somewhere. T3 rock mass failure is special and large scale disaster not often occurs. T4 mass movement (land slide) is commonly the largest scale. Moving body keeps its shape but breaks into pieces and moving speed is very slow as millimetre per day. However it can be finally changed into collapse and run down.T5 debris flow consists of very thick mud water and debris. Large size debris concentrate to the top of flow and it shows high destructive capability. T6 road collapse is special because it occurs in artificial embankment.

T3 Rock mass failure **T5 Debris flow**

Figure 9.2 Example photograph of rare disasters

9.2 Principle of Slope Disaster Countermeasure

There are 4 principles against slope disaster as shown table 9.2. Control work and deterrence work try to make the slope be stable directly. Control work expects the slope to get stability by itself. Deterrence work gives structural force to get balance with moving force. Traffic protection work try to protect traffic and let the slope be. When you face huge size obstruction, there is a possibility that avoidance plan is the best answer.

Table 9.2 Principle of slope disaster countermeasure

Classification	Principle
Control work	Control work makes the ground itself be stable. This is basic means of countermeasure. Represented by adoption of adequate slope gradient, subsurface drainage and so on.
Deterrence work	Structure deters soil mass movement by proportioning force. This work is broadly classified two. One counteracts moving force by structure's own weight as retaining wall. Another counteracts by structure's tension or stiffness as anchor or pile.
Traffic Protection work	Instead of treating disaster phenomenon directly, protection work protects road / traffic solely. Represented by catch wall, rock fall protection fence, rock shed and so on.
Avoidance plan	When size of disaster phenomenon is too large to treat from technical point or cost, road avoids disaster point by route change, bridge, tunnel etc. Avoidance plan must be reasonable than countermeasure works.

9.3 Common Countermeasure

Representative countermeasure is shown in table 9.3. Each disaster type has a column and each principle has a row.

Table 9.3 Common Countermeasure

Classification	T1 Slope collapse	T2 Rock fall	T3 Rock mass failure	T4 Mass movement	T5 Debris flow	T6 Road collapse
Control work	Cutting with adequate slope gradient Subsurface drainage	Removing of source rock	Removing of source rock mass	Surface water drainage Shallow groundwater drainage Deep groundwater drainage Earth removal works Counter weight embankment works	Mountainside works Valley works	Embankment with adequate slope gradient Groundwater drainage
Deterrence work	Shotcrete frame Sewing bar works Anchor works	Mortar spraying Concrete pitching Cover type rock fall prevention net Shotcrete cirb Rock bolt works	Wire rope works Adhesive bonding works Rock bolt works	Pile works Anchor works	None	Retaining wall Reinforced soil retaining wall Anchor works
Protection work	Catch wall	Rock fall protection fence Pocket type rock fall protection net Rock shed	None	None	Keeping of enough flow section Debris flow shed Opened check dam	None

9.4 Countermeasure DRBFC shall introduce at the First

9.4.1 Target disaster type

Target disaster type at the first shall be T1 slope collapse because;

T1 slope collapse occurs frequently everywhere. Existing countermeasure recut has limitation and cannot reach definitive solution.

T2 rock fall can be solved by introduce metallic structures such as rock fall protection fence or rock fall prevention net. Rock fall phenomenon is simpler than slope collapse phenomenon therefore civil engineer can solve rock fall problem easier than slope collapse problem.

T3 rock mass failure, T4 mass movement and T5 debris flow occur at certain points not everywhere and not so frequent. Countermeasures against these types generally need high level technology and high cost. Introduction priority seems lower than T1 countermeasure.

T6 road collapse can be solved by construction methodology such as density control by suitable compaction, bench cut on the foundation ground and underground drainage.

9.4.2 Existing countermeasure against slope collapse

Domestic contractor has heavy earth work machines so earth work is the existing methods in Timor-Leste. Countermeasure by earth work against slope collapse is recut. Re-cutting with adequate slope gradient is representative way of control works. There are two ways for recut; recut with gentler gradient and recut on the deeper line. When the road stands near the ridge line these methods can adopt. However the road locates on mountainside then this method application becomes impossible because recut line cannot touch the ground surface line till top of the slope.

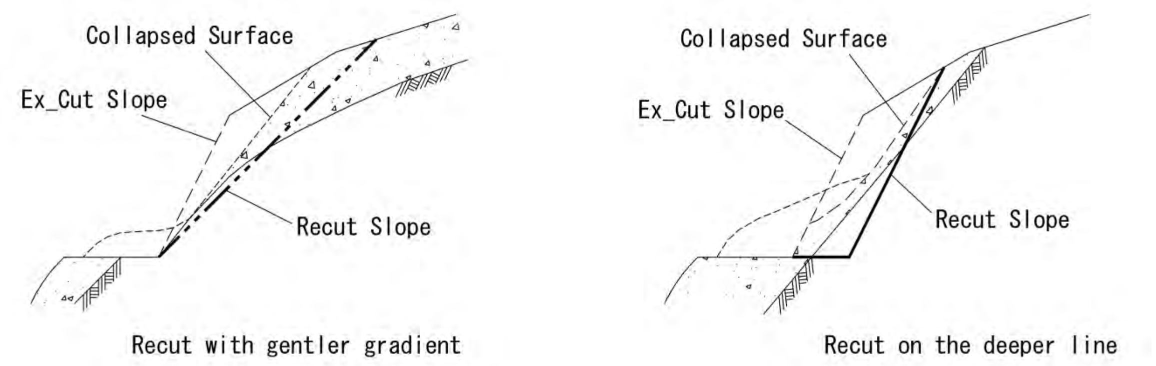
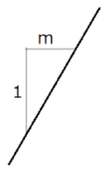


Figure 9.3 Two ways for recut

Table 9.4 Adequate gradient for cut slope

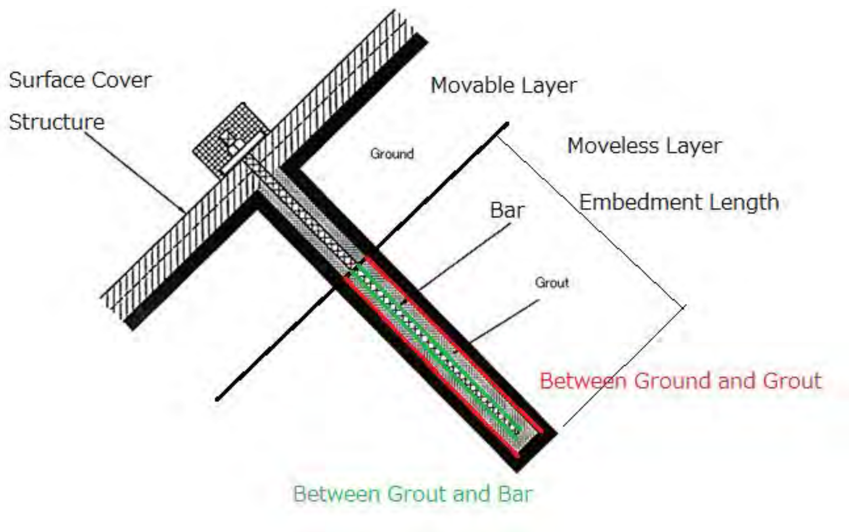
Soil classification		Cut Slope Height	Gradient
Hard rock			1:0.3 to 1:0.8
Soft rock			1:0.5 to 1:1.2
Sand	Not dense, and poorly graded		1:1.5 to
Sandy soil	Dense	Less than 5m	1:0.8 to 1:1.0
		5 to 10m	1:1.0 to 1:1.2
	Not dense	Less than 5m	1:1.0 to 1:1.2
		5 to 10m	1:1.2 to 1:1.5
Sandy soil mixed with gravel or rock masses	Dense, or well graded	Less than 10m	1:0.8 to 1:1.0
		10 to 15m	1:1.0 to 1:1.2
	Not dense, or poorly grade	Less than 10m	1:1.0 to 1:1.2
		10 to 15m	1:1.2 to 1:1.5
Clayey soil		0 to 15m	1:0.8 to 1:1.2
Clayey soil mixed with rock masses or cobble-stone		Less than 5m	1:1.0 to 1:1.2
		5 to 10m	1:1.2 to 1:1.5



Adapted from bibl. [5]
Technical Memorandum of PWRI No.3924-2 (2004.1) (Public Works Research Institute)

9.4.3 Prospective countermeasure against slope collapse

Combination of sewing bar and surface cover structure is representative countermeasure of deterrence works. The bars sew unstable soil to stable one and the cover structure distributes sewing effect all around. This method can adopt where recut cannot adopt. This method has wide coverage and so many actual achievement in Japan. Most popular casting is deform reinforcing bar for sewing bar and shotcrete frame for surface cover structure.



Adapted from bibl. [5]
Technical Memorandum of PWRI No.3924-2 (2004.1) (Public Works Research Institute)

Figure 9.4 Basis of sewing bar and surface cover structure

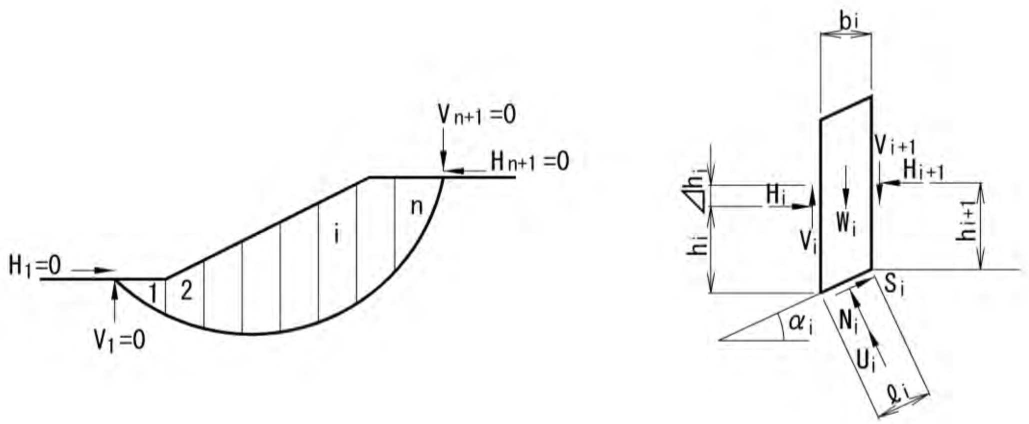
Figure 9.5 Example of most popular casting

10 Slope Stability Calculation

10.1 Calculating Formula

Calculating formula of slope stability is necessary in order to treat the problem in a quantitative way. We use the simplest one named "Simplified formula" as shown below.

$$F_S = \frac{\sum[c_i l_i + (W_i - u_i b_i) cos\alpha_i tan\varphi_i]}{\sum W_i sin\alpha_i}$$



Adapted from bibl. [2]

Figure 10.1 Explanation of simplified formula

Sliding surface is supposed as circular arc. Sliding body is divided into n slices by vertical slice lines and slices are treated as rigid bodies. Assumed condition "Acting forces on both side of the slices are even" changes the problem into statically determinate one. That is why named simplified.

10.2 Calculating Conditions

10.2.1 Shape Information

When we execute the slope stability calculation we need to set up shape information; ground surface line, groundwater surface line, soil layer boundary line and sliding surface line. Cross section survey gives ground surface line. Geological investigation such as outcrop observation and drilling gives hint for groundwater surface line and soil layer boundary line. Groundwater surface line is supposed higher position than usual when collapse occurs. Sliding surface is estimated from shape of actual collapse.

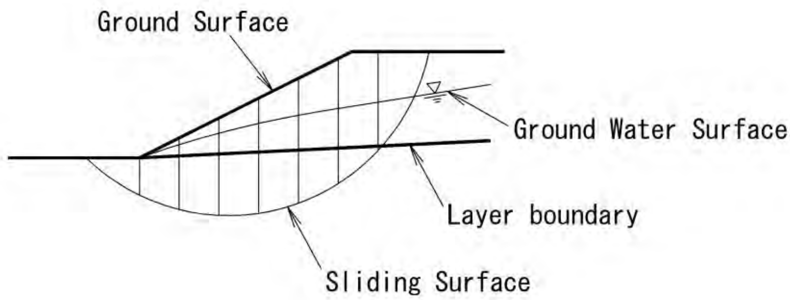


Figure 10.2 Shape Information

10.2.2 Soil Characteristics

Soil characteristics are also necessary for the calculation. They are unit weight of sliding body and shear strength of sliding surface.

You can set up unit weight easily because the value stands narrow range. Wet unit weight γ_t takes 17 to 19 kN/m^3 and saturated unit weight γ_{sat} takes 18 to 20 kN/m^3.

In contrast setting up shear strength is very difficult problem. There are tests to get shear strength such as Dokenbo vane cone test on site and tri-axial compressive strength test in laboratory. However value by test distributes wide range and compatibility between test-value and stability calculation is not so good. Therefore in practical problem reverse calculation method is applied to set shear strength very often.

When collapse occurs the safety factor is estimated as 1.0. It means that the collapse is just on balance so sliding force equals to resistance force. Before reverse calculation one of shear strength factor c (cohesion) or ϕ (internal friction angle) should be set on some reason. Then another strength factor ϕ or c can be get by calculation because there is only one unknown in the formula.

10.3 Excel worksheets for slope stability calculation

In the project excel worksheets for slope stability calculation are prepared for training and practical works.

You input slope gradient and collapse size (height and vertical depth), the worksheet calculates sliding circle (radius and theta). After that other worksheet divides sliding body into 6 slices and calculates values in the slope stability calculation formula with summary table. You can get not only safety factor but also cohesion c or inner friction angle φ in reverse calculation.

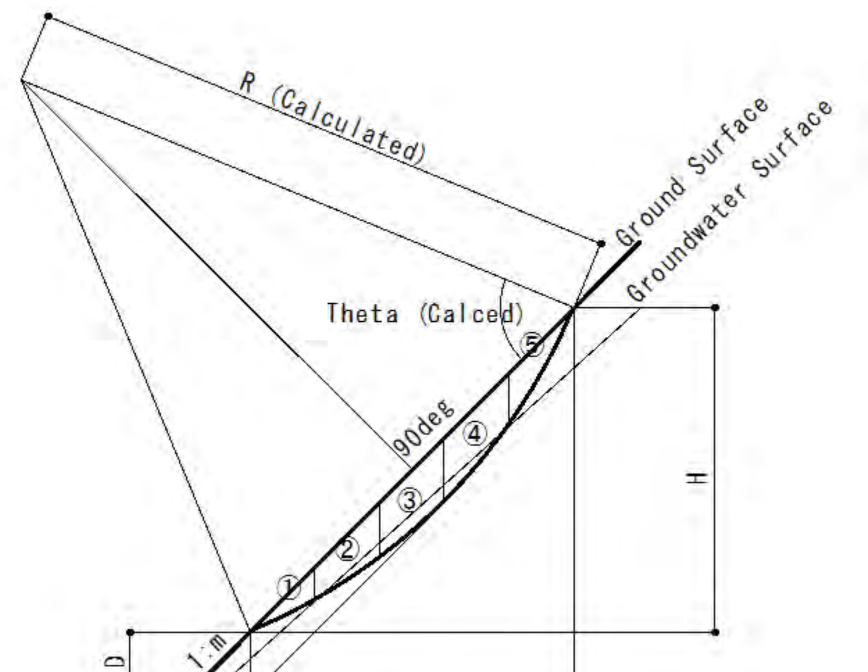


Figure 10.3 Sliding circle arc in the excel sheet

11 Influence of factors in slope stability calculation formula

Before you face actual problem you should know how each factor in the formula influences on safety factor.

11.1 Slope Gradient

When collapse occurs on some cut slope, re-cutting with milder gradient comes into countermeasure candidate at first. Figure 11.1 shows how slope gradient influences safety factor. When slope gradient is 1:1.2 safety factor becomes 1.05. When 1:1.5 safety factor becomes 1.15. Milder slope gradient unexpectedly gets small increase on safety factor.

Collapse conditions; slope gradient 1:1.0, all saturated (ground water surface equals ground surface), φ=30deg, c=7.23kN/m² (reverse calc.), γ_{sat}=20kN/m³, size (height=5m, vertical depth=2.07m)

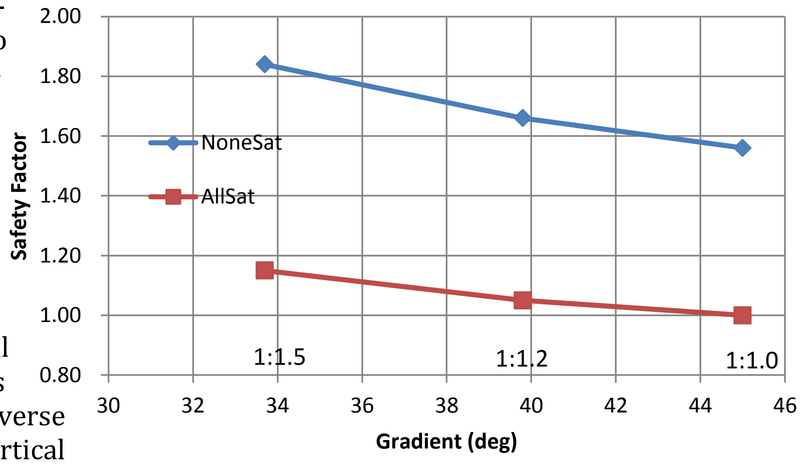


Figure 11.1 Influence of slope gradient

11.2 Shear Strength

Shear strength of sliding surface consists of cohesion c and inner friction angle φ. Both of them has direct influence to safety factor. C has stronger influence than φ. This fact indicates when you execute reverse calculation φ should be set and c should be calculated.

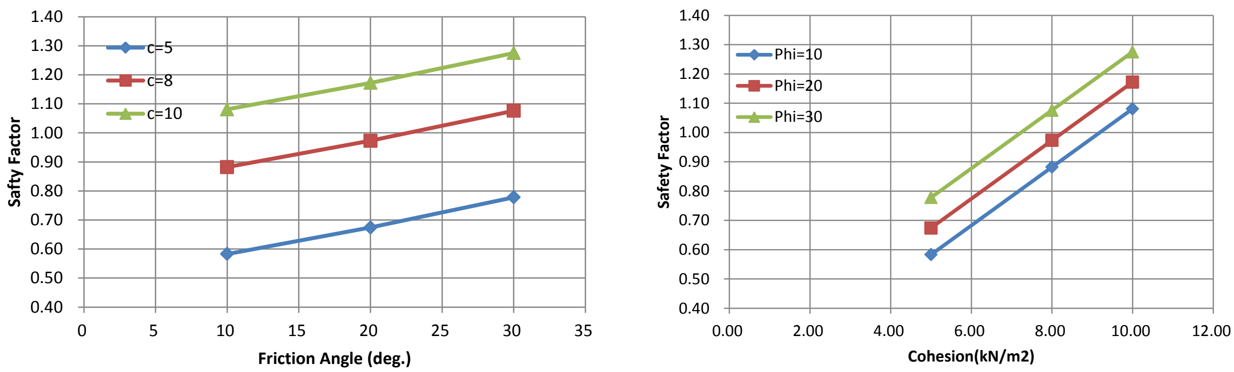
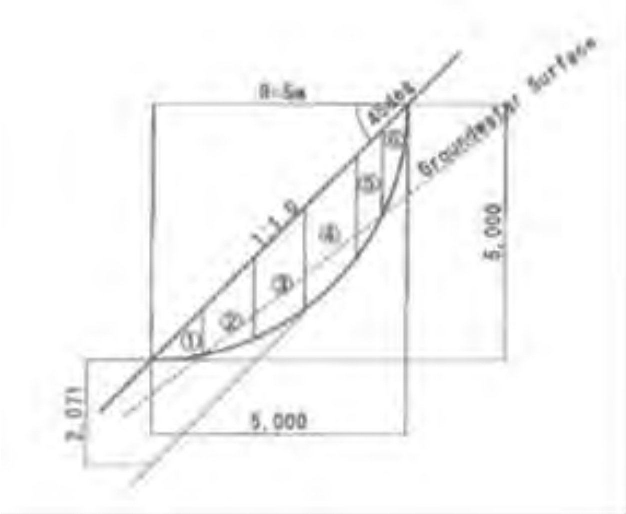


Figure 11.2 Influence of shear strength

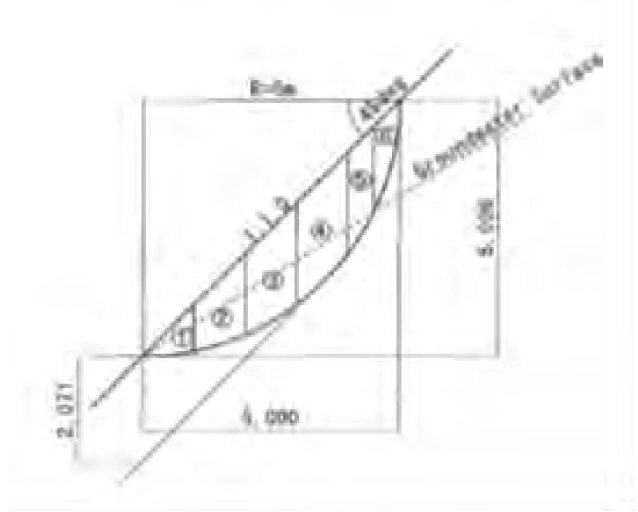
Conditions; slope gradient 1:1.0, all saturated (ground water surface equals ground surface), γ_{sat}=20kN/m³, size (height=5m, vertical depth=2.07m)

11.3 Ground Water

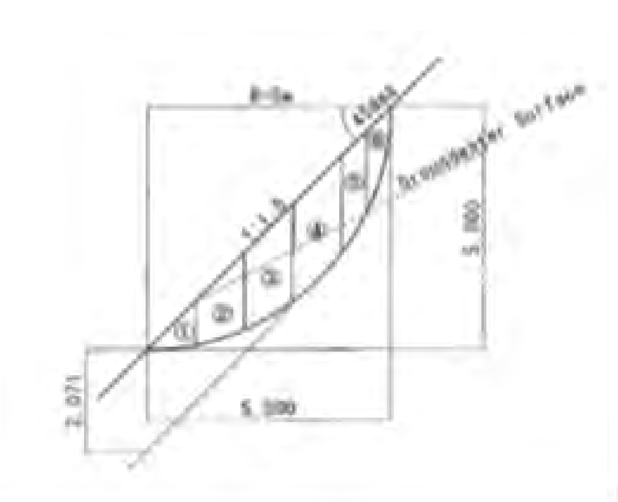
Shape of groundwater surface also has influence to safety factor. Here 6 variations of water shape are calculated. None of slices is under groundwater, all of slices are under groundwater and medium portion as shown in figure 11.3.



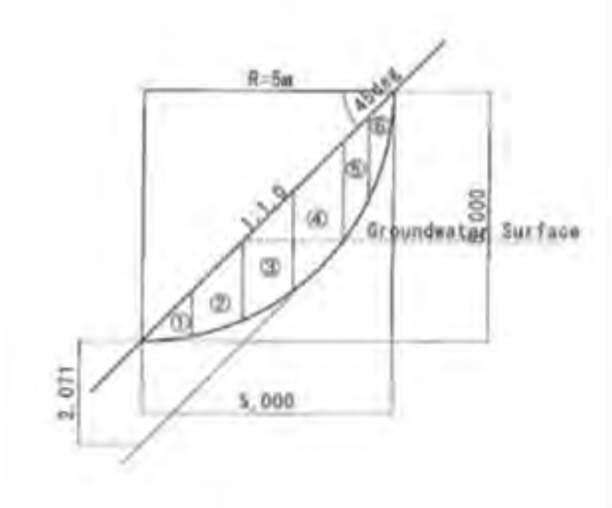
Groundwater S1 to S5



Ground water G0 to S5



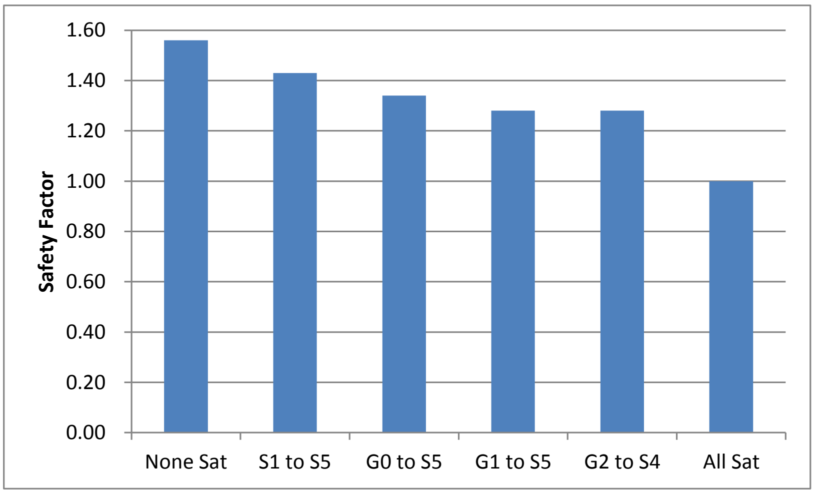
Groundwater G1 to S5



Groundwater G2 to S4

Figure 11.3 Variation of groundwater shape

Result is shown in figure 11.4. Safety factor goes down along groundwater rising. Lower portion of sliding body works for resistance. When buoyancy by groundwater acts these portion resistance force by friction decreases then safety factor gets down. Lateral borehole drainage can be effective countermeasure when they are set at adequate position.



Groundwater	Safety Factor
None Sat	1.56
S1 to S5	1.43
G0 to S5	1.34
G1 to S5	1.28
G2 to S4	1.28
All Sat	1.00

Figure 11.4 Influence of groundwater

12 Design Example of Countermeasure against Shallow Slope Collapse

12.1 Design Procedure

Figure 12.1 presents design procedure of sewing bar and surface cover structure.

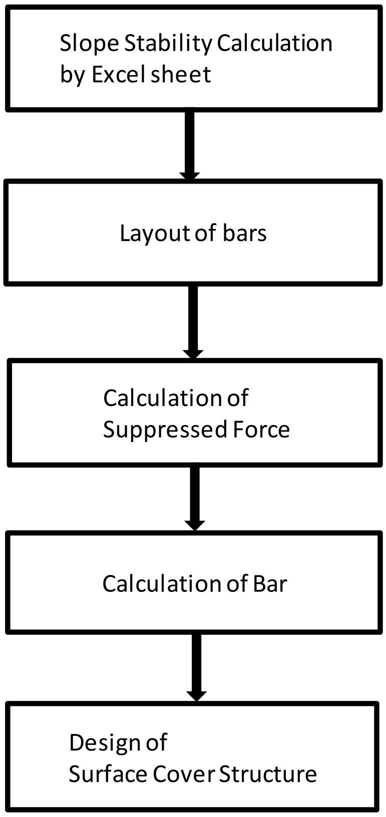


Figure 12.1 Design procedure of sewing bar and surface cover structure

12.2 Slope Stability Calculation

In the example slope stability calculation is executes as below.

Input data of Slope Stabilty Calculation

Shape of ground surface	Height Gradient ratio	m	10.00 1.20
Movable layer depth	ML depth	m	2.603
Groundwater depth	Grandwater level is as same as ground surface.		
Unit weight	Wet UW Saturated UW	kN/m3 kN/m3	18.0 20.0
	Water UW	kN/m3	9.8
Calculation Type	Calc Type		B
Input slip surface strenth	IP cohesion IP IF angle	kN/m2 deg	 30.0
Exsiting safety factor	ES Fs		1.00

Summary Table

Element	Angle Alpha	Length l	Area	Weight W	WcosAlph -ul	WsinAlph
#	deg	m	m2	kN	kN	kN
1	15.5	2.490	1.603	32.06	15.19	8.55
2	24.5	2.638	4.291	85.82	36.02	35.65
3	34.3	2.905	5.812	116.23	39.07	65.50
4	45.5	3.423	5.718	114.36	24.14	81.55
5	55.2	2.105	2.157	43.14	0.00	35.44
6	63.7	2.712	0.860	17.21	0.00	15.43
Total		16.273			114.42	242.12

A. Given c and Phi, Target is Fs

IP cohesion	kN/m2	0
IP IF angle	deg	30
Fs		-

B. Given Phi and Fs, Target is c

IP IF angle	deg	30
ES Fs		1
c	kN/m2	**10.82**

C. Given c and Fs, Target is Phi

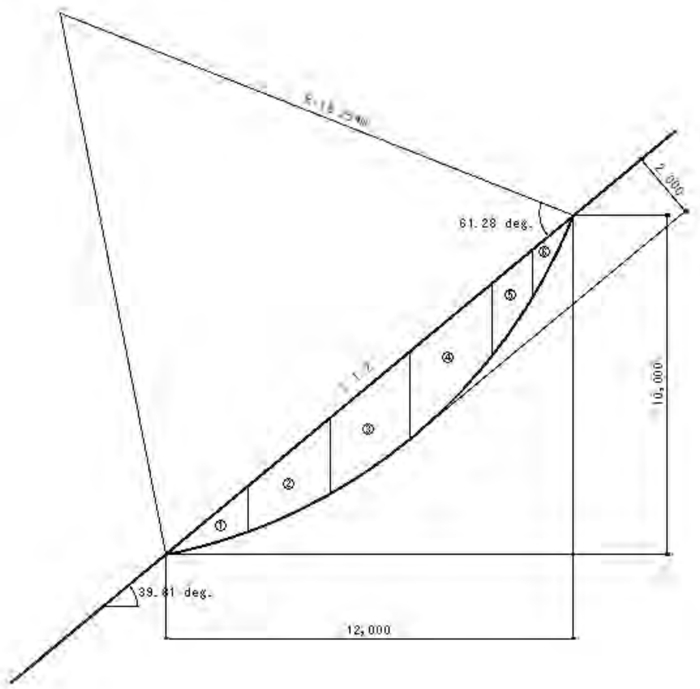


Figure 12.2 Cross section of Slope stability calculation

12.3 Layout of bars

Interval of bars are trade-off relationship between bar diameter and number of bars. Long interval of bars leads larger diameter and smaller number of bars. Short interval leads opposite result. Interval of bars generally distributes 1.5m to 3m. 2m can be applied for broad cases.

In the example horizontal interval "m" is 2 meters and number of sewing bars on the collapse "n" equals 7.

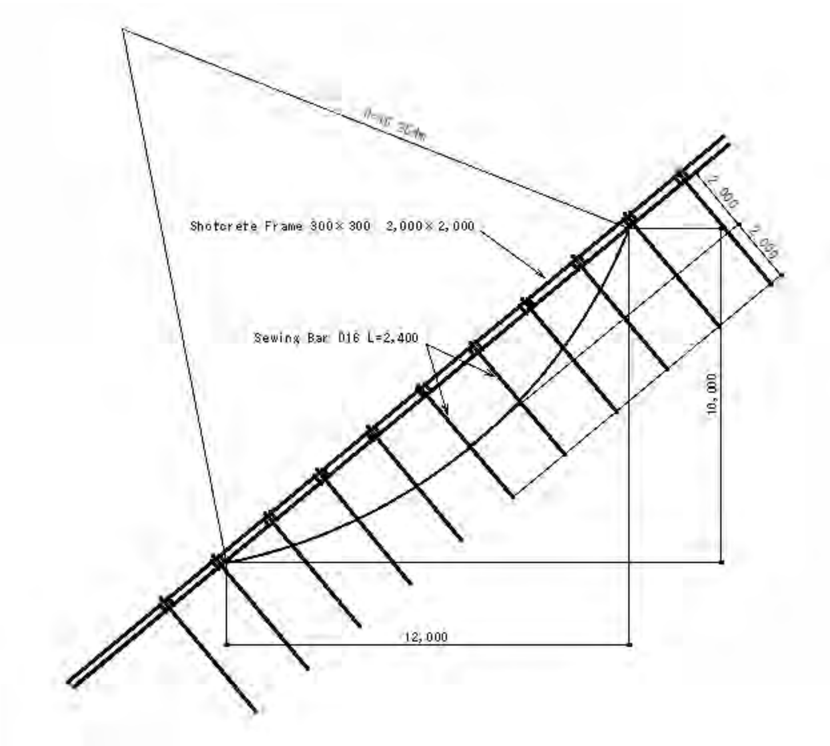


Figure 12.2 Layout of bars

12.4 Calculation of Suppressed Force

Suppressed force is calculated on below formula.

$$F_{SA} = \frac{\sum (c_i l_i + (W_i - u_i b_i)\cos\alpha_i \tan\varphi_i)}{\sum W_i \sin\alpha_i} = 1.00$$

$$F_{SP} = \frac{\sum (c_i l_i + (W_i - u_i b_i)\cos\alpha_i \tan\varphi_i) + P_T \tan\varphi_i}{\sum W_i \sin\alpha_i} = 1.20$$

$$F_{SP} - F_{SA} = \frac{P_T \tan\varphi_i}{\sum W_i \sin\alpha_i} = \Delta F_S = 0.20$$

$$P_T = \frac{\Delta F_S \sum W_i \sin\alpha_i}{\tan\varphi_i}$$

$$P_{eB} = \frac{m}{n} P_T$$

F_{SA}: Actual Safety Factor

F_{SP}: Planed Safety Factor

ΔF_S: Additional Safety Factor 0.2 commonly

P_T: Total Suppressed Force

m: Horizontal Interval of Sewing Bars

n: Number of Sewing Bars on the Collapse

P_{eB}: Suppressed Force of each Sewing Bar

We suppose collapse occurs on F_{SA}=1.00.

It means limit of the balance between resistance and sliding forces.

In the example calculation executes as below. We get ΣWsinα=242.12kN from the summary table of the excel worksheet.

$$P_T = \frac{\Delta F_S \sum W \sin\alpha}{\tan\varphi} = \frac{0.2 \times 242.12}{\tan 30} = 83.87kN$$

$$P_{eB} = \frac{m}{n} P_T = \frac{2}{7} \times 83.87 = 23.96kN$$

12.5 Calculation of Bar

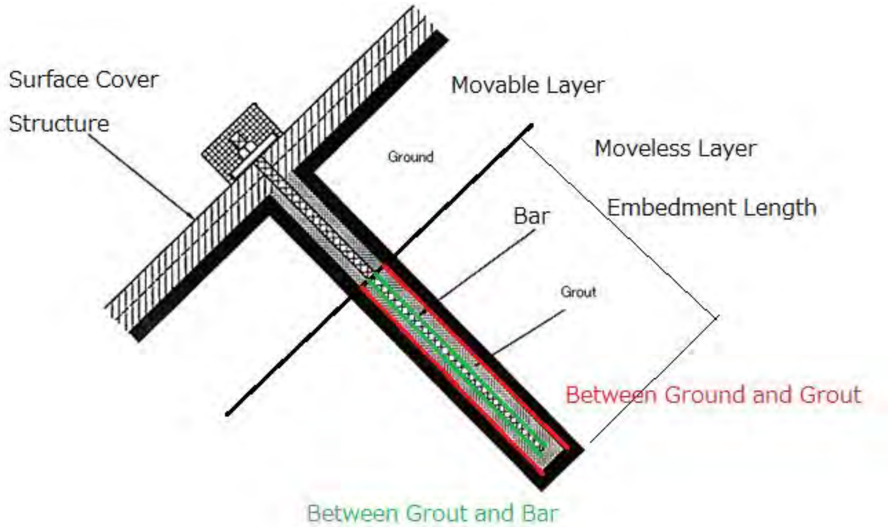
12.5.1 Selection of sewing bar

Reinforcing bar D16 is selected as sewing bar. There is possibility that bar will corrode and lose its cross section in the future. Diameter 1mm is margin for corrosion then cross section is A=176mm². Tension stress is calculated as below. The value is smaller than allowable value.

$$\sigma = \frac{P_{eB}}{A} = \frac{23.96\times10^3}{176} = 136 < 200N/mm^2$$

12.5.2 Embedment length

The bar is fixed in a layer that does not move. It is called embedment. If embedment length of the bar passes two check points then the bar can bear against drawing out. They are friction between ground and grout and friction between grout and bar.



Adapted from bibl. [5]

Figure 12.3 Check points of embankment length

12.5.2.1 Calculation of embedment length between ground and grout

Necessary embedment length between ground and grout is calculated on below formula.

$$l_b = \frac{P_{eB}F_{sb}}{\pi\cdot d\cdot \tau} = \frac{23.96\times10^3\times2.0}{\pi\times65\times0.14} = 1676mm \rightarrow 2.0m$$

l_b: Necessary embedment length between ground and grout to not draw out

Fsb: Safety factor for draw out; Standard value 2.0

d: Drilling diameter; 65mm is popular diameter

τ: Ultimate skin friction resistance;

Assumption condition: Gravel layer N-value=20

Then τ= 0.14 N/mm^2

Standard value of ultimate skin friction resistance is shown in table 12.1.

Table 12.1 Estimated ultimate skin friction

Ground type			USFR N/mm²
Base rock	Hard rock		1.2
	Soft rock		0.8
	Weathered rock		0.5
	Hard pan		0.5
Gravel Layer	N-value	10	0.08
		20	0.14
		30	0.20
		40	0.28
		50	0.36
Sandy soil	N-value	10	0.08
		20	0.14
		30	0.18
		40	0.23
		50	0.24
Clayey soil			0.8×C

Adapted from bibl. [1]

12.5.2.2 Calculation of embedment length between grout and bar

Necessary embedment length between grout and bar is calculated on below formula.

$$l'_b = \frac{P_{eB}}{\pi \cdot D \cdot \tau_{0a}} = \frac{23.96 \times 10^3}{\pi \times 15.9 \times 1.4} = 343mm < 1676mm$$

l'_b: Necessary embedment length between grout and bar to not draw out

D: Diameter of bar D16 → D=15.9mm

τ_{0a}: Ultimate skin friction resistance τ_{0a}=1.4N/mm²

Standard value of allowable adhesion stress between grout and deformed bar is shown in table 12.1.

Table 12.2 Allowable adhesion stress between grout and bar

DRSG σ_{ck}(N/mm²)	18	24	30	Over 40
AAS τ_{0a}(N/mm²)	1.4	1.6	1.8	2.0

DRSG: Design reference strength of grout

AAS: Allowable adhesion stress

Adapted from bibl. [1]

12.6 Design of surface cover structure

In the example shotcrete frame applies as surface cover structure. Figure 12.4 shows design procedure.

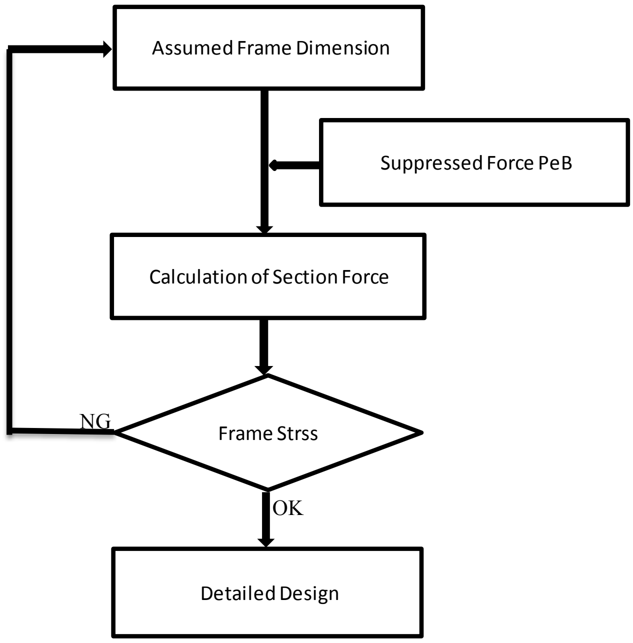


Figure 12.4 Design procedure of shotcrete frame

In the example assumed frame dimension is ;

frame interval 2.0 × 2.0m and frame cross section 300 × 300mm.

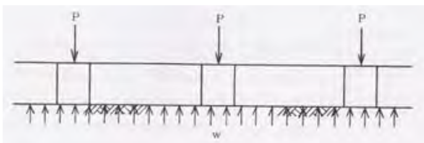
12.6.1 Calculation of section force

Section forces of the frame are calculated on below formulas.

$$w_x = w_y = \frac{P}{l_x + l_y - b} = \frac{23.96}{2.0+2.0-0.3} = 6.48\,kN/m$$

$$M_{max} = \frac{1}{10}wl^2 = \frac{1}{10} \times 6.48 \times 2.0^2 = 2.59kNm$$

$$S_{max} = \frac{3}{5}wl = \frac{3}{5} \times 6.48 \times 2.0 = 7.78kN$$



P: Tension of sewing bar

w: Uniformly-distributed subgrade reaction

l: Interval of frame

b: Width of frame

M_{max}: Maximum bending moment

S_{max}: Maximum shearing force

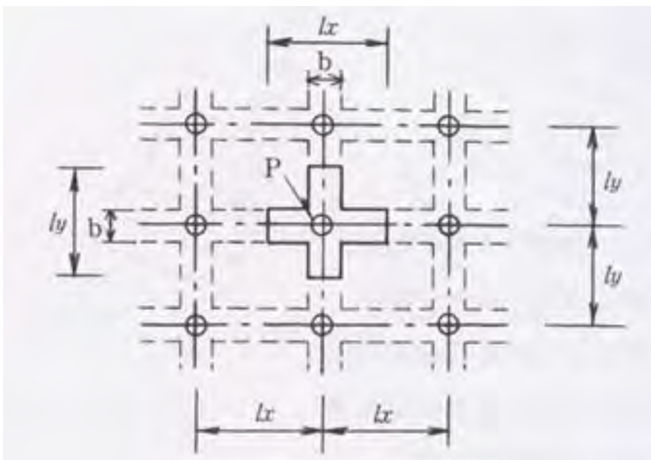


Figure 12.5 Calculation model of frame

12.6.2 Check for frame stress

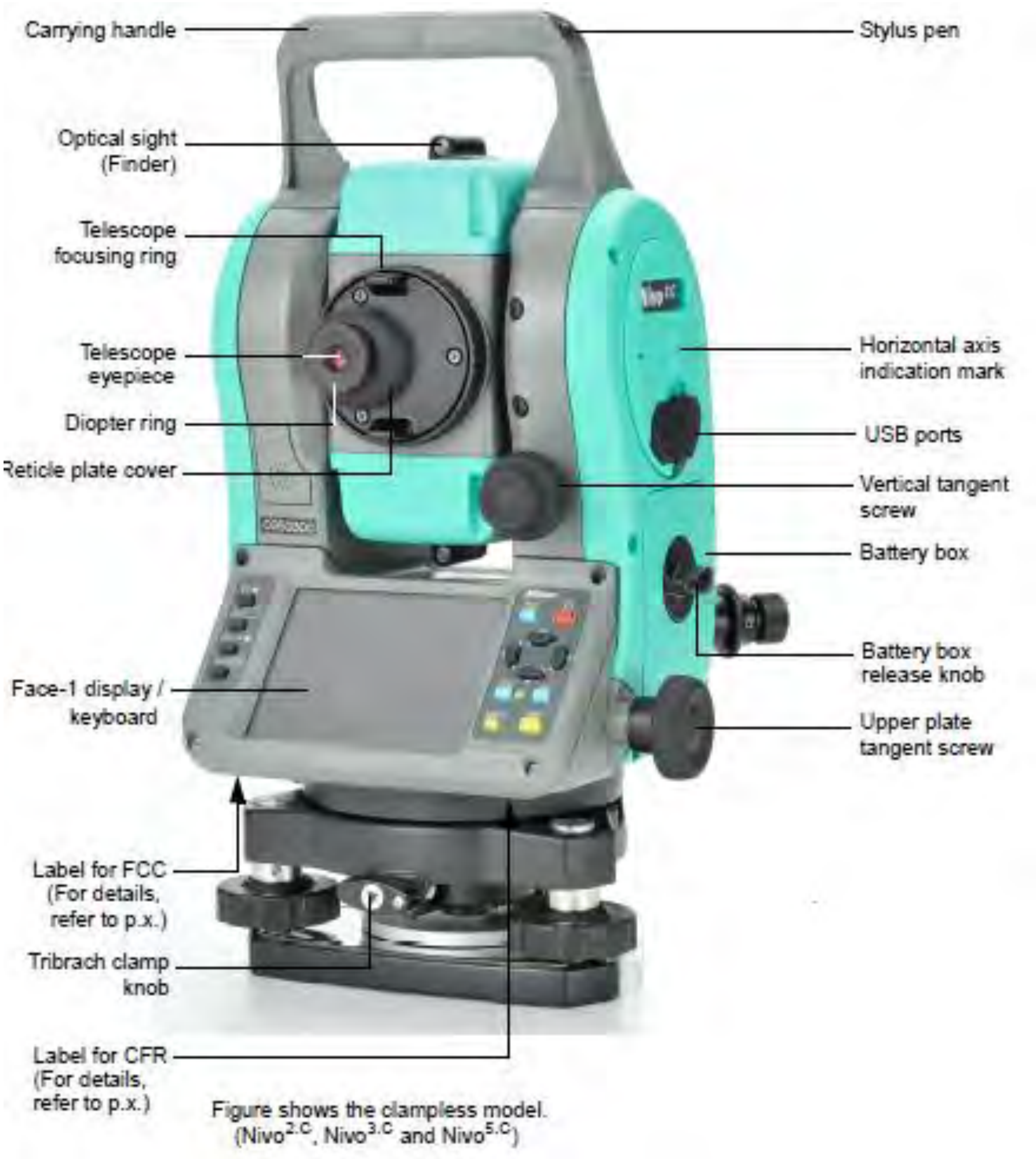
Check for frame stress is implemented in conditions as rectangular cross section, single reinforcement concrete and allowable stress design method. All of three stresses pass the check as below.

Frame cross section					
Item		Unit	Value	Memo	
Member width		cm	30.0		
Member height		cm	30.0		
effective height		cm	23.5		
Cross-section area of reinforcing bar		mm2	253.4	D13 * 2 Standard Layout	
Result of calculation					
Item		Unit	Calculated	Allowed	Judgement
Stress	Compression of concrete	N/mm2	1.24	6.00	OK
	Tension of R.F. bar	N/mm2	47.95	180.00	OK
	Avelage shear	N/mm2	0.110	0.400	OK

Annex A
(informative)

How to use the Total Station

A.1 Part names



Adapted from bibl. [3]

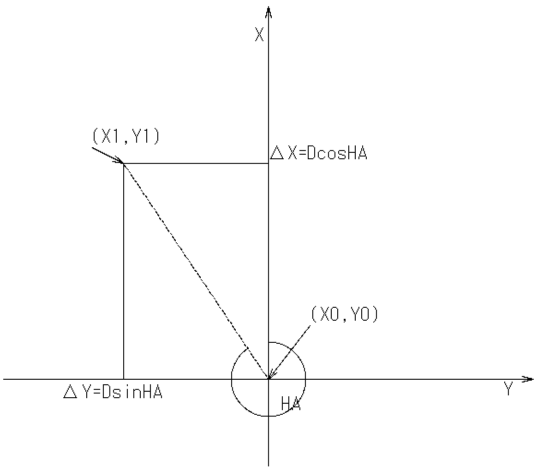
Adapted from bibl. [3]

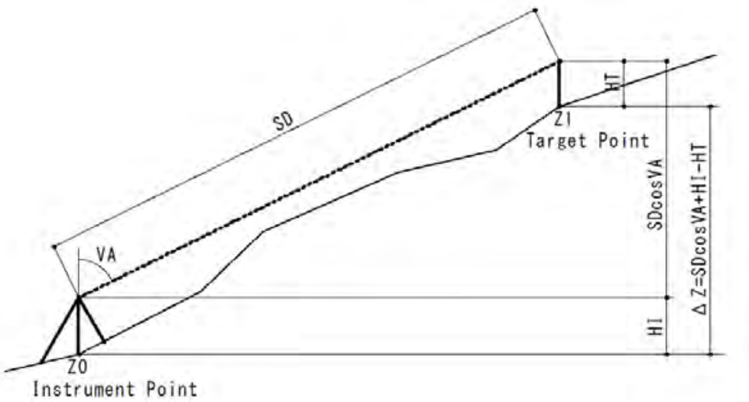
A.2 What values are measured by the total station

The total station measures horizontal angle, vertical angle and slope distance. In another words, all in one instrument to get a target coordination at once.

- HA: Horizontal Angle
- VA: Vertical Angle
- SDx: Slope Distance

Coordination of the target can be calculated from HA, VA and SDx as below figures.





A.3 Setting up the instrument

Setting up the instrument means centering and leveling.

- Centering: The TS must be set just on the station point mark.
- Leveling: Upper plate (tribranch) must be set as level.

[Procedure]

① The surveyor sets the tripod head as level as and as central as possible.

② He places the instrument on the tripod head.

③ He inserts the tripod mounting screw into the instrument.

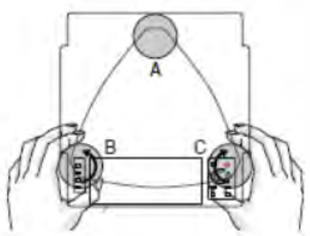
④ He levels the instrument adjusting tripod leg length after that using leveling screw.

⑤ He slides instrument on the tripod head by loosening mounting screw to centering with checking by optical plummet.

⑥ He repeats leveling and centering till both conditions are within allowable circles.

⑦ If there is only one station point in simple survey such as one cross section, then centering can be skipped.

[How to use the leveling screws]



- Two leveling screws are turned at one time by both thumbs and first fingers to different direction. It means both thumbs go inside or go outside. Slow and Gentle.
- Left thumb reads level bobble.

A.4 General procedure of simple survey

① The surveyor establishes two station points one for instrument another for back sight.

② He sets the instrument on the station point, measures instrument height.

③ He focuses on the back sight station point, and sets HA=0. Then X axis is set from the station point to the back sight point.

④ He orders the pole-man to put the pole on first target point.

⑤ He focuses on the reflector or the target and pushes the button to measure the slope distance.

⑥ He pushes the button to record and write down target name, target height and the values HA, VA, SD on the field note.

⑦ He returns the procedure ④ to ⑥ for all other target points.

⑧ If there is only one station point in simple survey such as one cross section only, then the procedure ① to ③ can be skipped.

A.5 Calculation of coordination from field Note

The project provides an excel worksheet for calculation of coordination from field note.

[Input table]

Station Name	Instrument Height	Target			Horizontal Angle			Vertical Angle			Slope Distance
		Name	Number	Height							
—	m	—	—	m	deg	minute	second	deg	minute	second	m
Room1	1.21	Coener A	1	0.95	35	32	3	91	58	24	8.273
	1.21	Coener B	2	1.07	318	44	48	93	23	23	2.451
	1.21	Clock	3	2.49	27	35	8	70	10	41	3.768
	1.21	Corner C	4	3.23	50	7	2	74	33	18	7.598
	1.21	Corner D	5	3.23	95	35	41	75	21	31	7.991

[Output table]

12.6.2.1

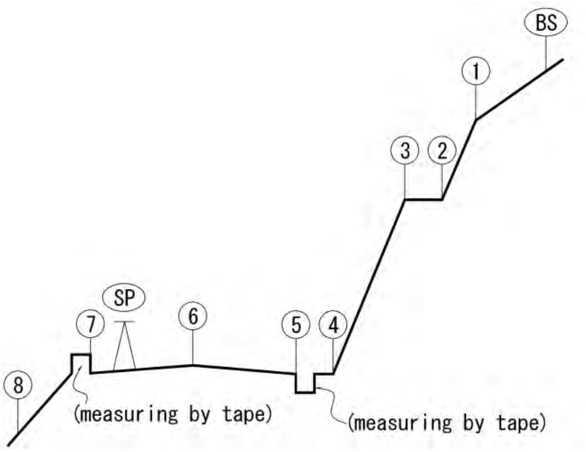
Target Number	X	Y	Z
	m	m	m
1	6.728	4.805	-0.025
2	1.840	-1.614	-0.005
3	3.142	1.642	-0.002
4	4.696	5.620	0.003
5	-0.754	7.695	0.000

A.6 Target points of cross section survey

What kind of points do you need when you draw a cross section? The answer is points where the gradient of ground surface is changing.

Boundary of materials is also needed, asphalt, concrete, soil and so on.

Small structure such as drainage, guard wall and so on can be measured by tape except one point of it instead of survey all.



A.7 Station point

Role of station point is to connect site and drawings. Surveyor makes survey products. Design engineer makes design drawing on the survey products. Contractor constructs along the design drawings. If there is no station point at the site the contractor cannot decide position of works.

There are two types of station point, one is temporary and another is permanent station. Temporary station is made with such as wood peg and pins for striking into pavement. In contrast permanent station is made with durable concrete peg or block to keep the position. Permanent station is often point of reference.

Annex B
(informative)

How to use the Dokenbo

B.1 General Information of Dokenbo

- What is Dokenbo?

Equipment for Soil layer prospection consists of

1)Cone 2)Rod 450mm 3)Rod 500mm ×9
4)Handle 5)Vane cone 6)Load meter
7)Dial torque wrench 8)Open-end wrench ×2
9)Connection sleeve 10)Carry bag

Kanji Letters	Pronunciation	Meaning	Abbreviation
土層	doso	Soil Layer	Do
強度	kyoudo	Strength	
検査	kensa	Prospection	Ken
棒	bou	Rod	Bo

[Developer and patent]

Public Works Research Institute PWRI in Japan developed Dokenbo and got patent in Japan. Anyone can use Dokenbo but only permitted one can make Dokenbo

B.2 Usage of Dokenbo

① Soil layer depth prospection
② Penetration test by spring load meter
③ Shear strength test by dial torque wrench with vane cone

B.3 Important caution

Dokenbo has two strict prohibitions;

The rods connects each other by right-screw.

Therefore,

Never turn anticlockwise

when the Dokenbo is in the soil layer.

If you do connection screw is released and apical end is lost in the soil layer.

Dokenbo is designed for static use.

Therefore,

Never hit top by hammer

to penetration.

If you do Dokenbo would buckle up or get broken.

B.4 Soil layer depth prospection

B.4.1 Procedure

- Apical end is the cone, top end is the handle.
- Set Dokenbo on prospect point, push the handle statically and slowly by investigator's own power.
- Dokenbo penetrates no more, then rod length from the surface is depth of soil layer. Investigator can read using 10cm scale mark on the rod.

B.4.2 Distribution of prospect points

- Random way; Investigator choices prospect points where soil layer seems deep. Maximum depth represents soil layer depth of the target slope.
- Regular way; Prospect points are distributed along preset line such as cross section line, contour line or fall line. All prospect points must have position information such as coordinate values.

B.5 Penetration test

B.5.1 Procedure

① Investigator penetrates Dokenbo till measurement depth.

② Investigator push Dokenbo through load meter slowly, when Dokenbo goes into action then investigator reads load meter.

③ Investigator fills data on 'Data Sheet for Dokenbo Penetration Test'.

B.5.2 Data sheet

- There are two ways of DPT. One is Normal Test.
- Weight of Rods is counted in calculation of penetration strength qdk.

Data Sheet for Dokenbo Penetration Test

Subject:	Date:	Weather:	
Survey Point:	Investigator:		
Ground Condition: Water Content:			
Normal Test	Area of Cone (m2): 1.76E-04	Mass of Cone and Apex Rod (kg):	0.310
Final Penetration Depth (m):		Mass of Ragular Rod (kg):	0.308

Depth D m	Load Mater Value W N	Load Mater Value W kN	Number of Rod n	Penetration Strength qdk kN/m2	Remark	Depth m	Penetration Strength (kN/m2) 400 800 1200 1600 2000
1.00	100	0.100	1	603			
1.00	300	0.300	1	1,739			
4.50	300	0.300	9	1,876			

$$q_{dk}=\frac{W+(m_0+n\cdot m)\cdot g}{A}$$

- Another is simplified Test.
- Weight of rods is not counted in calculation of apparent penetration strength qdk'.

Data Sheet for Dokenbo Penetration Test

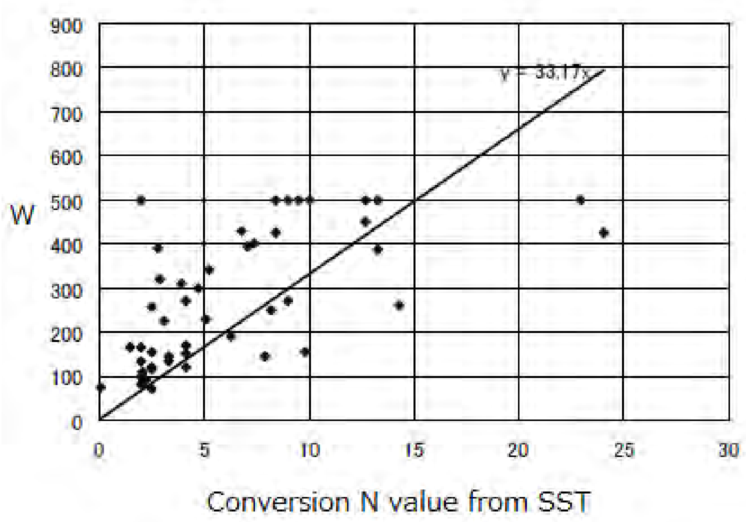
Subject:	Date:	Weather:	
Survey Point:	Investigator:		
Ground Condition: Water Content:			
Smplified Test	Area of Cone (m2): 1.76E-04	Mass of Cone and Apex Rod (kg):	
Final Penetration Depth (m):		Mass of Ragulaer Rod (kg):	

Depth D m	Load Mater Value W N	Load Mater Value W kN	Number of Rod n	Penetration Streneth qdk' kN/m2	Remark	Depth m	Penetration Strength (kN/m2) 400 800 1200 1600 2000
1.00	100	0.100	1	568			
1.00	300	0.300	1	1,706			
4.50	300	0.300	9	1,706			

$$q_{dk}'=\frac{W}{A}$$

B.5.3 Correlation of other tests' result

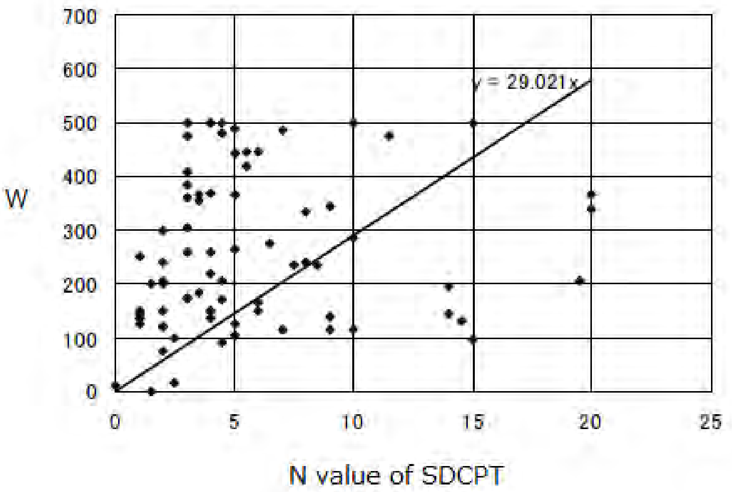
Next graph shows correlation of observed values between Dokenbo's W and conversion N value from Swedish Sounding Test. Dokenbo can roughly penetrate N≤10 ground under W≤300N.



Adapted from bibl. [4]

Technical Memorandum of PWRI No.4176 (2010.7) (Public Works Research Institute)

Next graph shows correlation of observed values between Dokenbo's W and N value from Simplified Dynamic Cone Penetration Test Dokenbo can roughly penetrate N≦10 ground under W≦300N



Adapted from bibl. [4]
Technical Memorandum of PWRI No.4176 (2010.7) (Public Works Research Institute)

B.6 Shear strength test

B.6.1 Member component

① Vane cone and Apex rod
② Rods
③ Dial torque wrench
④ Load meter and connection sleeve

① Load Meter
② Dial Torque Wrench
Maximum load of LM is 300N (30.5kgf)
Maximum torque of DTW Is 7Nm (0.71kgfm)

B.6.2 Procedure

This test needs two persons, operator is the leader of the test and turner is the assistant.

① The operator penetrates Dokenbo to target depth with vaneless normal cone.

② The turner turns Dokenbo slowly with dial torque wrench for clockwise under the load mater indicates 0. Maximum value shall be recorded as Torque by skin friction **T0**.

③ The operator replaces normal cone to vane cone.

④ The operator sets Dokenbo again at the same depth and adds some load to penetrate vane only into unbroken soil.

⑤ The operator loads vertical planned step load **Wi** through the load mater.

⑥ The turner turns Dokenbo slowly with the dial torque wrench for clockwise under the load mater indicates vertical load **Wi**. Maximum torque value is **Ti**.

⑦ The turner records test depth, **Wi** and **Ti** on the data sheet.

⑧ The operator pulls Dokenbo out and checks condition of vane cone.

⑨ The turner write remark about attached soil, influence of gravel, and so on.

⑩ This procedure is repeated till getting 5sets, at least 3 sets, of Wi and Ti. Each test must be executed at unbroken soil a little deeper portion of ex-step.

When the penetrated hole cannot stand alone then test procedure should change as below.

① The operator try to set vane cone similar depth at other new hole near the skin friction test hole.

② The operator <u>does not pull out Dokenbo each step</u> of the test in order to continue the test and to get 5 sets of **Wi** and **Ti**.

③ The operator sets the vane cone at 3 to 5cm deeper than ex step test to get unbroken soil.

B.6.3 Process to get shear strength

There are two ways to get shear strength from the test result. One is empiric formula way and another is correlation formula way. Correlation formula way needs 3 couples of triaxial compressive CU test and Dokenbo test at least. Therefore, these guidelines introduce empiric formula way only.

The empiric formula ties the test result to shear strength as below.

$$\sigma = 2.4\times10^{2}\cdot W_{VC}$$
$$\tau = 1.5\times10^{4}\cdot T_{VC}$$
$$W_{VC} = W + (m_0 + n\cdot m)\cdot g$$
$$T_{VC} = T - T_0$$

① Investigator makes chart of Sigma and Tau.

② He makes linear regression formula.

③ Y-intercept is **Cohesion**.

④ Gradient is tangent Phi.

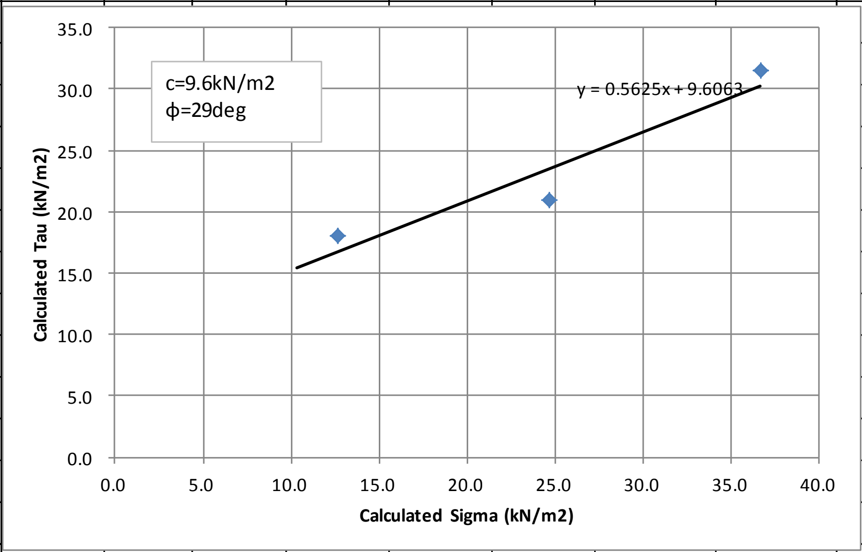
⑤ Phi is **Internal friction angle**.

B.6.4 Data sheet

The project provides data sheet for Dokenbo shear strength test. Example is shown as below with chart of σ and τ.

Data Sheet for Dokenbo Shear Strength Test					
Subject:	Aituto Landslide Monitoring OJT	Date:	1-Dec-17	Weather:	Fine
Survey Point:	Around No.3 BH	Investigator:	Minegishi and Trainee		
Ground Condition: Water Content:	Colluvium, clayey soil mixed with angulated gravel, gravel mean size is 10 to 30 cm.				
Empiric Formula	Height of Vane (m) 7.00E-03	Mass of Vane Cone and Apex Rod (kg):	0.310		
Final Test Depth (m):		Mass of Ragulaer Rod (kg):	0.308		

Depth D	Load Mater Value W	Number of Rod n	Vertical Load on Vane Wvc	Torque by Skin T0	Dial Torque Wrench T	Torque on Vane Tvc	Calculated Normal Stress Sigma	Calculated Shear Stress Tau	Remark
m	cN		kN	Nm	Nm	kNm	kN/m2	kN/m2	
0.30	5,000	0	0.053	0.0	1.2	0.0012	12.7	18.0	
0.35	10,000	0	0.103	0.0	1.4	0.0014	24.7	21.0	
0.40	15,000	0	0.153	0.0	2.1	0.0021	36.7	31.5	
0.45	20,000	0	0.203	0.0					Dokenbo go into motion by vertical load.



Remark:
Matrix is clayey soil.
However the result indicates sandy soil characteristics.
Without check of maximum vertical load, we failed the test when vertical load at 20,000cN.

Annex C
(informative)

Excel worksheets for Stability calculation of gravity retaining wall

C.1 Outline

The worksheets execute stability calculation of gravity retaining wall, consist of 4sheets, In_put, wall, earth pressure, and summary.

- Wall shape is trapezoid with 4 node points. Backfill is horizontal.
- Coordinate origin is heel of the wall, front side of the wall is plus direction of x axis and top side of the wall is plus direction of y axis.
- Earth pressure is calculated with Coulomb's formula.
- Earthquake is out of coverage.

C.2 Worksheets

[In_out]

Name of Conditions			Symbol	Nuit	Valu	
Wall	Shape	Node1	X, Y	m	0.000	0.000
		Node2	X, Y	m	1.800	0.000
		Node3	X, Y	m	0.600	3.000
		Node4	X, Y	m	0.000	3.000
	Unit weight		γc	kN/m3	23	
Backfill	Unit weight		γs	kN/m3	19	
	Internal friction angle		φ	deg.	30	
Foundation	Allowable bearing capacity		Qa	kN/m2	200	
	Friction coefficent walll and foundation		μ	ND	0.6	
Road	Surcharge on the Road		q	kN/m2	10	

[Wall]

Element	Area A (m2)	Weight V (kN)	Arm length x (m)	Moment M (kNm)
1	2.70	62.1	0.800	49.7
2	0.90	20.7	0.200	4.1
Total		82.8		53.8

[Earth pressure]

α degree	β degree	φ degree	δ degree	KA
0.0	0.0	30.0	20.000	0.297

Active Earth Pressure Coefficient	Backfill Unit Weight	Wall Height	Surcharge on the Road	Load Name	Load	Friction Angle of Wallback	Vertical Load	Arm Length	Moment	Horizontal Load	Arm Length	Moment
KA	γ kN/m3	h m	q kN/m2		PA kN	δ degree	V kN	x m	M kNm	H kN	y m	M kNm
0.297	19	3.000		Earth Pressure	25.4	20.000	8.7	0.000	0.0	23.9	1.000	23.9
0.297		3.000	10	EP by Surcharge	8.9	20.000	3.0	0.000	0.0	8.4	1.500	12.6
						Total	11.7		0.0	32.3		36.5
											ΣM=	36.5

[Summary]

Summary table for loads and Moments

Load Name	Vertical Load kN	Horizontal Load kN	Moment kNm
Wall Weight	82.8		53.8
Earth Pressure	11.7	32.3	36.5
Total	94.5	32.3	90.3

Three check points of stability index

1) Over-turnig

X-coordinate of resultant	X=	0.956	m
X-coordinate of bottom center	B/2=	0.900	m
Eccentricity of resultant	e=	0.056	m
Allowable eccentricity	B/6=	0.300	m
Judgment		**OK**	

2) Sliding

Total vertical load	ΣV=	94.5
Total hrizontal load	ΣH=	32.3
Friction coefficient	μ	0.6
Safety factor of sliding	Fs=	1.76
Judgment		**OK**

3) Bearing capacity

Reaction stress at wall's toe	qt=	62.3
Reaction stress at wall's heel	qh=	49.6
Allowable stress (Bearing capacity)	qa=	200.0
Judgment		**OK**

Annex D
(informative)

Excel worksheets for slope stability calculation

D.1 Outline

The worksheets execute slope stability calculation, consist of 3sheets, In_put, Cal_EUT and Calc

- Slope collapse is presumed as circular sliding.
- The slope is flat face with uniform gradient.
- Sliding size is given through height and depth of sliding.
- Sliding body is divided into 6 slices automatically.
- Ground water is flat face, it is handled as running through the node point.
- Simplified formula is applied for safety factor calculation.
- There are 3 types of calculation combination of given condition and target.

$$F_S = \frac{\sum\left(c_i l_i + (W_i - u_i b_i)\cos\alpha_i \tan\phi_i\right)}{\sum W_i \sin\alpha_i}$$

Calculation type	Given condition	Target
A	c, ϕ	Fs
B	ϕ , Fs	c
C	c, Fs	ϕ

D.2 Worksheets

[In_put]

Input data of Slope Stabilty Calculation

Shape of ground surface	Height	m	10.00
	Gradient ratio		1.20
Movable layer depth	ML depth	m	2.603
Groundwater depth	Grandwater level is as same as ground surface.		
Unit weight	Wet UW	kN/m3	18.0
	Saturated UW	kN/m3	20.0
	Water UW	kN/m3	9.8
Calculation Type	Calc Type		B
Input slip surface strength	IP cohesion	kN/m2	
	IP IF angle	deg	30.0
Exsiting safety factor	ES Fs		1.00

[Cal_EUT] Calculation of slip circular equation

Theta_d	Theta	Sine Theta	Cosine Thet	Left	Right	DFR
85	1.4835299	0.9961947	0.0871557	0.0436609	0.2560328	-0.212371844
45	0.7853982	0.7071068	0.7071068	0.4142136	0.2560328	0.158180775
70	1.2217305	0.9396926	0.3420201	0.176327	0.2560328	-0.079705806
60	1.0471976	0.8660254	0.5	0.2679492	0.2560328	0.011916406
65	1.134464	0.9063078	0.4226183	0.2216947	0.2560328	-0.034338124
62	1.0821041	0.8829476	0.4694716	0.249328	0.2560328	-0.006704784
61	1.0646508	0.8746197	0.4848096	0.2586176	0.2560328	0.002584797
61.3	1.0698868	0.8771462	0.4802235	0.2558264	0.2560328	-0.000206412
61.2	1.0681415	0.8763067	0.4817537	0.2567564	0.2560328	0.000723573
61.28	1.0695378	0.8769785	0.4805296	0.2560123	0.2560328	-2.04485E-05
61.27	1.0693632	0.8768946	0.4806827	0.2561053	0.2560328	7.25397E-05
61.28	1.0695378	0.8769785	0.4805296	0.2560123	0.2560328	-2.04485E-05

Slip circular			
	mH/2		6
	H/2		5
	R-t		14.2544
	xc		-3.1254
	yc		15.9505
	R		16.2541

[Calc]

Summary Table

Element	Angle	Length	Area	Weight	WcosAlph	WsinAlph
	Alpha	l		W	-ul	
#	deg	m	m2	kN	kN	kN
1	15.5	2.490	1.603	32.06	15.19	8.55
2	24.5	2.638	4.291	85.82	36.02	35.65
3	34.3	2.905	5.812	116.23	39.07	65.50
4	45.5	3.423	5.718	114.36	24.14	81.55
5	55.2	2.105	2.157	43.14	0.00	35.44
6	63.7	2.712	0.860	17.21	0.00	15.43
Total		16.273			114.42	242.12

A. Given c and Phi, Target is Fs

IP cohesion	kN/m2	0
IP IF angle	deg	30
Fs		-

B. Given Phi and Fs, Target is c

IP IF angle	deg	30
ES Fs		1
c	kN/m2	**10.82**

C. Given c and Fs, Target is Phi

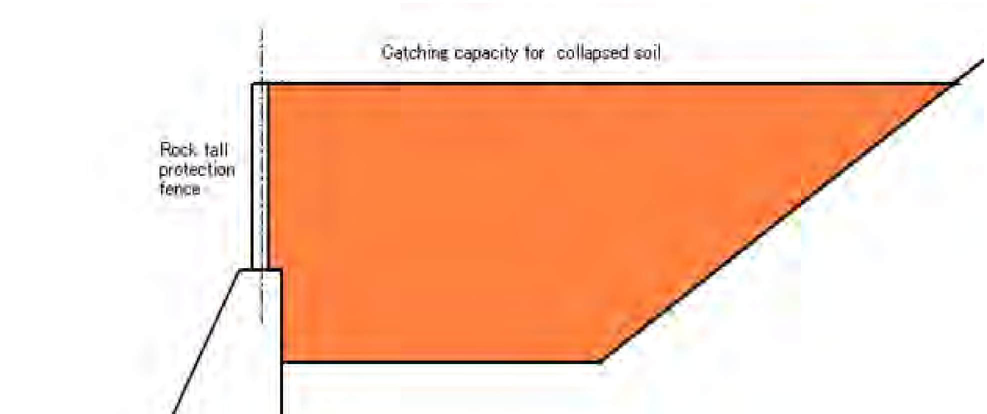
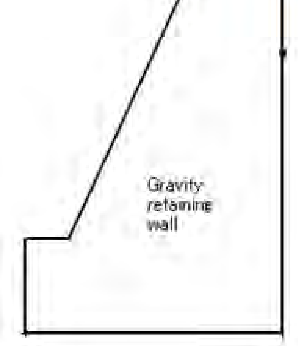
IP cohesion	kN/m2	0
ES Fs		1
Phi		-

Annex E
(informative)

Catch wall

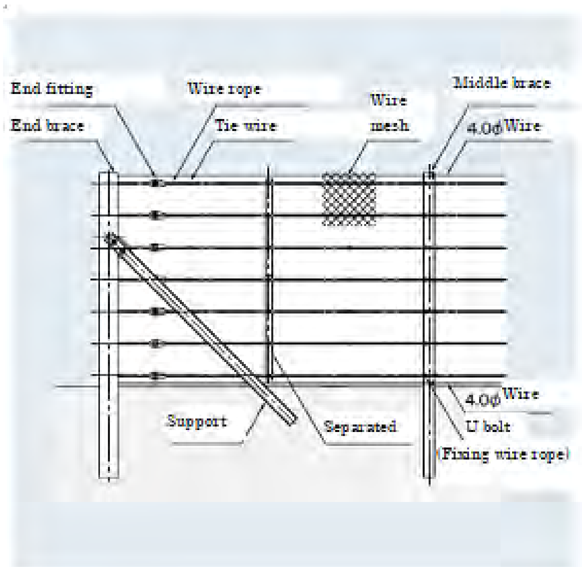
E.1 General information of catch wall

Catch wall which is introduced here is combination of gravity retaining wall and rock fall protection fence. Catching capacity is decided based on mass of collapsing soil. The wall has durability against impact force of collapsing soil.

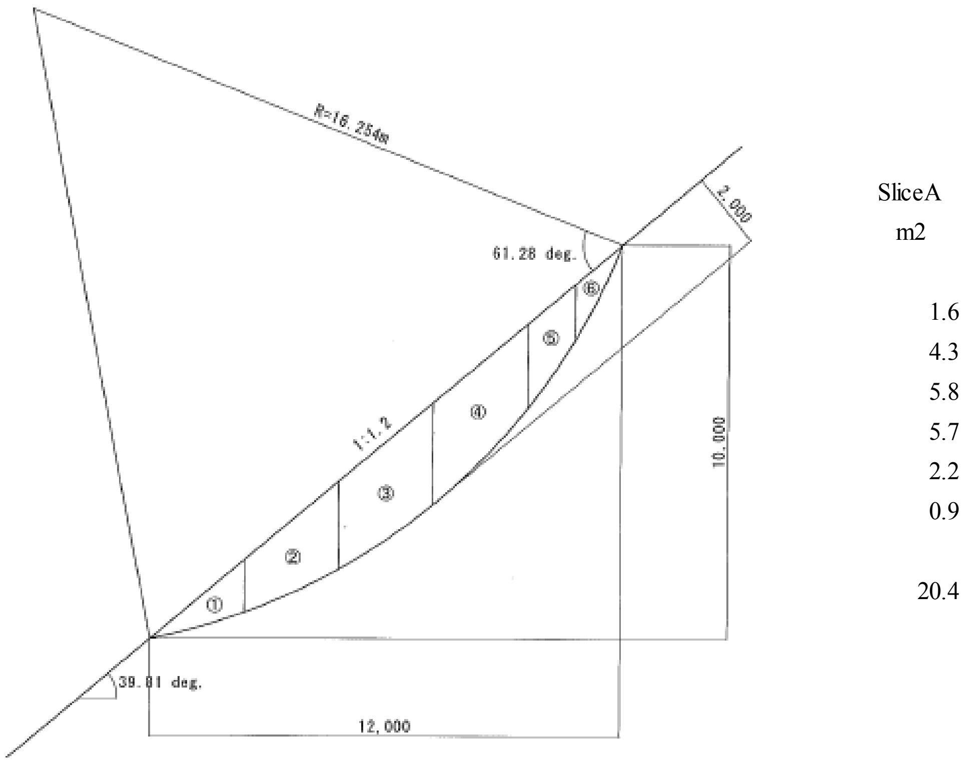
[Characteristics]

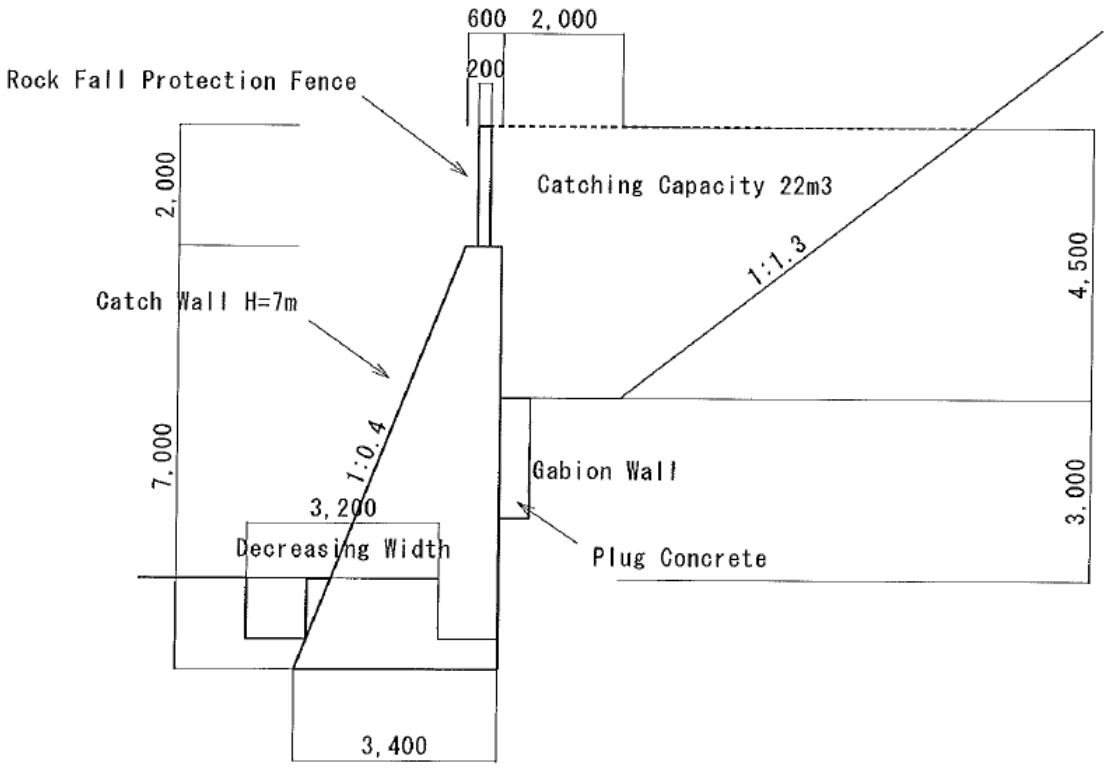
- Classified into traffic protection works
- Steel fence can reduce weight of top portion.
- Catching capacity must be bigger than collapsing soil.
- The wall must bear impact force by collapsing soil.



E.2 Catching capacity

Catching capacity is decided based on mass of collapsing soil. In this example scale of slope collapse is estimated as the drawing. Mass (Cross section) is 20.4m². Catching capacity becomes 22m² when additional height is 4.5m as below. Rock fence H=2m is often adopted for the combination.





E.3 Design procedure

① Catching capacity decides elevation of the fence top.

② Elevation of the wall top is often decided 2m down from the fence top.

③ Wall shape can be selected from Type1 of the common drawings. Original shape is also adoptable.

④ Calculation of impact force.

⑤ Same as stability calculation of ordinary gravity retaining wall

E.4 Stability calculation

[Calculation conditions]

Calculation conditions of catch wall consists of local values which is decided case by case and standard values which is used commonly.

Calculation Conditions of Catch Wall

Items	Symbol	Unit	Local Value	Standard Value
Items for Calculation of Impact Force				
Possible Collapsing Height	H	m	40	
Slope Gradient	θu	deg.	38	
Gradient between Slope-end and Wall	θd	deg.	0	
Distance between Slope-end and Wall	Xb	m	2	
Height of Moving Soil	hsm	m		1.0
Density of Moving Soil	ρs	t/m^3		1.8
Specific Weight of Moving Soil	σ	DL		2.6
Volumetric Concentration of Moving Soil	c	DL		0.5
Acceleration of Gravity	g	m/s^2		9.8
Coefficient of Fluid Resistance	fb	DL		0.025
Coefficient of Impact Force absorption	α'	DL		0.5
Internal Friction Angle of Moving Soil	Φd	deg.	35	
General Items				
Unit Weight of Wall Concrete	γc	kN/m^3		22.56
Unit Weight of Backfill Soil	γb	kN/m^3	18	
Unit Weight of Moving Soil	γ	kN/m^3	18	
Internal Friction Angle of Backfill Soil	Φb	deg.	35	
Friction Angle between Wall and Soil	δ	deg.	23.3	2/3Φb

[Allowable value on stability check]

Stability checks are implemented on three situations as normal, impact force acting (collapse just occurring) and collapsed soil earth pressure acting (after collapse occurred). Each situation has different allowable value as below.

Allowable Value on Stability Check

	Over-turning Eccentric Length e is	Sliding Safety Factor is	Bearing Capacity Reaction Force is
Normal	Smaller than B/6 Middle Third	Bigger than 1.5	Smaller than qu/3=300 kN/m^2
Impact Force Acting	Smaller than B/3	Bigger than 1.0	Smaller than qu=900 kN/m^2
Collapsed Soil Earth Pressure Acting	Smaller than B/3	Bigger than 1.2	Smaller than qu/2=450 kN/m^2

[Calculation of impact force]

Impact force is calculated by below equation. Excel worksheets are provided.

$$\mathrm{F} = \alpha' F_{sm}$$

F: Impact Pressure on the Wall (kN/m^2)

F_{sm}: Pressure by Moving Soil

α': Coefficient of Impact Pressure absorption

$$F_{sm} = \rho_s g h_{sm} \left[\left\{ \frac{b_u}{a} \left(1 - exp\left(\frac{-2aH}{h_{sm} \sin \theta_u} \right) \right) cos^2(\theta_u - \theta_d) \right\} exp\left(\frac{-2aX_b}{h_{sm}} \right) + \frac{b_d}{a} \left(1 - exp\left(\frac{-2aX_b}{h_{sm}} \right) \right) \right]$$

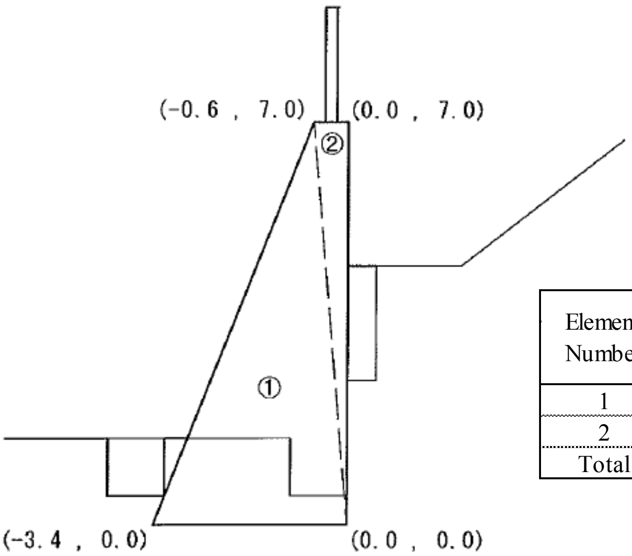
$$\mathrm{a} = \frac{2}{(\sigma-1)c+1} f_b$$

$$b_u = \cos \theta_u \left\{ \tan \theta_u - \frac{(\sigma-1)c}{(\sigma-1)c+1} \tan \varphi_d \right\}$$

$$b_d = \cos \theta_d \left\{ \tan \theta_d - \frac{(\sigma-1)c}{(\sigma-1)c+1} \tan \varphi_d \right\}$$

Item	Symbol	Unit	Value
Coefficient	a	DL	0.027778
	bu	DL	0.370430
	bd	DL	-0.311203
Pressure of Moving Soil	Fsm	kN/m2	106.39
Impact Pressure on the Wall	F	kN/m2	53.20
Impact Pressure Acting Area	Asm	m2	1.00
Impact Force	Fc	kN	53.2

[Wall body weight and gravity center]



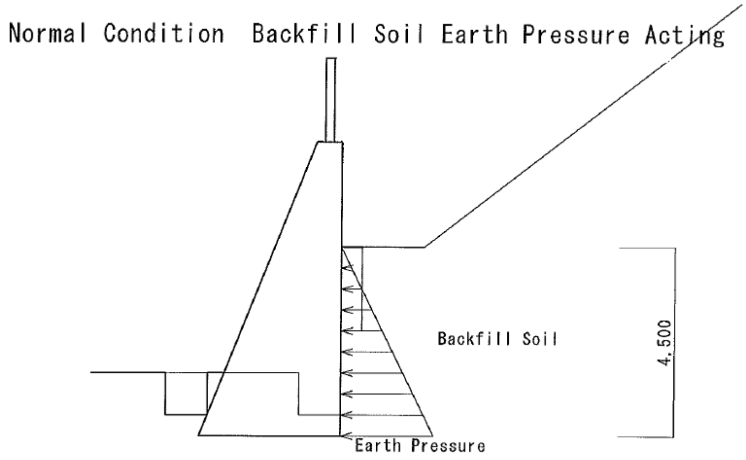
Element Number	Area A (m2)	Weight V (kN)	Arm Length x (m)	Moment M (kNm)
1	11.90	268.5	-1.333	-357.9
2	2.10	47.4	-0.200	-9.5
Total		315.9		-367.4

[Coulomb's active earth pressure]

Earth pressure is calculated by Coulomb's formula. One is earth pressure in normal situation. Another is in collapsed soil earth pressure acting situation.

α degree	β degree	φ degree	δ degree	KA	γ kN/m3	h m	PA1 kN/m	q kN/m2	PA2 kN/m	ΣPA kN/m	PAH kN/m	PAV kN/m
0.0	0.0	35.0	23.333	0.244	18	4.5	44.47	0	0.00	44.47	40.8	17.6
0.0	0.0	35.0	23.333	0.244	18	9	177.88	0	0.00	177.88	163.3	70.4

[Stability calculation in normal situation]



Summary of Load and Moment

Condition	Normal				
Loads	Vertical Loads V (kN)	Arm Length x (m)	Horizontal Loads H (kN)	Arm Length y (m)	Moment M (kNm)
Wall Body	315.9		0.0		-367.4
Earth Pressure	17.6	0.000	-40.8	1.500	-61.2
	333.5		-40.8		-428.6

Three Check Points of Stability Index

1) Over-turning

X coordinate of ΣV	X=	-1.285
X coordinate of Wall Toe	Xt=	-3.400
X coordinate of Wall Heel	Xh=	0.000
Width of Base	Bh=	3.400
X coordinate of Limit for ΣV	Xa=	-2.833
Judgment		**OK**
Eccentric Length	e=	-0.415
Middle-third/2		0.567
Shape of Reaction Force		**Trapezoidal Shape**

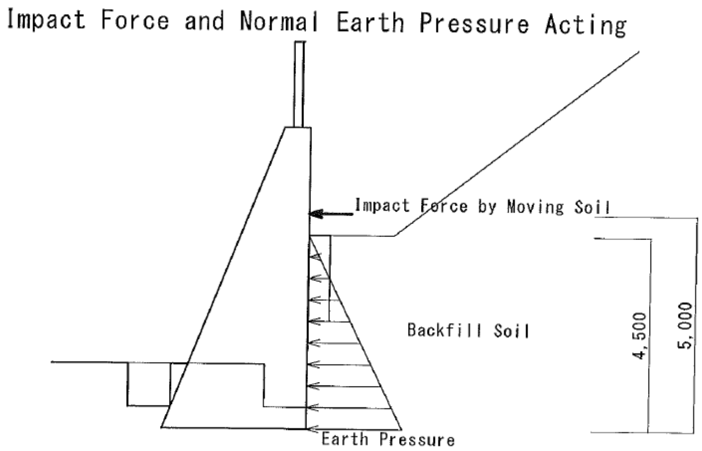
2) Sliding

Friction Coefficient	μ=	0.6
Sliding Safety Factor	Fs=	4.90
Needed Safety Factor	Fsn=	1.50
Judgment		**OK**

3) Bearing Capacity of Foundation Ground

Reaction Force at Wall Toe	qt=	26.3
Reaction Force at Wall Heel	qh=	169.9
Allowable Bearing Capacity	qa=	300
Judgment		**OK**

[Stability calculation in impact force acting situation]



Summary of Load and Moment

Condition	Impact Force Acting				
Loads	Vertical Loads V (kN)	Arm Length x (m)	Horizontal Loads H (kN)	Arm Length y (m)	Moment M (kNm)
Wall Body	315.9		0.0		-367.4
Earth Pressure	17.6	0.000	-40.8	1.500	-61.2
Impact Force			-53.2	5.000	-266.0
	333.5		-94.0		-694.6

Three Check Points of Stability Index

1) Over-turning

X coordinate of ΣV	X=	-2.083
X coordinate of Wall Toe	Xt=	-3.400
X coordinate of Wall Heel	Xh=	0.000
Width of Base	Bh=	3.400
X coordinate of Limit for ΣV	Xa=	-2.833
Judgment		**OK**
Eccentric Length	e=	0.383
Middle-third/2		0.567
Shape of Reaction Force		**Trapezoidal Shape**

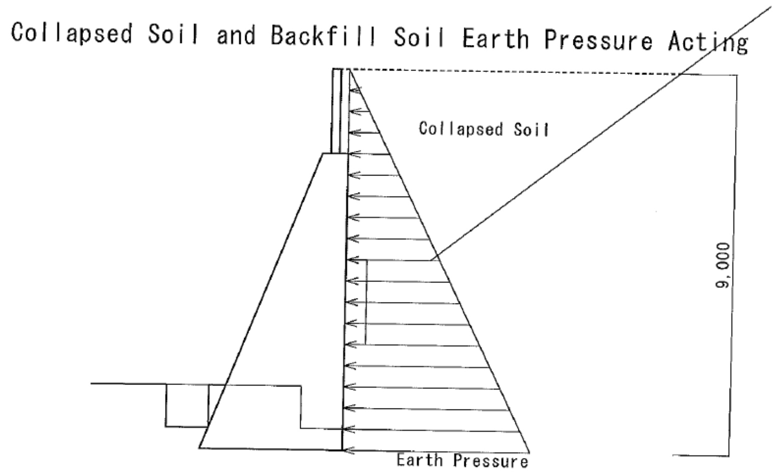
2) Sliding

Friction Coefficient	μ=	0.6
Sliding Safety Factor	Fs=	2.13
Needed Safety Factor	Fsn=	1.00
Judgment		**OK**

3) Bearing Capacity of Foundation Ground

Reaction Force at Wall Toe	qt=	164.4
Reaction Force at Wall Heel	qh=	31.8
Allowable Bearing Capacity	qa=	900
Judgment		**OK**

[Stability calculation in collapsed soil earth pressure acting]



Summary of Load and Moment

Condition	Collapsed Soil Earth Pressure Acting				
Loads	Vertical Loads V (kN)	Arm Length x (m)	Horizontal Loads H (kN)	Arm Length y (m)	Moment M (kNm)
Wall Body	315.9		0.0		-367.4
All Earth P.	70.4	0.000	-163.3	3.000	-489.9
	386.3		-163.3		-857.3

Three Check Points of Stability Index

1) Over-turning

X coordinate of ΣV	X=	-2.219
X coordinate of Wall Toe	Xt=	-3.400
X coordinate of Wall Heel	Xh=	0.000
Width of Base	Bh=	3.400
X coordinate of Limit for ΣV	Xa=	-2.833
Judgment		**OK**
Eccentric Length	e=	0.519
Middle-third/2		0.567
Shape of Reaction Force		**Trapezoidal Shape**

2) Sliding

Friction Coefficient	μ=	0.6
Sliding Safety Factor	Fs=	1.42
Needed Safety Factor	Fsn=	1.20
Judgment		**OK**

3) Bearing Capacity of Foundation Ground

Reaction Force at Wall Toe	qt=	217.7
Reaction Force at Wall Heel	qh=	9.6
Allowable Bearing Capacity	qa=	450
Judgment		**OK**

E.5 Comparison of other countermeasure

This catch wall design example is competitive countermeasure to combination of sewing bar and shotcrete frame presented in clause 12. Comparison table is shown as below.

Item	A. Sewing Bar and Shotcrete Frame	B. Catch Wall
Principle Classification	Deterrence Work	Traffic Protection Work
Out line	The bar sews the collapsing soil to unmoving ground, the frame distributes the bar force to collapsing soil.	Catch wall protects traffic from collapsed debris by own catching capacity. Catch wall must bear impact force by the debris
Quantity per 10m	Shotcrete frame: 370m Sewing Bar: 100, 400m	Wall concrete: 140m3 Rock fence: 10m
D.C. cost per 10m In Japan	USD 86,000.-	USD 36,000.-
Others	No loss	Road width 3.2m loss
Maintenance	Nothing	Debris shall be removed after collapse.
Selection	No demerits but high cost.	Low cost but some demerits.

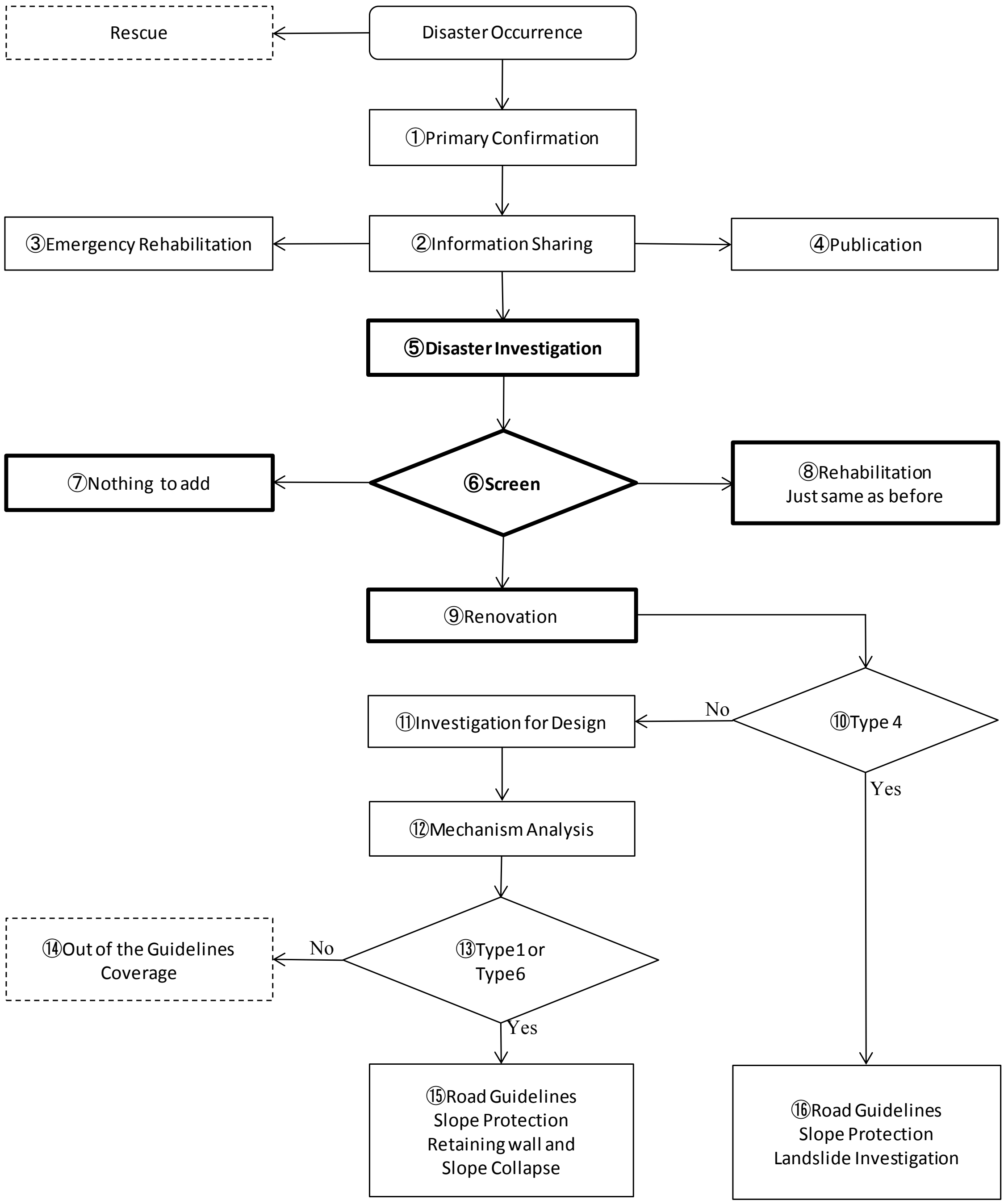
Characteristics of catch wall can be summarized as below.

- Catch wall can be lower cost than other countermeasure in many cases.
- A certain level of space to place the wall base is required along foot of the slope. Therefore catch wall is not adequate to place a narrow place such as foot of steep slope.
- A certain level of bearing capacity of foundation ground is required along slope side of the road. This is the absolute requirement.
- Debris shall be removed after collapse to keep space for next collapse.
- If the target slope collapse is expansive to upper portion of slope, impact force can increase because of higher potential to the catch wall. Possible collapsing height in the design conditions must be decided with deep consideration.

Annex F
(informative)

Disaster Investigation Sheets

F.1Decision process of disaster countermeasure



Rainy season brings some road disasters every year. A long process as the flowchart is necessary to connect each disaster affected site to the “Road Guidelines-Slope Protection”

① Primary confirmation: Municipal public works office staff or DRBFC staff visits the disaster affected site after occurrence to confirmation.

② Information sharing: The man of primary confirmation distributes the information to all parties concerned.

③ Emergency rehabilitation: Local contractors and IGE removes debris on the road to open traffic.

④ Publication: Road brock information helps road users.

⑤ Disaster investigation: The engineer who is in charge of disaster rehabilitation visits the sites with "Disaster Investigation Sheets".

⑥ Screen: The sheets helps him to screen each site into following three ways.

⑦ Nothing to add: Phenomena is small and damage is limited so that nothing is necessary to add to emergency rehabilitation.

⑧ Rehabilitation just same as before: If extreme heavy rain is the cause of the damage then rehabilitation just same as before can stand up to less than moral heavy rain.

⑨ Renovation: Same phenomena will occur under same condition. Only renovation avoid repeated disaster.

⑩ Type 4: Slope disaster is classified into 6 types (ref. page29). Type 4 is mass movement (land slide).

⑪ Investigation for design: Mechanism analysis and countermeasure design needs not only information of ground shape and content but also detailed damage situation. Survey, geological investigation and surficial observation are usually implemented to get them.

⑫ Mechanism analysis: The engineer consider what phenomena occur under what condition, and why (cause). He decides disaster type, size (height and depth) and mechanism on all achieved information.

⑬ Type 1 or Type 6: Type 1 is slope collapse on natural and cut slope. Type 6 is road collapse in embankment.

⑭ Outside of the scope of these guidelines: Type 2 rock fall, Type 3 rock mass failure and Type 5 debris flow are topics not covered by these guidelines.

⑮ Road Guidelines Slope Protection Retaining Wall and Slope Collapse: these guidelines.

⑯ Road Guidelines Slope Protection Landslide Investigation: other guidelines made by CDRS project

F.2 Example of Description

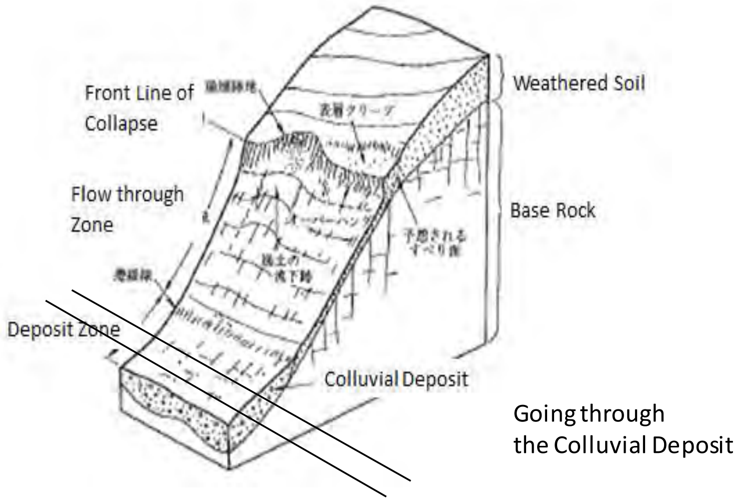
Example of description on the Disaster Investigation sheets are shown on following pages. The articles should be adjusted along usage, purpose, stage and so on for easy to use.

Disaster Investigation Sheets 1/4

Code/Number		Example #1
Place Infromation	Road Number	Ex-Japan Road
	Station	STA.14
	Latitude	-8.621653
	Longitude	125.522562
	Special Note	Slope protection Case Study site

Birds-eye Photo

Road Location on the mountainside

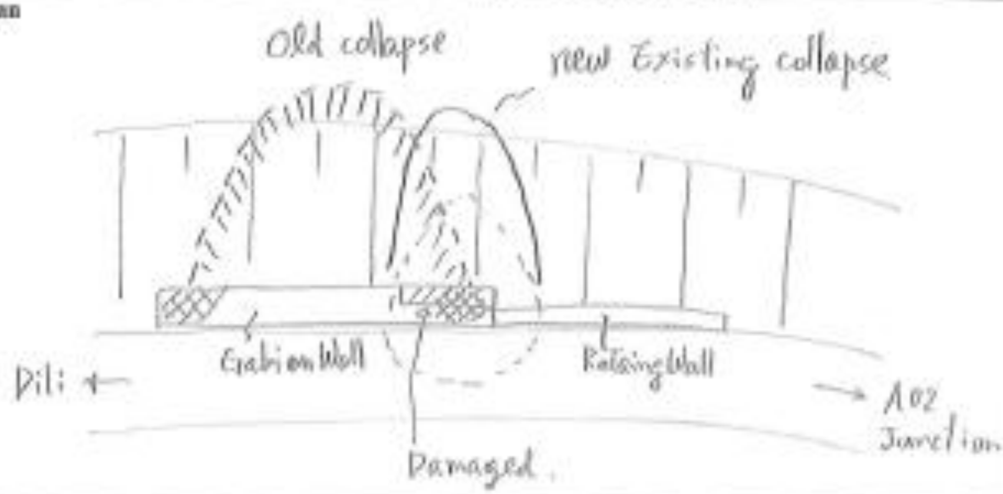


~~**Others**~~

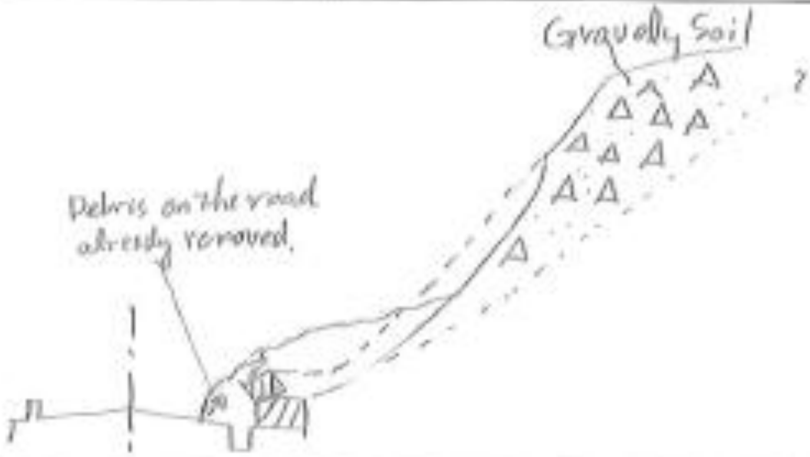
Alluvial Fan   Along a rive   Along seaside

Disaster Investigation Sheets 2/4

Plan



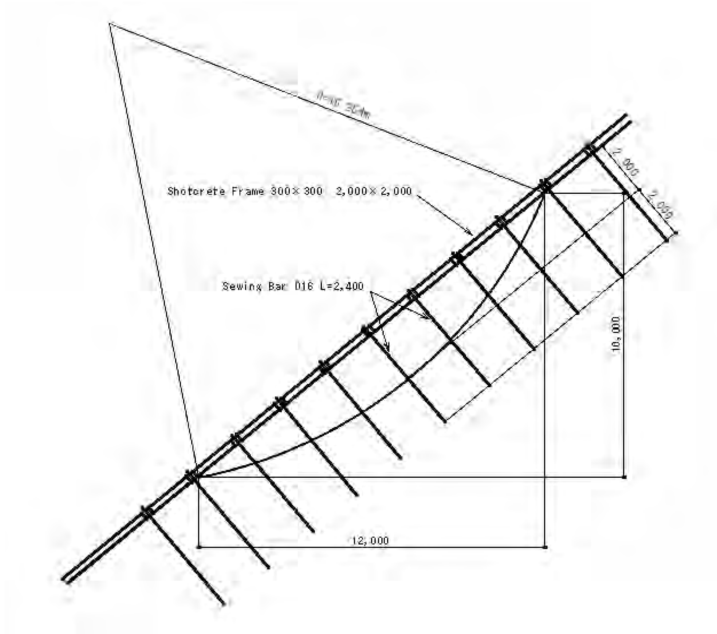
Cross Section



Sketch

Estimated Size Height= 20m Width= 20m Depth= 1m

<table>
<tr><th colspan="4">Disaster Investigation Sheets 3/4</th></tr>
<tr><td rowspan="5">Time line</td><td>Occurrence</td><td colspan="2">Feb. in 2018</td></tr>
<tr><td>Primary Investigation</td><td></td><td>Executioner</td></tr>
<tr><td>Removing Debris</td><td></td><td></td></tr>
<tr><td>Disaster Inviestigation</td><td>16th Apr. 2018</td><td>Minegishi</td></tr>
<tr><td>Conference</td><td>26th Apr. 2018</td><td>CDRS Work shop
7 perticipants</td></tr>
<tr><td rowspan="2">Geological Information</td><td>Cover Soil</td><td colspan="2">Gravelly soil
Matrix is clayey, but this layer behave like a sandy one.</td></tr>
<tr><td>Base Rock</td><td colspan="2">Sedimentary Rock</td></tr>
<tr><td rowspan="4">Drainage /Water Information</td><td>Roadside Ditch</td><td colspan="2">Mountain side 1m*1m
River side none</td></tr>
<tr><td>Cross Culvert</td><td colspan="2">none</td></tr>
<tr><td>Stream /Spring</td><td colspan="2">There is some traces of stream on the retaing wall
Spring is none</td></tr>
<tr><td>Others</td><td colspan="2"></td></tr>
<tr><td colspan="2">Slope Classification</td><td colspan="2">Natural slope (Cut slope) Embankment Not clear
Natural slope involving cut slope
Natural slope involving embankment
Natural slope involving both of cut slope and embankment</td></tr>
<tr><td colspan="2">Classification of Slope Disaster</td><td colspan="2">(Type1 Slope Collapse) Type2 Rock Fall
Type3 Rock Mass Failure Type4 Mass Movement
Type5 Debris Flow Type6 Road Collapse Not clear
Comment</td></tr>
<tr><td colspan="2">Damage Fact Discription</td><td colspan="2">Gabion wall: Top step is over-turned
Cut sloope: Traces of collapse reaches to a tree on the natural sloope.
Ditch on sloope side: No damage
Road: No damage</td></tr>
<tr><td colspan="2">Trend of Continuity and Expansion</td><td colspan="2">There seems to be both of continuity and expansion.
There is same soil layer with same gradient at upper portion of the slope.</td></tr>
<tr><td rowspan="3">Open or Close for Traffic</td><td>Until Now</td><td colspan="2">(All Width Open) One Lane Open Close</td></tr>
<tr><td>From Now</td><td colspan="2">(All Width Open) One Lane Open Close</td></tr>
<tr><td>Coment</td><td colspan="2">Debris were already removed.</td></tr>
</table>

Disaster Investigation Sheets 4/4	
Speculated Mechanism	Exsiting slope gradient seems near to critical gradient for stable. Because of Ground water level rising, the collapse occurred
Screen	Nothig is necessary
	Rehabilitation just same as before
	Renovation Renovation is necessary to stop similar slope collapse.
Recommendation	
Additional Investigation for Design	Survey Plan (with contour map) 200m*100m Cross sections 10 lines Mechanical boring (Soil 3m, Rock 3m)*3 holes to get bar emvedment layer's information

Disaster Investigation Photo Sheets 1/1	
Code/Number	

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[2] Japanese Geotechnical Society: 斜面の安定・変形解析入門 First Step for Slope Stability and Deformation Analysis, Japanese Geotechnical Society, Tokyo Japan (2006) ISBN 978-4-886-44434-9

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[5] Public Works Research Institute: Technical Memorandum of PWRI No.3924-2, Manual for Highway Earthworks in Japan, Public Works Research Institute, Ibaraki Japan (2004) ISSN 0386-5878

República Democrática de Timor-Leste

Ministério das Obras Públicas

Direcção Geral das Obras Públicas

Direcção Nacional de Estradas, Pontes e Controlo de Cheias

Matadalan Estrada — Protesaun Rai Halis — Moru Retensaun & Colapso de Declive

Road Guidelines — Slope Protection — Retaining Wall & Slope Collapse

Faze EFM

Atensaun

Documentos ida ne'e laos Padraun Nacional Timor Leste. Dokumentus ne'e sei fahe hodi halo revisaun no fo komentario. Materia ida ne bele halo mudansa no sein fo hatene no la refere hanesan padraun nacional.

Benefisiariu ba esbosu hetan convida atu submite, sira nia komentario, notifikasaun kona ba sira nia direitu ba patent nebe relevante no sira hatene no fornese apoio ba dokumentasaun.

Tipu Dokumentu: Spesifikasaun Teknikaocument
Subtipu Dokumentu:
Faze Dokumentu: (EFM) Esbosu Final Matadalan
Dokumentus ho lingua: TDT

Konteudu

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REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTÉRIO DAS OBRAS PÚBLICAS
GABINETE DO VICE-MINISTRO
Av. Nicolau Lobato, Mandarin, Dili, Timor Leste

Prefasiu

Iha interese ba harii ho qualidade as no ekonomikamente viabiliza infrastrutura hodi servi nasaun, matadalan ida ne'e atu dezeñu protesaun rai halis nebe prepara ona husi JICA Projeito Desenvolvimento Kapasidade ba Servisu Estrada iha República Democrática de Timor-Leste (CDRS) nebe iha kolaborasaun ho Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC), Ministério das Obras Públicas. Ami hakarak hato'o agradese ba JICA ba kontinua suporta.

Setembru, 2019

Eng. Nicolau Lino Freitas Belo
Vice-Ministro das Obras Públicas
Ministério das Obras Públicas

Prefasiu husi JICA

Japan International Cooperation Agency (JICA) halao ona projetu kooperasaun téknika ida ba desenvolvimento kapasidade kona ba servisu estrada, nebe'e hanaran CDRS, nune atu fasilita DNEPCC jere no halo manutensaun ba infra-estrutura estrada bazea ba actividade soscial no ekonomiku. Ba ida-ne'e nia rohan, JICA despasa ona ekipa espesialista sira husi fulan-Marsu tinan 2016 to'o fulan Dezembru tinan 2019. Hanesan resultadu husi kolaborasaun servisu husi parseira DNEPCC, matadalan ba protesaun rai halis finalisa ona. Ha'u espera katak matadalan ida-ne'e sei kontribui ba dezenvolvimentu infra-estrutura no manutensaun, no valorizasaun relasaun belun di'ak entre nasaun rua.

Ikus liu, ha'u hakarak hato'o ha'u-nia apresiasaun sinceriamente ba funcionariu governu República Democrática de Timor-Leste nia ho equipa peritu.

Setembru, 2019

Masafumi NAGAISHI
Representante Chefe Gabinete JICA iha JICA Timor-Leste
Japan International Cooperation Agency

Agradesimentu

Projetu ba Desenvolvimentu Kapasidade Servisu Estrada iha República Democrática de Timor-Leste (CDRS) hakarak atu fó-agradese ba parte hotu-hotu ne'ebé envolve an hodi prepara matadalan.

Apoia projetu ne'e, ofisial husi (eis) Ministério de Desenvolvimento e de Reforma Institucional: M. R. M. Cruz, J. L. C. C. P. Mestre and J. Santos; no ofisial husi Ministerio Obras Publiku: C. M. Henrique no especialmente ba R. H. F. Guterres; hodi rekonese.

Durante halo preparasaun ba dokumentus ida ne'e hetan kontribuisaun husi ofisial DNEPCC: M. R. C. Monteiro, J. P Amaral, J. M. G. Sousa, J. G. Carlvalho, I. M. L. Gutteres, N. Lobato, L. Luis, M. Soares, J. L. Kehy; no Organizasaun Internasional Trabalho ou International Labour Organization's (ILO) nudar ekipa asistente teknika ba apoiu programa Desenvolvimento Estrada (R4D-SP): A. O. Asare, K. H. Myaing, S. Done, U. Yat, L. Thakuri; hodi rekonese.

Komentariu:

Sei apresia tebes ba komentariu nebe positivu ba posibilidade inkorporasaun ba edisaun tuir mai. Favor fo komentario no sugestaun ba iha enderusu tuir mai ne'e.

Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
Enderesu: Avenida da Restauração, Rai Kotu, Comoro, Dili, Timor-Leste
Nu. Kontaktu: +670 3311408

Introdusaun

Matadalan ida ne'e dezenvolve husi JICA Projecto Dezemvolvimetu ba Kapasidade Servisu Estrada nian iha Republica Democratica Timor-Leste ne'ebe kolabora ho Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC) ho objectivo atu dezemvlv kapasidade instiuisaun nian relasionl ho protesaun rai halis.

Generalidade koalia kona ba dezennu Enjinerru Civil nian tenki bazea ba informasaun geological no dezennu peskiza ne'ebe hanean ho impresaun iha terrenu. Tamba id ne'e mak Matadalan ida ne'e hahu ho "Informasaun requeridas ne'ebe minimu ba Dezennu".

Maioria projectos sira iha Timor-Leste uza dezennu komum. Maske nune Enjineriu interna barak mak iha fundos konsensia husi sira, ho liafuan seluk sira nia dezennu orijinal. Matadalan ne'e trata stabilidade kalkulasaun ba gravidade moru retensaun iha dezennu comum Iha parte seluk,kalkulasaun stabilidade gravidade moru retensaun mak odamatan oin ba dezennu strutura sira seluk. Mestre ba kalkulu tama ona ba etapa nivel alto

kontra medida ne'ebe eziste iha Timor Leste mak re-cortar No Metodu protesaun rai halis mak ai horis no Cover sheet. Ida ne'e signifika katak tenki hasoru limitasaun iha caso collapso declive ne'ebe badak. kombinasaun entre homan besi no superficie strutura nia cobertura hare hanesan contrameidda ne'ebe adequada liu hasoru collapso declive ne'ebe badak. Tamba ne'e mak metodu id ne'e tenki introdus ba Timor Leste hodi bele kontrollu Colapso declive ne'ebe badak.

Iha tipu seluk husi dezastre i ri hlis hanesan fatuk monu,rock mass failure,ri hlai,fluxo decris no collapso iha embankment. Matadalan ida ne'e consentra iha colapso rai halis iha rai halis tamba corta ou natural tamba dezemvolvimento kapsidade ne'ebe seguru. Projeitu da ne'e mos fornese Matadalan seluk ne'ebe hanaran Proteasun Taludes-movimento de massa.

Matadalan Estrada — Protesaun Rai Halis — Moru Retensaun & Colapso de Declive

1 Ambitu

Matadalan ida ne'e konsite tema tolu, investigasaun, pede retensaun gravidade no proesaun rai halis.

Wainhira hasoru prolema rum iha enjinaria civil nian ne'ebe occore, etapa dahuluk ne'ebe tenki halo mak investigasaun cientifika. Investigasaun ida ne'e tei inklui mos forma rai nian no subtancia. Artigo 4 apresenta informasaun minimu ne'ebe requeridas ba dezennu.

Artigo 5 to'o 7 trata gravidade moru retensaun. Artigo 5 hatudu prosedimentu dezennu gravidade moru retensaun. Artigo 6 ho objektivu atu supporta uzuariu dezennu komum iha kazu ne'ebe selesiona. Karakteristiku husi tipu 1 no tipu 2 hanesan hatudu. Failansu barak liu ne'ebe akontese ba moru rentensaun mak hanesan falta capasidade suporta ba fundasaun iha rai okos. Artigo 7 handles this matter.

Artigo 8 to'o 12 trata stabilidade rai halis. Artigo 8 no 9 apresenta informasaun geral kona ba rai halis nodezastre iha rai halis hanesan konnesementu basico ba stabilidade rai halis. Artigo 10 introdusaun metodu kalkulsaun stabilidade rai halis. Artigo 11 mak analiza influensia iha fator seguru ba rai halis husi gradiente superficie, resistência ao cisalhamento e água subterrânea. Artigo 12 mak ezemplu dezennu kombinasaun husi barra de costura no cobertura strutura superficie hasoru shallow slope collapse on a cut slope.

Matadalan ida ne'e konsentra liu ba iha colpaso de declive iha rai halis tamba corta no natural tamba dezemvolvementu kapasidade ne'ebe seguru.

2 Referensia normativu

Dokumentus ida ne'e laiha referensia normativu.

3 Termu no definisaun

Ba objektivu dokumentu ida ne'e, aplika termu no definisaun tuir mai ne'e.

ISO mantein terminalojia baze dadus ba benifisiariu sira atu uja padraun iha enderesu tuir mai ne'e:

– Plataforma navigasaun online ISO: iha https://www.iso.org/obp

3.1
moru retensaun
moru suporta rai aterramento, rai aterru ka corte declive

[FONTE:ISO 23469:2005(en),3.46]

3.2
pressaun rai
presaun husi rai iha moru ka porsaun strutura iha embedded

[FONTE:ISO 23469:2005(en),3.11]

3.3
kapasidade suporta rai nian
tensaun máxima admissível iha fundasaun rai ne'ebe fornese seguransa ne'ebe adequada hasoru failansu rolhamento rai, ka penurunan fundasaun hanesan madnitude ne'ebe prejudika strutura

[FONTE:ISO 28842:2013(en),3.9]

4 Investigasaun (minimu informasaun dezennu ne'ebe requeridas)

Fenomena dezastre iha rai halis mak rai ne'ebe muda an ba okos liu husi forsa gravidade ne'ebe influensia husi be. Tamba ne'e mak informasaun forma rai nian no ninia konteudu, be nian kondisaun wainhira hetan dezastre bele dehan katak informasaun ne'ebe requeridas ne'ebe minimu ba dezennu kontramedida. Iha kazu barak mak lahatene kondisaun be tamba laiha observasaun nune'e estimasaun mak alternativo ba ida ne'e. Peskiza fo informasaun kona ba forma rai nian. Investigasaun geological fo informasaun koan ba konteudu rai nian.

4.1 Forma rai nian

Seksaun transversal representativa mak vital ba contra medida dezennu baziku. Ita bele hetan ho fasil liu husi peskiza seksaun transversal iha terrenu.

Dezennu planu ho mapa kontur, seksaun longitudinal no seksaun transversal mak nessesariu liu hanesan informasaun rai nia forma. Ita bele estuda kolokasaun,kobertura na hapar malu kona ba rai iha planu. No planu tenke iha bankada marcos ne'ebe bele hetan iha-fatin ho pasak (Indonesia). Seksaun longitudinal halo tuir duni ninia funsaun atu hatudu gradiente estrada longitudinal no elevasaun no fatin pontu levantamentu. seksaun transversal husi pontu levantamentu aprezenta area servisu no quantidade servisu.

4.2 Infomasaun geological

Bazikamente geologista sira toma konta ba investigasaun geologia nian no enjinerria civil sira mak sai hanesan uzuariu ba informasaun geological sira ne'e, nune'e enjineeria civil sira mos tenki hasae konnesementu kona ba geologia nian nune bele sai uzuario ne'ebe matenek. Wainhira la iha geologista ida iha projeitu laran maka enjinneria civil mak tenki buka rasik informasaun geologia nian.

Abordagem Geomorfológica

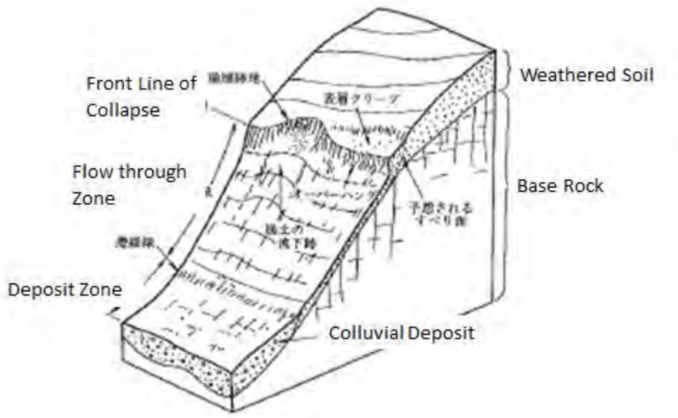
Basically geologist is in charge of geological investigation and civil engineer is a user of geological information however the civil engineer should approach actively geological knowledge to become a smart user. If there is no geologist in the project civil engineer must get geological information by himself.

(1) Abordagem geomorfológica

Forma rai ne'ebe refleta konteudu rai nian. Abordagem geomorfológica mak hanesan etapa dahuluk ba investigasaun geologico. Ita bele hetan foto aerial ka satelite liu husi internet ho fasil. Fotografia ne'e hanorin ita kona ba forma rai besik pontu targetu. Geologo deskobre klean liu tan kona ba karakteristika geomórficas hanesan depósito coluvial, leque alluvial, terraço fluvial do movimento de massa no liu husi fotografia estéreo aérea.

Figura 4.1 Visão panorâmica da foto de satélite

Konkursu tipu geologiku iha area foho hanesan hatudu iha Figura tuir mai ne'e. Wainhira estrada besik ba iha lina ridge ria intemperizado dala barak mosu hanesan taludes corte, no besik ba dasar vale ita dala barak hasoru colluvial deposit. Rua ne'e iha potensial para atu hetan colapso tamba dalas ne'ebe la konsolida.



Adopta husi biblia. [1]

Figura 4.2 Tipu structura iha parte foho nian

(2) Observasaun geológica superficial

Objectivo observasaun geológica superficial; atu koleta informasaun geological iha ekspojisaun ne'ebe bele hetan declive no declives laterais, atu observa kondisaun be subterrâneasliu husi aliran kanal, traço de fluxo, spring, no atu komfirma escala terrenu impressão geomórfica.

(3) Teste perfurasaun mekanikal no padraun penetrasaun

Maioria investigasaun geological mak perfuração mekaniku no padraun teste penetrasaun ba dalas rai nian. Claro que persija tempu no custo tamba iha laiha opção seluk atu hean evidencia ne'ebe claro husi conteusdu rai nia. Valor-N desde padraun teste penetrasaun mak liga ho avaliasaun kona ba capacidade de carga e resistência ao cisalhamento. Tamba ne'e ita bele dehan katak valor-N mak hanesan regulador comun ba rai nia dalas. Iha pontu fraco husi valor-N wainhira dalas rai iha gravel mak barak, gravel bele mexe valor-N maior liu.

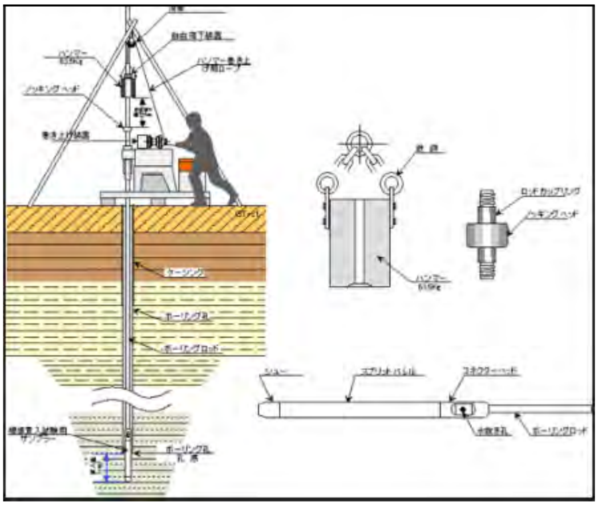


Figura 4.3 Mekaniku Perfuração no SPT

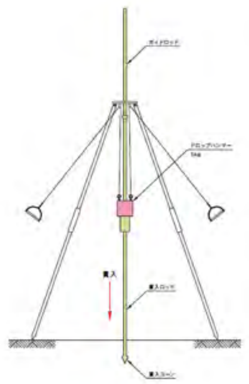
(4) Teste penetrasaun sira seluk

Iha ne'eba iha tipu teste penetrasaun ne'ebe uza ma nia forsa hanesan hatudu iha Figura 4.4. Teste sira ne'e bele ezekuta kstu n'ebe baratu liu do que mechanical boring aibe iha limitasan ba dalas no nnia profundidade. Iha projeitu ne'e Dokenbo ida fornese tiha ona ba DNEPCC ba investigasaun Geologia ne'ebe simples. Uzu manuál ne'e kompila hanesan Anexu A.

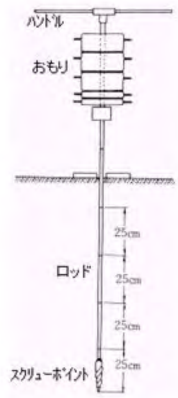
Tabela 4.1 Karakteristika teste penetrasaun

	Standard Penetration Test SPT	Simplified Dynamic Cone Penetration Test	Swedish Sounding Test	Portable Cone Penetration Test	Prospect Rod for Soil Layer Strength Cone Penetration Test Dokenbo
Driving Method	Dynamic Hammering by Weight	Dynamic Hammering by Weight	Static Pushing by Weight and Turning by Hand	Static Pushing by Hand	Static Pushing by Hand
Power	Mechanical Power	Man power	Man power	Man power	Man power
Portability	Un-portable	16kgf / 1set	More than 100kgf		4.5kgf / 1set
Penetrator	Sampler ϕ51mm	Cone ϕ25mm	Screw-point ϕ33.3mm	Cone ϕ28.6mm	Cone ϕ15mm
Rod Diameter	ϕ40.5mm	ϕ16mm	ϕ19mm	ϕ16mm	ϕ10mm
Weight and Stroke	63.5kgf, 760mm	5kgf, 500mm	5,15,25,50,75,100kgf		
Unit testing Length	30cm, Pre-Blow 15cm	10cm	25cm	Every 10cm	At the Point
Allowable Layer	All Soil Layer Except Gravel Layer	All Soil Layer Except Gravel Layer	All Soil Layer Except Gravel Layer	Clayey Layer	Soil Layer except Dense Sandy Layer
Maximum Depth	Limitless	15m	15m	5m	5m
Outcome	SPT- N: Number of hammering per 30cm penetration	N_d: Number of hammering per 10cm penetration	N_{sw}: Number of half revolution per 1m penetration	D: Pushing Load q_c: Penetration resistance	W: Pushing Load q_{dk}: Penetration strength
Characteristics	King of penetration test So many past results Established outcome usage With boring	Downsized SPT	Common test for house foundation in Japan	Test only for soft soil layer	Good for slope investigation Multi use for Soil depth prospection Penetration test Shear strength test

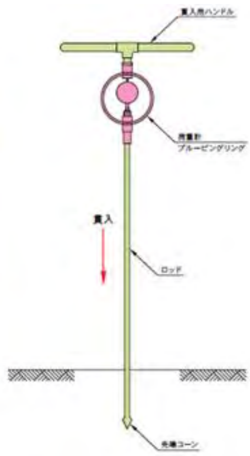
Simplified dynamic cone penetration test



Swedish sounding test



Portable cone penetration test



Prospect rod for soil layer strength

<u>Dokenbo</u>

Figura 4.4 Teste Penetrasun utiliza ema nia forsa

5 Dezennu gravidade moru retensaun

Dezennu gravidade moru retensaun hanesan odamatan atu tama ba iha dezennu enjenaria sivil nian. Ida ne'e simples maibe inclui mos ho metodu ne'ebe útil. Se imi komprende ida ne'e sei sai, ameira ne'ebe fasil liu atu hakbesik ba estrutura hanesan moru gabion, ponte nia abutment, fluxo debritos iha bareira, gravidade baragem konkreto no seluk tan. Tamba ne mak matadalan ida ne'e trata tema ida ne'e.

5.1 Prosedimentu dezennu

Moru retensaun jeralmente aplika hodi hapara aterru rai. Prosedimentu dezennu ba moru retensau hanesan hatudu iha Figura 5.1. Prosedimentu ida ne konsiste principalmente ba kalkulasaun ba stabilidade. Estrutura ne'ebe hamrik rasik hanesan ponte nian abutment no barragem gravidade ne'ebe iha posedimentu ne'ebe hanesan tam ba ne'e komprende didiak prosedimentu sira ne'e diak tebes ba etapa dahuluk Enjenaria sivil foun sira.

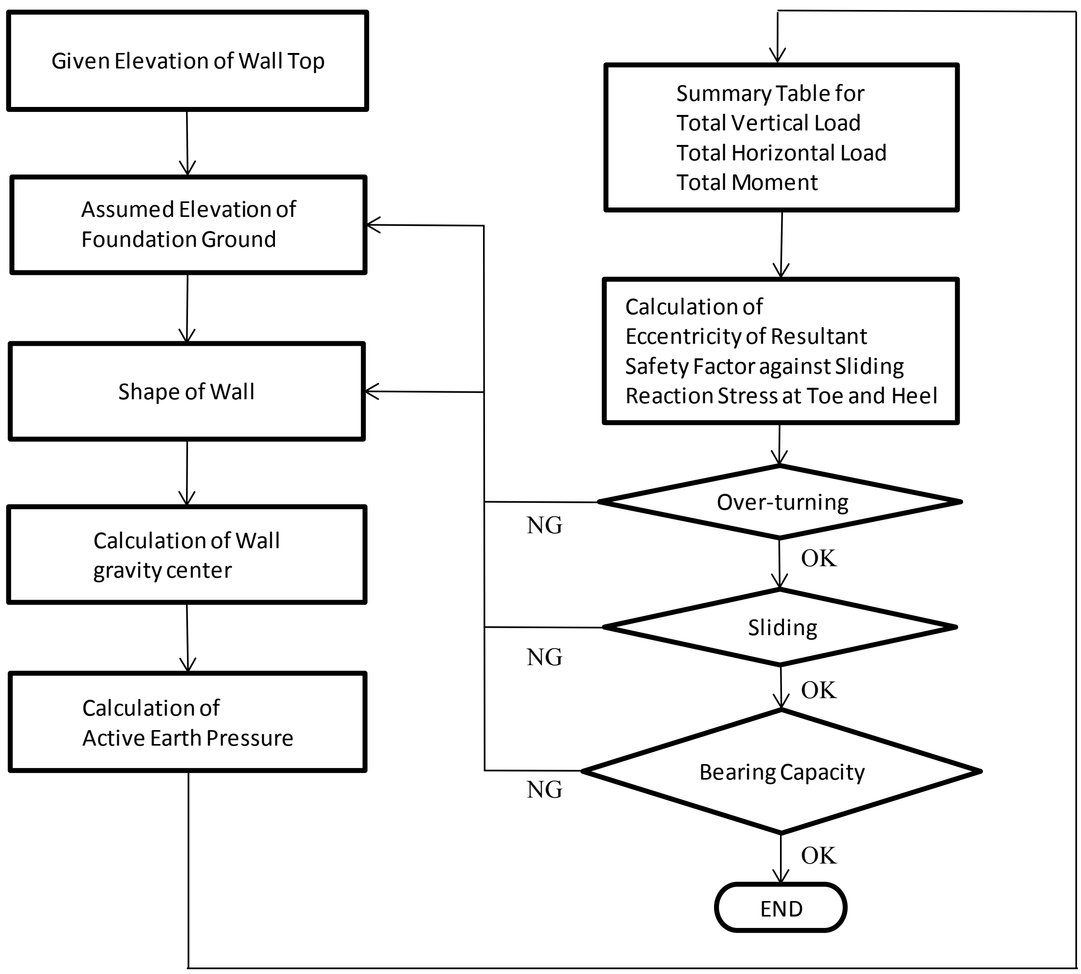


Figura 5.1 Dezennu prosedimentu gravidade moru retensaun

5.2 Kada etapa husi prosedimentu

Kada etapa husi prosedimentu sei deskreve tuir ezemplu iha karaik ne'e.

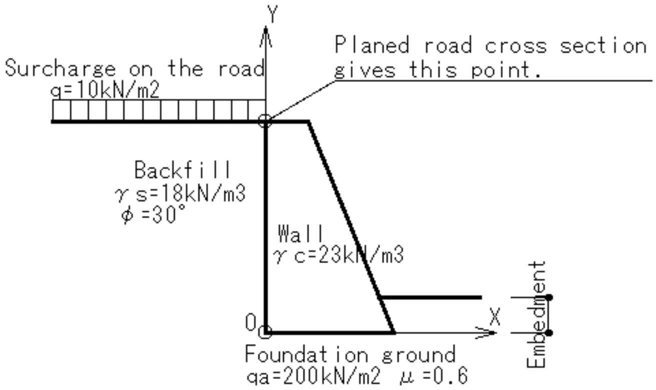


Figura 5.2 Ezemplu gravidade moru retensaun

(1) Posição moru nia leten husi estrada sorin

Plano seksaun transversal estrada nian babain nia posição iha moru leten estrada sorin.

(2) Asume elevasaun moru nia okos

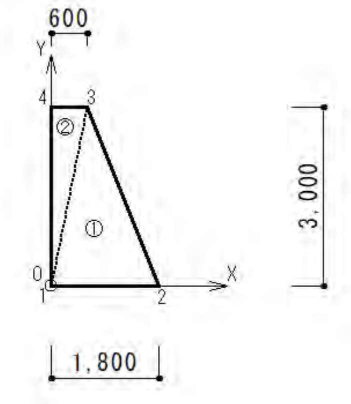
Elevasaun ba didin nia okos depende ba kondisaun rai okos nia tamba rai okos tenki suporta didin. Profundidade husi embutir ida ne'ebe nia distancia entre rai superficie no moru nia okos tenki bo'ot liu 0.5 m.

(3) Forma moru nian

Ita bele selesiona forma moru liu husi dezennu comuns. Ita mos bele configura forma original. Iha ezemplu ida ne'e Tipu 1 H=3m mak selesiona.

(4) Kalkulasaun ba sentru gravidade moru

Moru ne fahe ba figura simples balun hanesan trianglu atu bele kalkula central gravidade ho fasil. Excel sheet bele kalkula centro gravidade waihira ita fo nia koordinat ne'ebe fahe ba traingulo ho baze horizontal.



Element	Area A (m2)	Weight V (kN)	Arm length x (m)	Moment M (kNm)
1	2.70	62.1	0.800	49.7
2	0.90	20.7	0.200	4.1
Total		82.8		53.8

(5) Cálculo da pressão ativa da terra

Moru retensaun dobro ho rai aterru fo presaun rai activu ba moru retensaun. Iha ne'eba iha metodu balu atu kalkua presaun rai activu, ita uza formula Coulomb nia.

$$K_A = \frac{\cos^2(\varphi - \alpha)}{\cos^2\alpha \cos(\alpha+\delta)\left\{1 + \sqrt{\frac{\sin(\varphi+\delta)\sin(\varphi-\beta)}{\cos(\alpha+\delta)\cos(\alpha-\beta)}}\right\}^2}$$

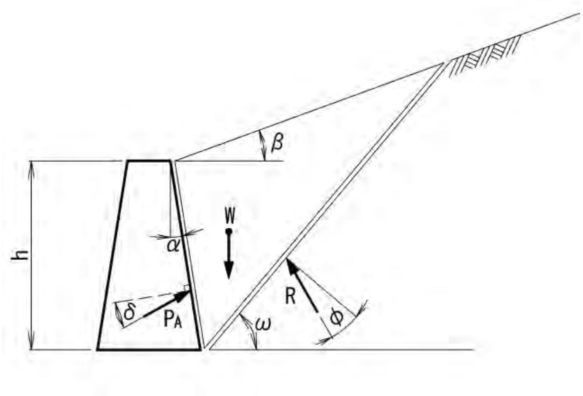
K_A: Active earth pressure coefficient

α: Angle between back surface of the wall and vertical line

β: Angle between ground surface and horizontal line

φ: Internal friction angle

δ: Friction angle between back surface of the wall and the soil



α degree	β degree	φ degree	δ degree	KA
0.0	0.0	30.0	20.000	0.297

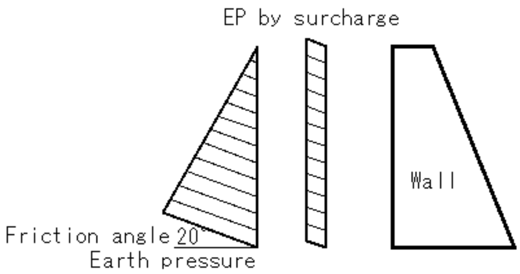
$$P_A = K_A\left(\frac{1}{2}\gamma h^2 + qh\right)$$

P_A: Active earth pressure acting on the wall

γ: Unit weight of the backfill

h: Height of the wall

q: Surchargeload on the road



Active Earth Pressure Coefficient	Backfill Unit Weight	Wall Height	Surcharge on the Road	Load Name	Load	Friction Angle of Wallback	Vertical Load	Arm Length	Moment	Horizontal Load	Arm Length	Moment
KA	γ kN/m3	h m	q kN/m2		PA kN	δ degree	V kN	x m	M kNm	H kN	y m	M kNm
0.297	19	3.000		Earth Pressure	25.4	20.000	8.7	0.000	0.0	23.9	1.000	23.9
0.297		3.000	10	EP by Surcharge	8.9	20.000	3.0	0.000	0.0	8.4	1.500	12.6
						Total	11.7		0.0	32.3		36.5
											ΣM=	36.5

(6) Tabela Sumariu ba todan no moments

Kada todan no ninia moments halo umario tiha ona ba iha todan vestikal total, todan horizontal total no total momen iha tabela sumariu hanesan iha karik ne'e.

Load Name	Vertical Load kN	Horizontal Load kN	Moment kNm
Wall Weight	82.8		53.8
Earth Pressure	11.7	32.3	36.5
Total	94.5	32.3	90.3

(7) Check pontus 3 husi index sabilidade

Moru retensaun tenke pasa pontu tolu kontrolu kona-ba índise estabilidade. Mak hanesan guling,geser no capacidade de carga fondasi rai. Sira ne'e hotu verifika liu husi excentricidade de resultante, fator seguransa hasoru geser no reasaun estresse iha moru nia ain hun no tumit.

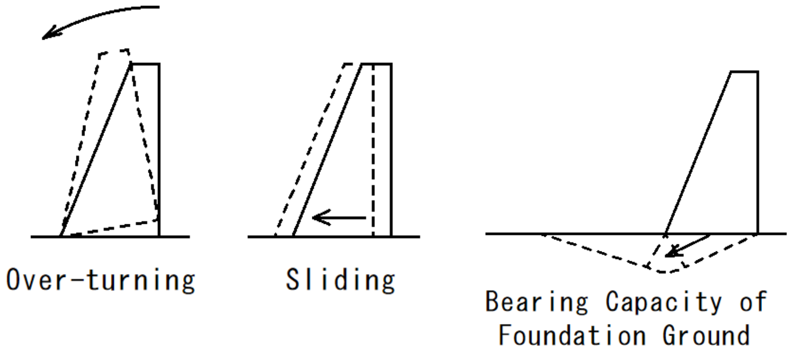


Figura 5.3 Tolu pontu kontrolu kona-ba índise estabilidade

(8) Kalkulsaun ba excentricidade ba rezultante

Koordinat X husi rezultante hanesan tuir mai ne'e.

$$\mathrm{X} = \frac{\sum M}{\sum V} = \frac{90.3}{94.5} = 0.956m$$

Excentricidade ba rezultante hanesan tuir mai ne'e.

$$\mathrm{e} = \mathrm{X} - \frac{B}{2} = 0.956 - 0.900 = 0.056m$$

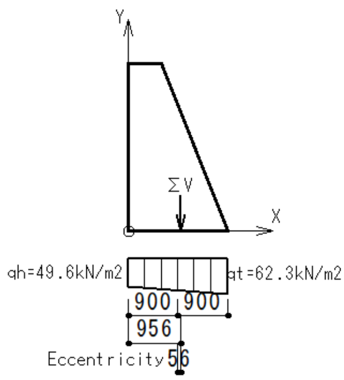
Excentrisidade ne'ebe mak permesivel B/6=0.300m, tanba ne'e, rezultadu tuun ba iha klaran terseiru. Kontrola pontu hasoru over-turning paasa ona.

$$\mathrm{e} = 0.056\mathrm{m} < \frac{B}{6} = 0.300m \quad \mathrm{OK}$$

(9) Kalkulasaun fatores ne'ebe seguru hasoru rai halai

Fatores seguru hasoru rai halai hanesan tuir mai ne'e. Fatór sira ne'ebé mak boot liu fali 1.5 tuirmai pontu kontrolu hasoru sliding aprova ona.

$$F_S = \frac{\mu \sum V}{\sum H} = \frac{0.6\times 94.5}{32.3} = 1.76 > 1.5 \ \ \mathrm{OK}$$



(10) Kalkulasaun reação tensão iha moru nia ain no tumit

Reação tensão iha moru nia ain no tumit mak hanesan tuir mai ne'e.

$$q_t = \frac{\sum V}{B}\left(1 + \frac{6e}{B}\right) = \frac{94.5}{1.800} \times \left(1 + \frac{6\times 0.056}{1.800}\right) = 62.3\ kN/m^2$$

$$q_h = \frac{\sum V}{B}\left(1 - \frac{6e}{B}\right) = \frac{94.5}{1.800} \times \left(1 - \frac{6\times 0.056}{1.800}\right) = 49.6\ kN/m^2$$

Tensão sira ne'ebe mak permitida 200 kN/m2 no pontus verifikasaun hasoru capacidade de rolamento ne'ebe passa.

5.3 Presaun rai ativo liu husi aterramento

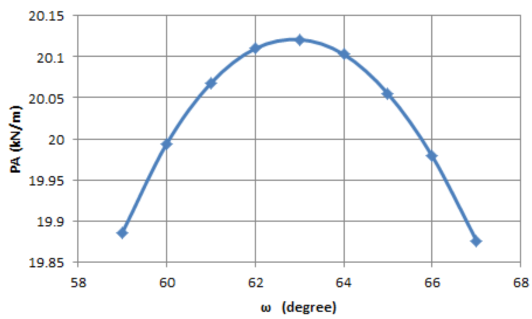
When a slope stands just behind of the wall trial wage method is applied for active earth pressure calculation instead of Coulomb's equation. Presaun rai mak aprezenta hanesan equasaun tuir mai. W mak todan husi upah, wainhira angulo deslizamento ω mak atribuido tuir mai W ita bele kalkula. Valor masimo ba P_A mak hanesan presão rai nian ne'ebe targetu tiha ona.

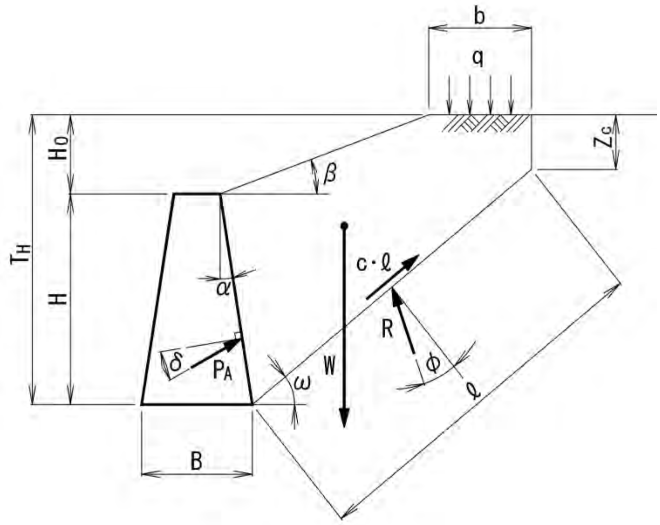
$$P_A = \frac{W\sin(\omega-\varphi)}{\cos(\omega-\varphi-\alpha-\delta)}$$

P_A: Active earth pressure

W: Weight of soil wedge

ω : Sliding angle of the wedge





Ita tenki determina unidade todan no resistência ao cisalhamento ba aterro ba kalkulasaun presão rai. Ita bele refere tabela tuirmai ba ida-ne'e.

Tabela 5.1 Unidade todan no resistência ao cisalhamento husi aterro

Type of Soil	Unit weight	Internal friction angle	Cohesion
	(kN/m³)	(degree)	(kN/m²)
Gravelly soil	20	35	0
Sandy soil	19	30	0
Clayey soil	18	25	0

Adopta husi biblia. [5]

5.4 Fondasi rai

Ita mos presija determina capasidade carga ne'ebe permite no cofiente atrito entre moru no fondasi rai. Ita bele konsulta tabela 5.2 ba ida ne'e. Se ita hasoru rai at barak nune'e ita bele konsulta ho Tabela 5.3 no 5.4.

Moru retensaun ne'ebe falha dala barak relasiona ho escassez husi capacidade de carga fondai rai. Halo estimasaun ba capasidade rekarga mak hanesan assunto ida ne'ebe defisil tebes ba enjineriu sira. Rai ne'ebe dura hanesan dalas fatuk baze ka dalas diluvium la apresenta problema. En kontráriu rai ne'ebé fraku hanesan colluvium ka fatuk weathered maka'as obriga ita avaliasaun sira ne'ebé loos. Informasaun jeolójika liuhusi investigasaun ajuda ita atu halo avaliasaun ba rai. Klasifikasaun, SPT-N ne'ebe tuan (penetrasaun Padraun teste N-valór) sira no informasaun ne'ebé mak bele konvense. Observasaun direta fondasi rai nian durante servisu sai oportunidade ikus ba avaliasaun.

Tabela 5.2 Capasidade rekarga ne'ebe permite no coefisiente atrito ba fondasi rai

Type of foundation ground		Allowable bearing capacity	Friction coefficient between wall and foundation	Remarks	
				Unconfined compressive strength	SPT N vale
		(kN/m²)	-	(kN/m²)	-
Base rock layer	Homogeneous hard rock with few cracks	1,000	0.7	10,000 and up	-
	Hard rock with a lot of cracks	600		10,000 and up	-
	Soft rock, Mudstone	300		1,000 and up	-
Gravel layer	Dense one	600	0.6	-	-
	Not dense one	300		-	-
Sandy layer	Dense one	300	0.6	-	30 to 50
	Medium one	200		-	20 to 30
Clayey layer	Very stiff one	200	0.5	200 to 400	15 to 30
	Stiff one	100		100 to 200	10 to 15

Adopta husi biblia. [5]

Tabela 5.3 Índice iha Terrenu atu estima capacidade de suporte ba iha dalas rai henek

Type	Condition	Index on Site	Allowable Bearing Capacity kN/m²	SPT N-value
Sandy Layer	Very loose	Reinforcement bar ϕ13mm easily penetrates by the hand.	0	Less than 4
	Loose	Scoop-able by the hand with shovel	50	4 to 10
	Medium	Reinforcement bar ϕ13mm easily penetrates by the hand with 2.2kgf hammer.	100	10 to 15
		Same as above Some effort is required.	200	15 to 30
	Dense	Same as above Depth reaches approx. 30cm.	300	30 to 50
	Very dense	Same as above Emitting metallic sound Depth reaches approx. 5cm.	300	Greater than 50

Tabela 5.4 Indice iha terrenu atu estima capacidade de carga ba dalas argilosa

Type	Condition	Index on Site	Allowable Bearing Capacity kN/m²	SPT N-value
Clayey Layer	Very soft	Fist easily penetrates about 10cm depth.	0	Less than 2
	Soft	Thumb easily penetrates about 10cm depth	20	2 to 4
	Medium	Thumb penetrates about 10cm with medium effort.	50	4 to 8
	Stiff	Thumb dents the surface with normal effort and penetrates with much effort	100	8 to 15
	Very stiff	Remove-able with spade	200	15 to 30
	Hard	Removing requires pickax	200	Greater than 30

6 Moru retensaun gravidade iha dezennu komuns

DNEPCC iha ona dezennu komun ne'ebe mosu bebeik ona iha projetu barak atu bele halo poupansa ba traballu kona ba drenajen,cross culvert, moru retensaun, gabion. pavementu nsst. Kapitulu ida ne'e trata moru retensaun iha dezennu komuns.

6.1 Forma moru nian

Iha tipu 2 ba retensaun moru gravidade iha dezennu komuns, forma sira ne'e hanesan hatudu tuir mai ne'e. Tipu 1 iha parte kotuk ne'ebe vertical no entre nia gradiente 1:0.4 iha parte oin. En kontrario, tipu 2 iha gradiente inverso 1:0.45 to'o 1:0.49 iha parte kotuk no gradiente 1:0.1 iha parte oin. Largura topo nia mak 0.6 m ba kada tipu.

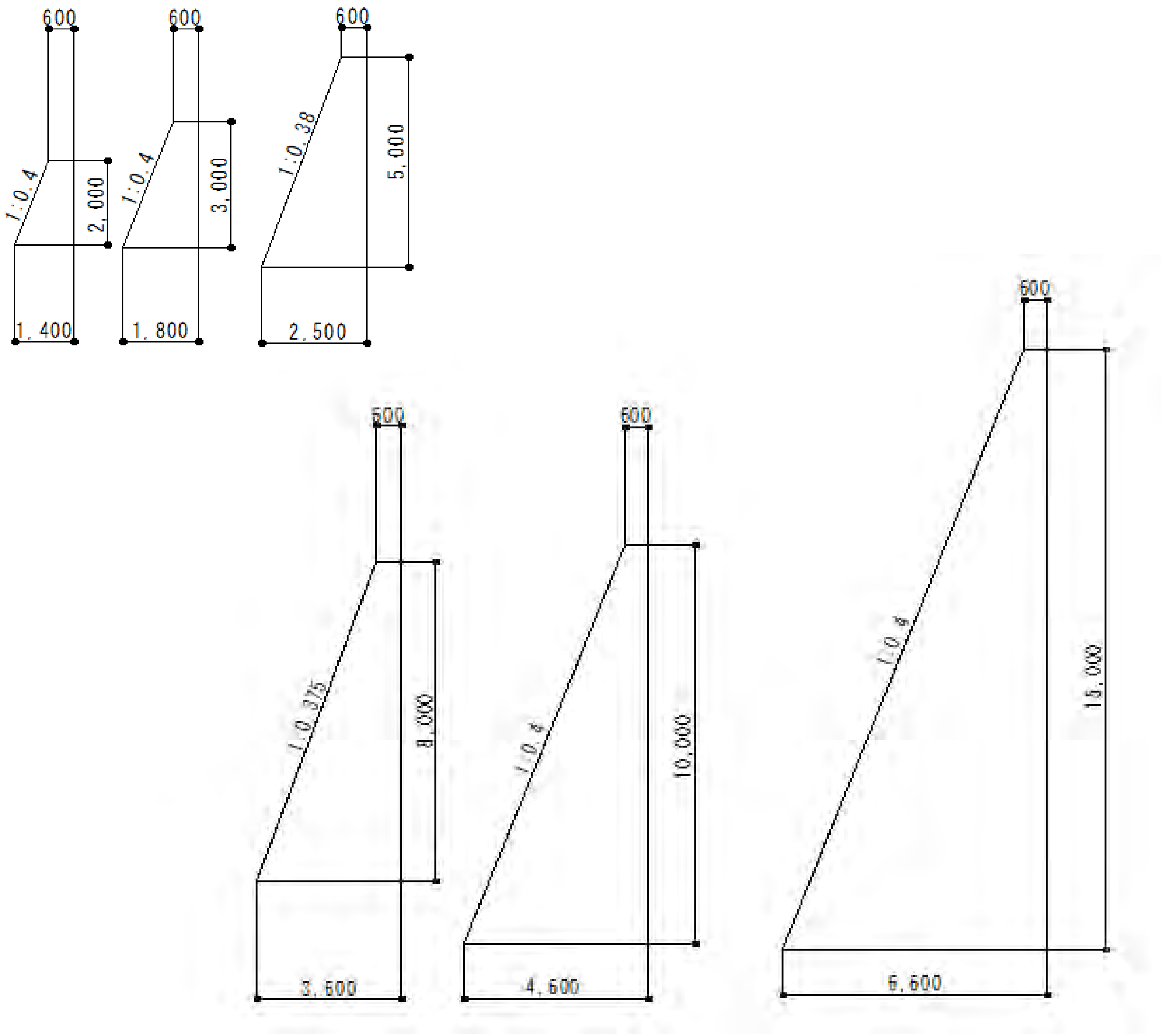


Figura 6.1 Forma husi moru tipu 1

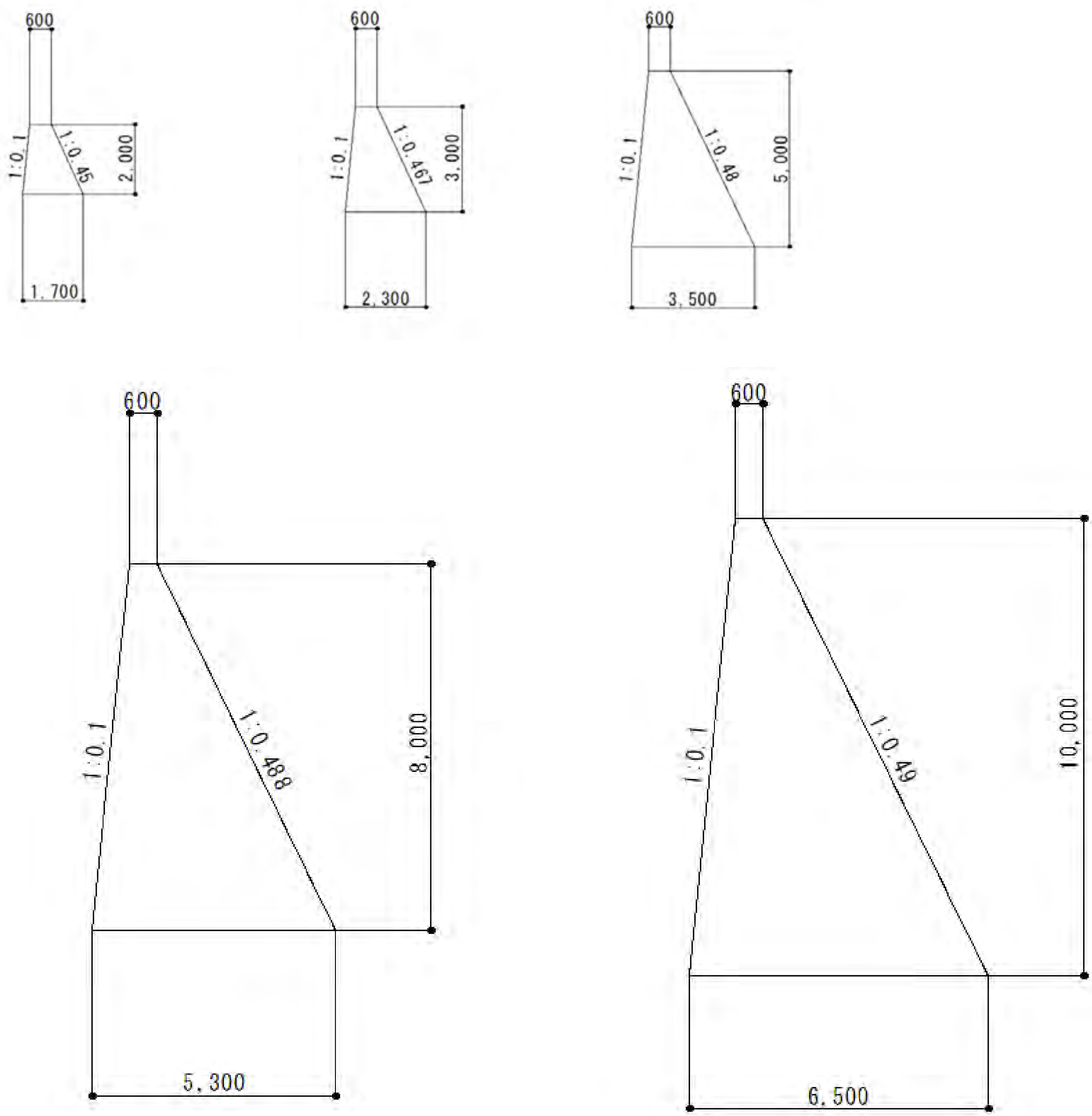


Figura 6.2 Forma husi moru tipu 2

6.2 Rezultadu kalkulasaun stabilidade

Tabela sira ne'e hatudu rezultadu husi kalkulasaun stabilidade iha tipu 1 no tipu 2. Kondisaun kalkulasaun nia mak; altura aterro nian ne'ebe mak hanesan ho moru nia topu, superficie aterro mak horizonta, presão rai nia kalkula iha unidade aterrro nia okos 19 kN/m^3 no o ângulo de atrito 30deg, sobretaxa estrada 10 KN/m^2 iha estrada nia superficie.

Tabela 6.1 Rezultadu tipu 1 kalkulasaun stabilidade

Wall Body			Earth Pressure			Load Summary			Eccentricity		Bearing Capacity
Wall Height H m	Base Width B m	CS_Area A m2	Total EP PA kN/m	Vertical EP PAV kN/m	Horizontal EP PAH kN/m	Siguma_V ΣV kN	Sigma_H ΣH kN	Siguma_ Moment ΣM kNm	Eccentric Length e m	6e/B	Max Reaction Stress qmax kN/m2
2	1.40	2.00	17.24	5.90	16.20	51.90	16.20	37.43	-0.021	-0.09	40.4
3	1.80	3.60	34.34	11.74	32.27	94.54	32.27	84.08	0.011	0.04	54.5
5	2.50	7.75	85.48	29.24	80.32	207.54	80.32	229.60	0.144	0.35	111.7
8	3.60	16.80	204.55	69.96	192.22	456.36	192.22	654.39	0.366	0.61	204.1
10	4.60	26.00	312.18	106.77	293.35	704.77	293.35	1,332.20	0.410	0.53	235.2
15	6.60	54.00	680.11	232.61	639.09	1,474.61	639.09	3,779.74	0.737	0.67	373.1

Tabela 6.2 Rezultadu tipu 2 kalkulasaun stabilidade

Wall Body			Earth Pressure			Load Summary			Eccentricity		Bearing Capacity
Wall Height H m	Base Width B m	CS_Area A m2	Total EP PA kN/m	Vertical EP PAV kN/m	Horizontal EP PAH kN/m	Siguma_V ΣV kN	Sigma_H ΣH kN	Siguma_ Moment ΣM kNm	Eccentric Length e m	6e/B	Max Reaction Stress qmax kN/m2
2	1.70	2.30	30.90	21.56	22.15	74.46	22.15	52.37	0.147	0.52	66.5
3	2.30	4.35	62.80	44.42	44.39	144.52	44.39	129.99	0.251	0.66	104.0
5	3.50	10.25	158.85	113.57	111.06	349.37	111.06	448.93	0.465	0.80	179.4
8	5.30	23.60	383.56	275.86	266.50	818.66	266.50	1,520.90	0.792	0.90	293.0
10	6.50	35.50	587.13	423.09	407.08	1,239.59	407.08	2,786.94	1.002	0.93	367.1

6.3 Kondisaun guling

Seguransa kontra guling mak avalia forsa rezultante muda ba iha area terço médio husi moru nia baze. Kriteria ida ne'e signifika katak iha ne'eba laiha zona de tensão iha baze hanesan hatudu iha Figura 6.3.

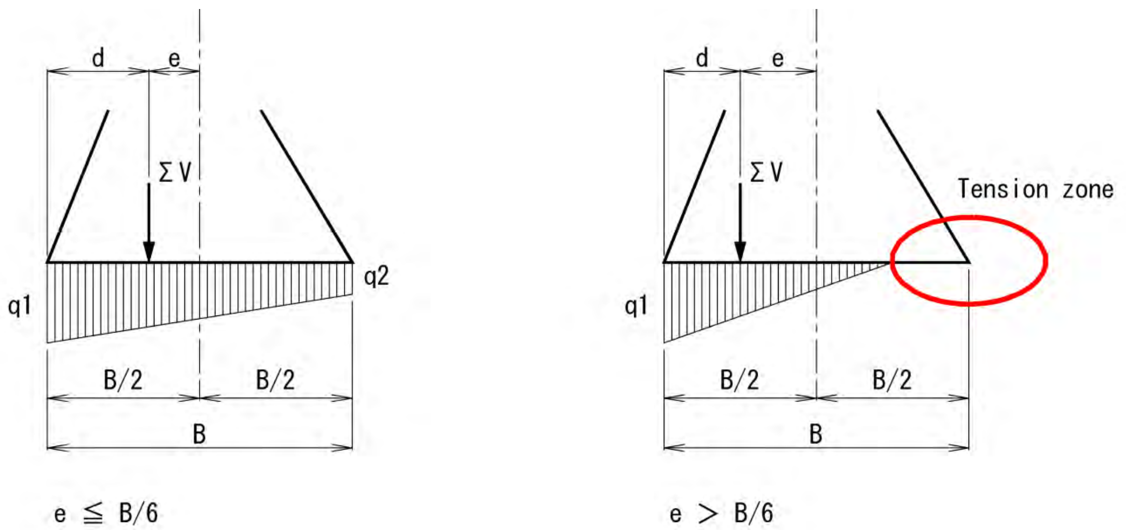


Figura 6.3 Korelasaun entre excentricidade no distribuisaun husi reaksaun ba presaun rai

Ida-ne'e bele fó husi equasaun tuir mai.

$e \leq \frac{B}{6}$ $\frac{6e}{B} \leq 1$

6e/B ne'ebe ita tenki bolu proposaun eksentridade mak hanesan hatudu iha figura tuir mai. Moru hotu-hotu pasa pontu kontrolu ba médiu terseiru. Pontu kontrolu ida ne'e la liga fondasi rai maibé forma moru no aterro presaun rai. Zona negativa husi proporção signifika katak forsa rezultante muda parte sorin husi tumit baze moru nian.

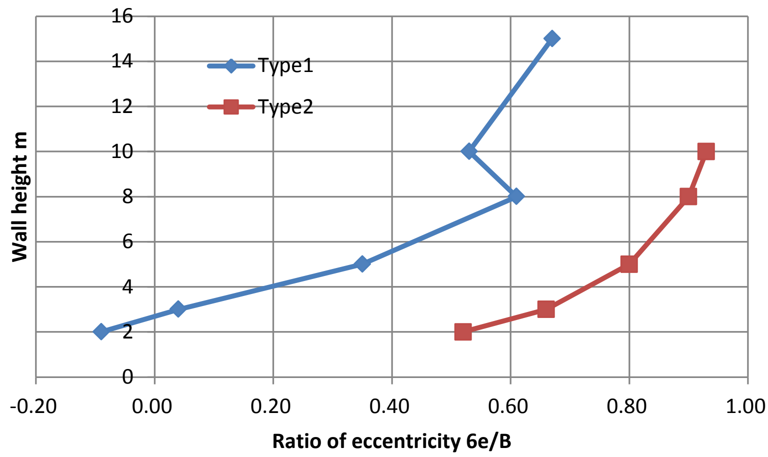


Figura 6.4 Kondisaun guling iha moru

6.4 Condição de deslizamento

Fator seguransa kontra deslizamento mak hanesan fo ona iha equasaun tuir mai.

$F_S = \frac{\mu \sum V}{\sum H} \geq 1.5$ $\mu \geq \frac{1.5 \sum H}{\sum V}$

Coeficiente de atrito solicitado entre moru no fondasi no bele kalkulaho equasaun hanesan figura tuir mai ne'e. Hare ba tabela 5.2 coeficientes de atrito mak;dalas fatuk baze 0.7, dalas gravel no rai henek 0.6, dalas rai lempung 0.5. Tamaba ne'e tipu 1 ho as liu 7 m tenki hamrik iha rai ho dalas fatuk, ho as 3 m to'o 6 m tenki hamrik iha rai ne,ebe nia dalas arenosa no as 2 m bele hamrik iha rai ne'ebe ho nia dalas argilosa. Iha sorin seluk tipu 2 ho as sira ne'e hotu laiha problema kona ba kondisaun geser.

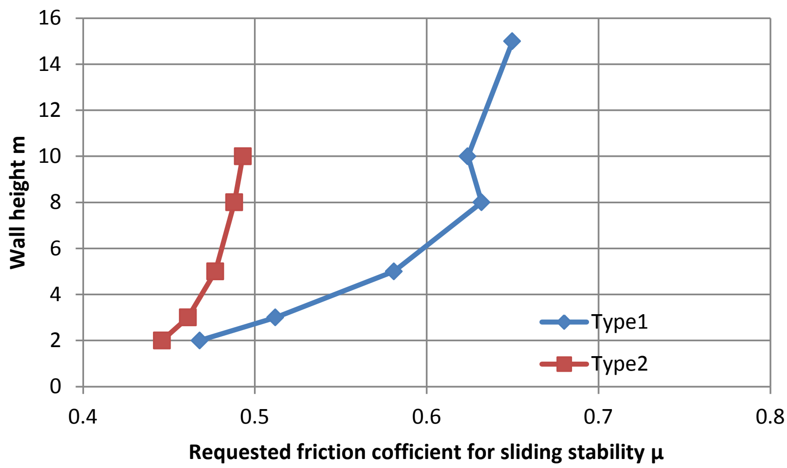


Figura 6.5 Kondisaun deslizamento moru/parede

6.5 Condição de capacidade de rolamento

Presaun reasaun tenki kiik kompara ho capasidade suporte ne'ebe permiti husi fondasi rai. Reasaun presaun masimu ba rai fondasi normalmente mosu iha moru nia ain. ida ne'e bele kalkula ho Equasaun tuir mai ne'e.

$$q_t = \frac{\sum V}{B}\left(1 + \frac{6e}{B}\right)$$

Tipu 1 iha vantagem iha pontu ida ne'e tamba tensaun ne'ebe kiik liu tipu 2 ho moru nia as ne'ebe hanesan. Refere Tabela 5.2 to 5.4 capasidade rolhamento ne'ebe permite mak; lapisan batuan dasar 300 to'o 1,000 kN/m^2, dalas gravel 300 to'o 600kN/m^2, dalas rai henek 0 to'o 300kN/m^2 no dalas argilosa 0 to 200kN/m^2. Iha area foho leten,dala barak ita hasoru deposito colluvial iha ne'ebe konsite matriz argilosa e cascalho. Matrix argila tenki atinji etapa rigido iha kondisaun diak nune'e capasidade rolhamento bele iha entre 100kN/m^2. Ita bele dehan katak rai iha area foho bele tahan ho tipu 1 H≤4m no tipu 2 H≤2m deit. Tamba ne'e moru nia as H>5m iha area foho tenki hamrik ho rai ne'ebe nia baze fatuk tamba ninia capasidade ba suporta nian.

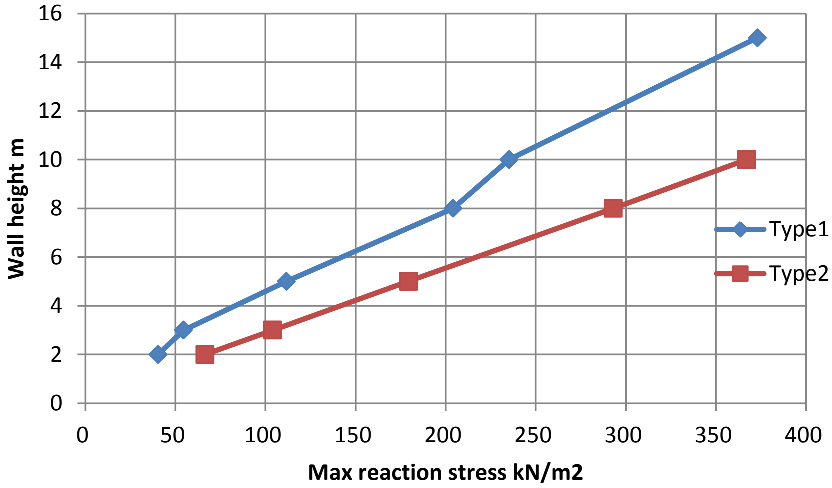


Figura 6.6 Kondisaun capacidade de rolamento moru

6.6 Tipu ne'ebe adequada

Kuandu ita deside tipu gravidade didin ita tenke fó atensaun ba asuntu adekuasaun kona-ba tipu.

(1) Area seksaun transversal

Figura tuir mai komparasaun ba area seksaun transversal entre tipu 1 no tipu 2. Tipu 1 iha vantagem liu iha pontu ida ne'e, especialmene tipu 1 baratu liu do que tipu 2 ho moru nia as ne'ebe hanesan.

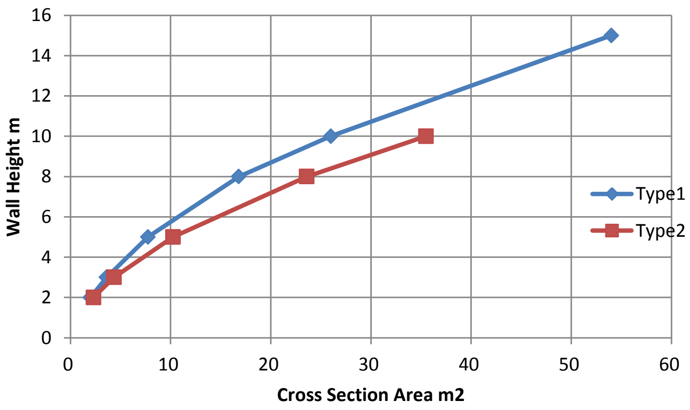


Figura 6.7 Komparasaun ba area seksaun transveresal

(2) Fondasi rai

Type 2 iha vantajen ba kondisaun deslizamento hanesan ita estuda iha seksaun 6.4 maibé type1 iha vantajen ba kondisaun kapasidade de carga hanesan ho seksaun 6.5. Kondisaun 2 ne mak relasaun pontu komersiu. Type 1 iha ΣV ne'ebé ki'ik liu type2, nia bele hetan vantajen tanba ki'ik reasaun presaun, q_t, ki'ik hasoru capasidade carga no bele sai desvantajen tanba forsa rezisténsia ki'ik liu hasoru deslizamento.

(3) Forma rai nian

Bainhira didin iha rai orizontál didin presiza naruk mak 5 m hanesan mos ba tipu rua ne'e. Por ezemplu, oinsa ho inclinasaun 30 grau? Tipu 1 presiza adicional 1,952 m atu bele kaerrai iha moru okos. Tipu 2 bele kona rai ho addicional 0.647 m. Tamba ne'e, tipu 2 mak adequado liu ba declive nia okos.

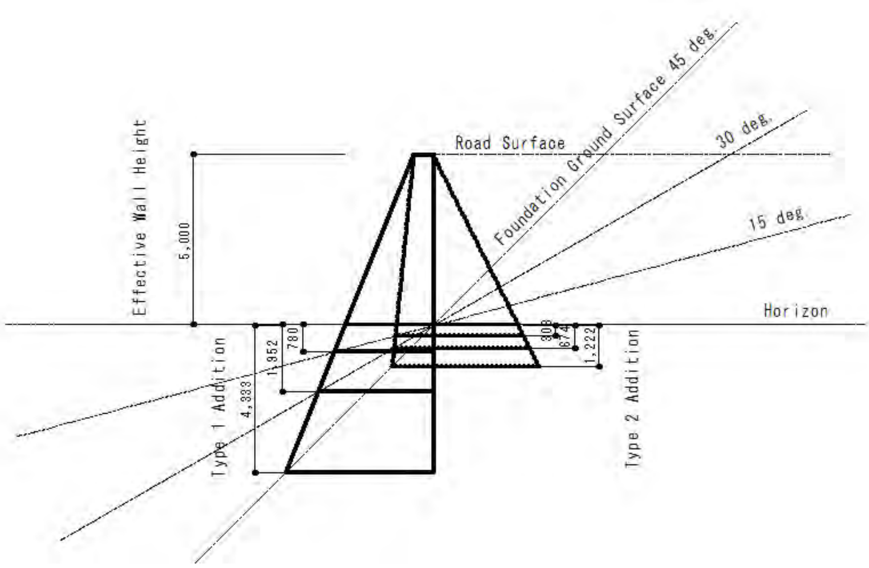


Figura 6.8 Presenta adequasaun ba rai ne'ebe halis

7 Capasidade de carga

Hanesan deskreve iha seksaun 5.4 estimasaun ba bearing capacity ba fondasi rai nia mak sai hanesan asuntu ne'ebe defisil tebes ba enjineru sira. Valor ba referensia mak hanesan iha Tabela 5.2 to'o 5.4 iha seksaun 5.4. Kapítulu ida ne'e aprezenta abordajen sira selukba kapasidade carga.

7.1 Capacidade de rolamento final da Terzaghi

Waihira aplika todan ida iha rai horizontal mak iha ne'eba iha tipu rua husi relasaun todan liquidação hanesan hatudu iha figura tuir mai. Rai ne'ebe iha forsa nivel mediu hanesan dense sandy layer hatudu "Failansu cisalhamento jeral". Capacidade de rolamento final bele identifika kona ba relasaun faillansu ida ne'e.

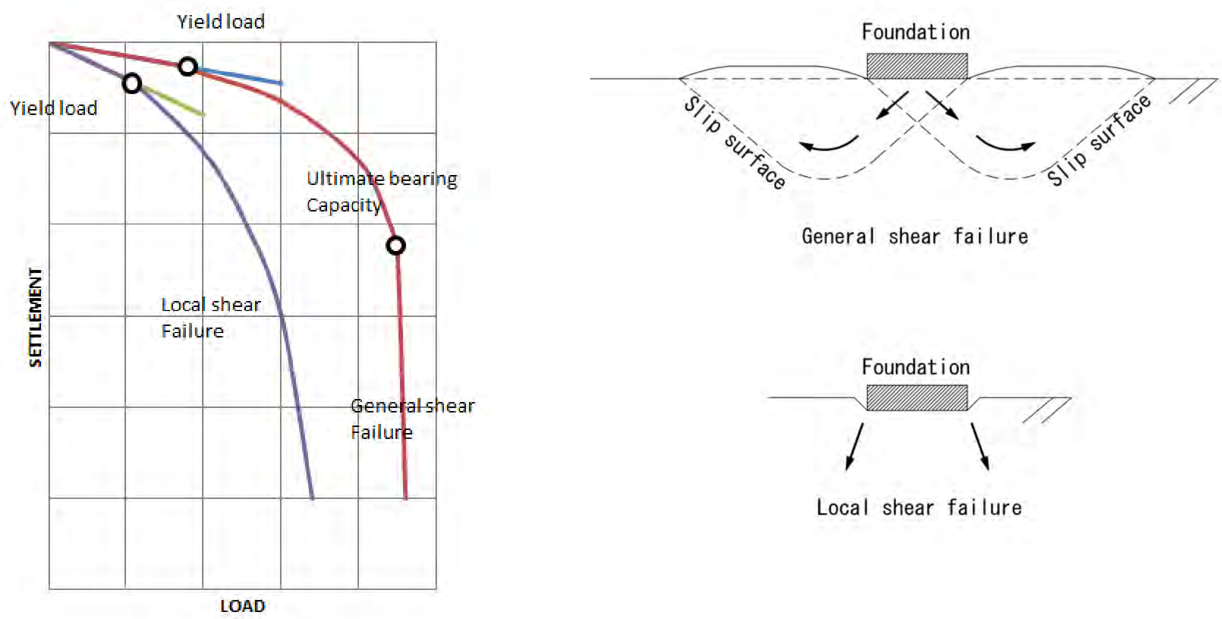


Figura 7.1 Relasaun entre todan-Penurunan

Terzaghi mak hanesan aman mekánika rai ne'ebé halo equasaun ida ba últimu bandu kapasidade hanesan tuirmai ne'e.

$$\frac{Q}{B} = cN_c + q_s N_q + \frac{1}{2}\gamma_t B N_\gamma$$

Q: Ultimate bearing capacity of the foundation ground

B: Width of Base

c: Cohesion of the foundation ground

qs: Uniform load on the foundation ground (Surcharge loads)

γt: Unit weight of the foundation ground

Nc, Nq, Nγ: Coefficient of bearing capacity

$$N_c = 2\left(K_p^{1.5} + K_p^{0.5}\right) \qquad N_q = K_p^2 \qquad N_\gamma = \frac{1}{2}\left(K_p^{2.5} - K_p^{0.5}\right)$$

$$K_p = tan^2\left(\frac{\pi}{4} + \frac{\varphi}{2}\right)$$

7.2 Influencia husi resistência ao cisalhamento ba capacidade de carga final

Wainhira ita halo kalkulasaun ba capasidade rolamento final liu husi equasaun Terazaghis ita persija atu defini peso unitaria, coesão no ângulo fricção internal rai nian. Iha ne'e ita koko atu hatene oinsa valor influensia husi rezultadu iha ezemplu rua ne'e.

Ezemplu 1; Type1, H=2m, ΣV=51.90kN, ΣH=16.20kN, e=-0.021m Rezultadu iha Figura 7.2

Ezemplu 2; Type1, H=3m, ΣV=94.54kN, ΣH=32.27kN, e=-0.011m Rezultadu iha Figura 7.3

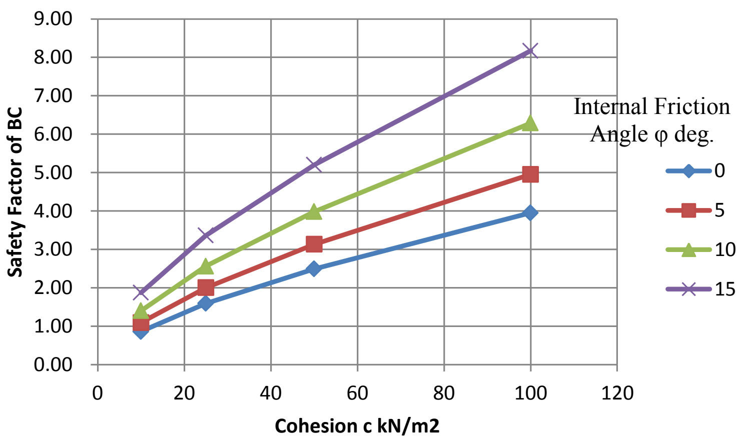
$$F_s = \frac{Q_u}{\Sigma V} \geq 3$$

Fs: Safety factor of bearing capacity

Qu: Ultimate bearing capacity

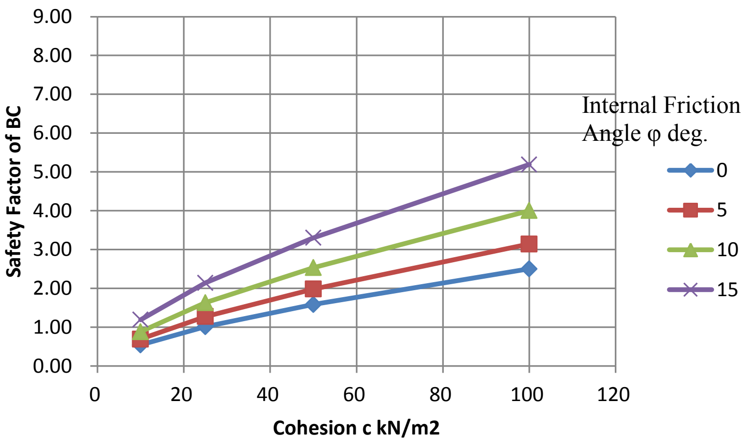
ΣV: Total vertical load

Influência valor resistência ao cisalhamento rai nia bo'ot. Tamba ne'e ita tenki kuidade atu defini valores. Se rai permite ba teste Dokenbo shear strength, ita bele hetan clue balun husi rezultadu teste ne'e.



Foundation Ground			Result	
Internal Friction Angle φ degree	Cohesion c kN/m2	Unit Weight γ kN/m3	Ultimate Bearing Capacity Qu kN	Safty Factor Fs -
0	10	18	445	0.86
	25		824	1.59
	50		1,292	2.49
	100		2,049	3.95
5	10		564	1.09
	25		1,037	2.00
	50		1,622	3.13
	100		2,568	4.95
10	10		728	1.40
	25		1,328	2.56
	50		2,068	3.98
	100		3,267	6.29
15	10		971	1.87
	25		1,743	3.36
	50		2,697	5.20
	100		4,241	8.17

Figura 7.2 Influencia husi c no ϕ ba Qu Tipu 1 H=2m



Foundation Ground			Result	
Internal Friction Angle φ degree	Cohesion c kN/m2	Unit Weight γ kN/m3	Ultimate Bearing Capacity Qu kN	Safty Factor Fs -
0	10	18	515	0.54
	25		952	1.01
	50		1,493	1.58
	100		2,368	2.50
5	10		651	0.69
	25		1,199	1.27
	50		1,876	1.98
	100		2,971	3.14
10	10		835	0.88
	25		1,539	1.63
	50		2,396	2.53
	100		3,784	4.00
15	10		1,127	1.19
	25		2,020	2.14
	50		3,124	3.30
	100		4,911	5.19

Figura 7.3 Influencia husi c no ϕ ba Qu Tipu 1 H=3m

7.3 Influensia husi parte oin taludes ba capasidade rolhamento final

Iha area foho dala barak ita labele escolha maibe estabele moru encosta ba taludes. Iha ne'e, ita koko atu hatene parte oin husi taludes nia influensia ba capacidade de carga iha ezemplu rua ne'e.

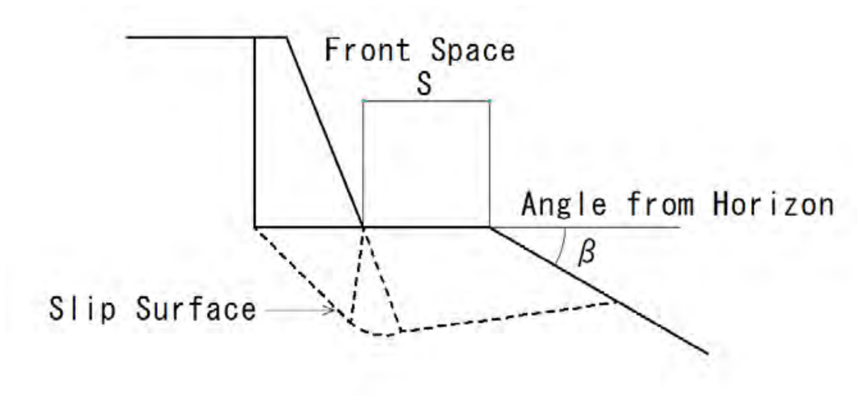


Figura 7.4 Espasu oin no angulo taludes iha kazu moru hari besik ba iha taludes

[Kondisaun kalkulasaun]

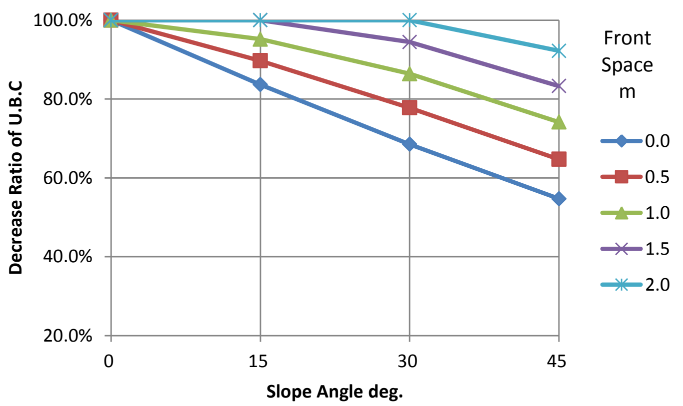
Forsa resultante no excentricidade mai husi tipu 1 H=3m

Ezemplu 1; Fundasaun rai argilosa (tanah lempung), φ=15deg, c=50kN/m^2, γ=18kN/m^3

Ezemplu2; Fundasaun arenoso, φ=30deg, c=10kN/m^2, γ=19kN/m^3

(1) Kazu fundasaun rai argilosa (tanah lempung)

Sob S=0m no β=45deg, capasidade rolhamento final diminuis 55% husi rai horizontal iha kazu rai argilohusi. Sob S=2m, Qu nafatin liu 90% tan ne'e ita bele dehan katak 2m iha pate oin mak efektivu liu hasoru influensia iha parte oin taludes iha kazu rai argilosa.

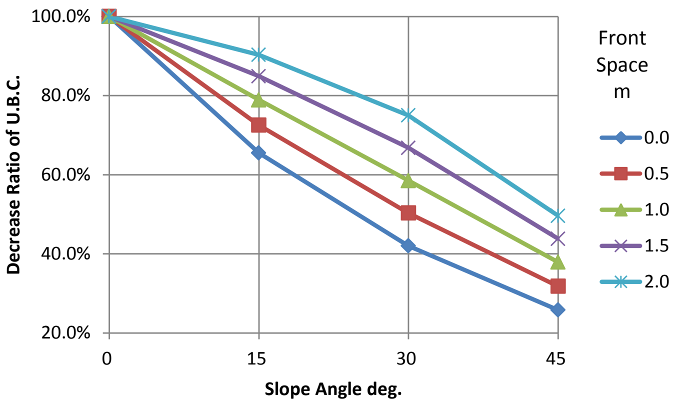


Slope Shape		Result		
Front Space S m	Angle from Horizon β degree	Ultimate Bearing Capacity Qu kN	Decrease Ratio of U.B.C %	Safty Factor Fs -
0.0	0	3,193.0	100.0	3.38
	15	2,670.8	83.6	2.83
	30	2,187.6	68.5	2.31
	45	1,746.2	54.7	1.85
0.5	0	3,193.0	100.0	3.38
	15	2,864.5	89.7	3.03
	30	2,483.9	77.8	2.63
	45	2,066.0	64.7	2.19
1.0	0	3,193.0	100.0	3.38
	15	3,038.9	95.2	3.21
	30	2,758.8	86.4	2.92
	45	2,367.8	74.2	2.50
1.5	0	3,193.0	100.0	3.38
	15	3,193.0	100.0	3.38
	30	3,016.0	94.5	3.19
	45	2,659.3	83.3	2.81
2.0	0	3,193.0	100.0	3.38
	15	3,193.0	100.0	3.38
	30	3,193.0	100.0	3.38
	45	2,943.9	92.2	3.11

Figura 7.5 Influensia husi parte oin taludes nia iha fundasaun rai argiloso

(2) Kazu fundasaun rai arenoso

Sob S=0m no β=45deg, capasidade rolhamento diminui 26% husi rai horizontal ba kazu rai arenoso. Sob S=2m no β=45deg, Qu diminui nafatin 50%. Rai arenoso sensitivo liu ba iha infliuensia parte oin taludes do que rao argiloso. Tamba ne'e ita tenki tau etensaun ba kazu ida ne'e.

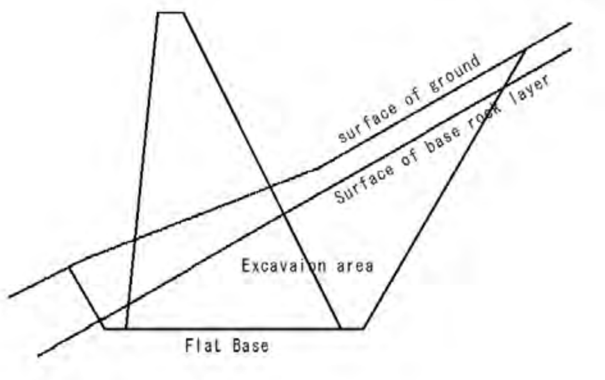


Slope Shape		Result		
Front Space S m	Angle from Horizon β degree	Ultimate Bearing Capacity Qu kN	Decrease Ratio of U.B.C %	Safty Factor Fs -
0.0	0	4,115.0	100.0	4.35
	15	2,696.1	65.5	2.85
	30	1,726.3	42.0	1.83
	45	1,060.5	25.8	1.12
0.5	0	4,115.0	100.0	4.35
	15	2,981.8	72.5	3.15
	30	2,068.4	50.3	2.19
	45	1,310.6	31.8	1.39
1.0	0	4,115.0	100.0	4.35
	15	3,247.6	78.9	3.44
	30	2,409.1	58.5	2.55
	45	1,559.0	37.9	1.65
1.5	0	4,115.0	100.0	4.35
	15	3,492.5	84.9	3.69
	30	2,748.4	66.8	2.91
	45	1,803.6	43.8	1.91
2.0	0	4,115.0	100.0	4.35
	15	3,714.2	90.3	3.93
	30	3,085.2	75.0	3.26
	45	2,039.3	49.6	2.16

Figura 7.6 Influensia husi parte oin fundasaun rai arenoso

7.4 Etapa corte fundasaun

Hanesan deskreve ona iha seksaun 6.5 moru nia as H>5m iha area foho tenki hamrik iha rai dalas fatuk tamba capasidade de carga. Iha kazu ne'ebe fondasi tetuk presija eskavasaun hanesan hatudu ne'e.



Etapa corte fundasaun bele resolve problema ne'e. Ezemplu mak hanesan hatudu iha Figura 7.7.

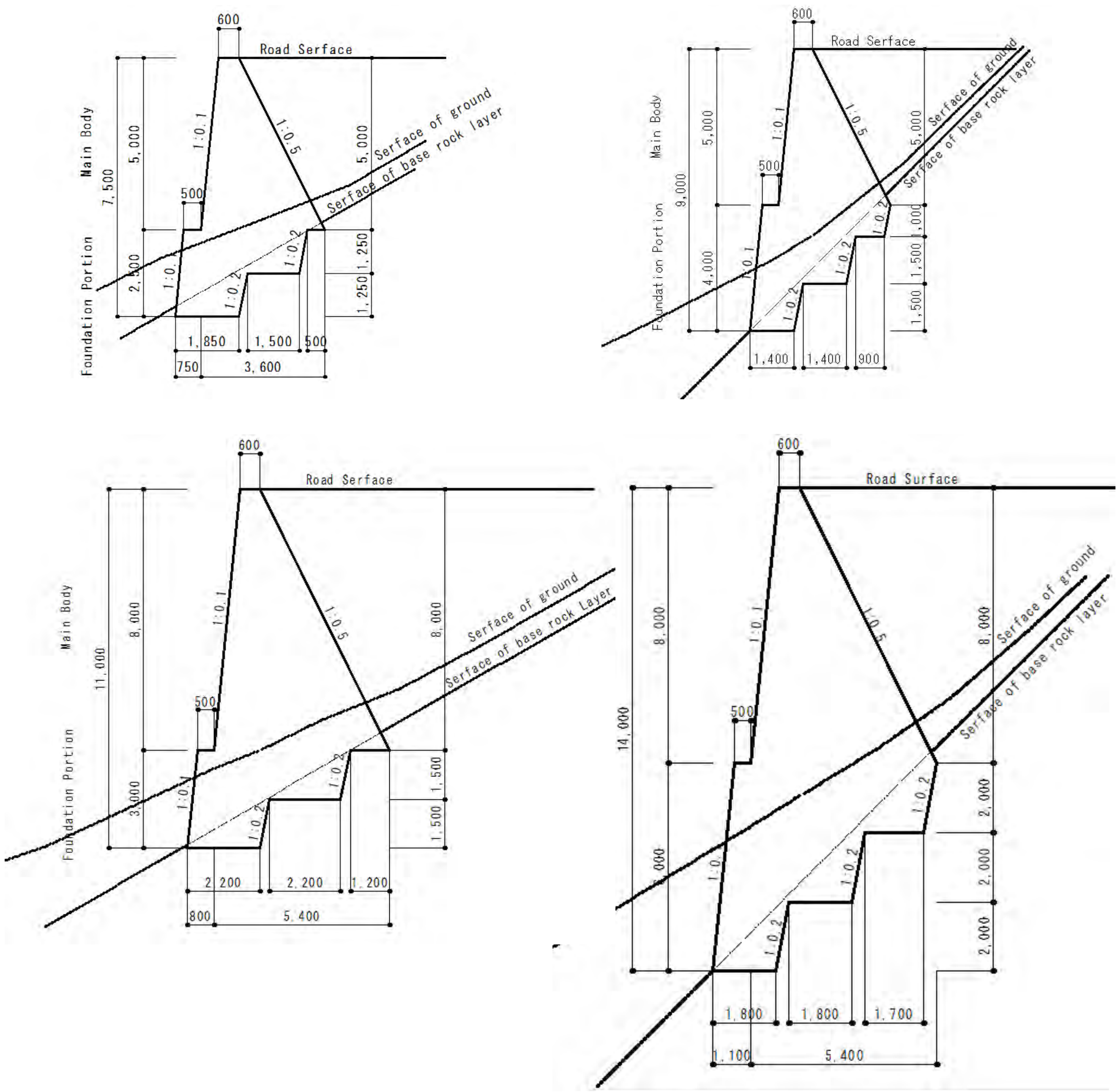


Figura 7.7 Ezemplu husi corte fundasaun

8 Taludes

8.1 Klasifikasaun Taludes

Saida mak taludes? Taludes laos tetuk maibe inklinasaun iha rai tetuk. Rai iha area foho barak liu konsiste ho taludes. En kontrariu superficie be'e laos inklina maibe tetuk. Saida mak halo diferenten entre rai no be? Be laiha resistência cisalhamento. Rai, ida ne'e signifika katak rai ho massa fatuk, bele manten taludes ninia forma hasoru forsa gravidade tangensial liu husi forsa cisalhemento rasik. Iha liafuan seluk, rai carrega gravidade iha momentu hotu-hotu.

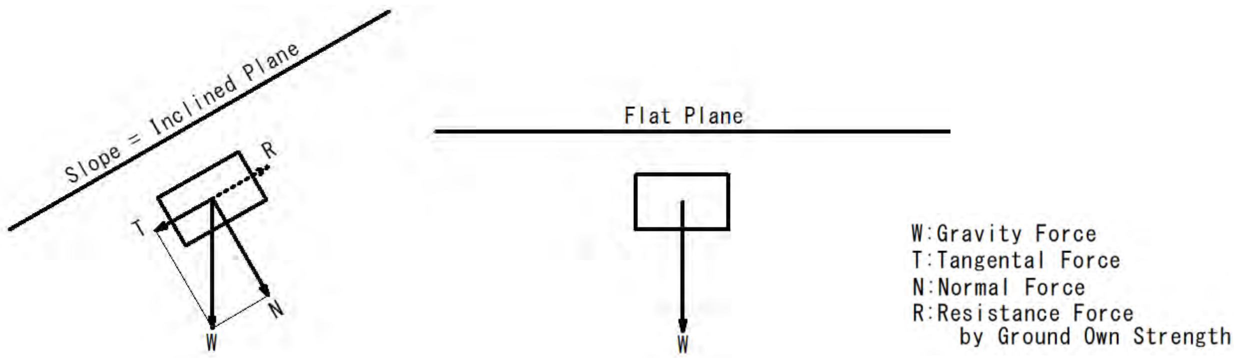


Figura 8.1 Diferensia entre taludes no rai tetuk

Taludes prinsipalmente bele klasifika ba iha declive natural no declive aterru. Declive natural bele fahe ninia orjinalidade, collapso no declive corte. Tabela ne'e hatudu karakteristika husi declive. Unika inclinação ba aterro mak konsiste husi material bancário nune'e ita bele kontrola ninia forsa iha konstrusaun.

Tabela 8.1 Klasifikasaun no karakteristika rai halis

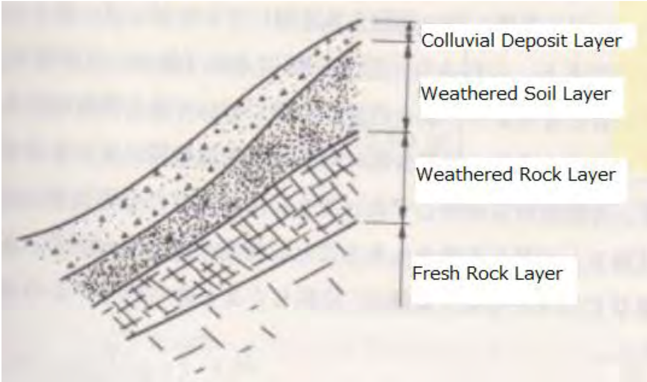
Classification	Shape	Geology	
Natural Slope	Natural Terrain	Natural Ground	Complexity Inhomogeneous
Collapsed Slope	Collapsed Gradient		
Cut Slope	Cut Gradient		
Embankment Slope	Embankment Gradient	Banking Material	Random –Selected material Homogeneous

8.2 Declive natural

Foho ne'e baibain halo husi massa fatuk exceto rai ho ninia dalas superficie ne'ebe mihis. En kontrariu,planície aluvial iha rai nia dalas ne'ebe mihis. Kompojisaun típica superfície ba declive natural mak hatudu ona iha Figura 8.2. Depósito coluvial no pelapukkan rai mak superficie rai nia dalas. Depósito coluvial muda ona husi collapso iha passado maibe pelapukkan rai nafatin iha ninia prozisaun orijinal. Collapso akontese bebeik iha rai nia dalas tamba ninia fraqueza.

Wainhira akontese collapso iha dalas massa fatuk quase sempre trava durante retak. Forsa durante retak domina hotu collapso dalas fatuk.

Be'e subterrânea hela iha dalas rai ne'ebe mamuk no dalas fatuk ne'ebe retak. Be iha rai okos ne'ebe sae dala barak bele provoka collapso.



Adopta husi biblia. [2]

Figura 8.2 Composição da superfície do declive natural

8.3 Recortar declive

Recortas declive ne fraco liu declive orijinal,tamba razaun tuir mai ne'e. Primeiro, corte halo presaun rai nia kondisaun muda an. Dala ruma pressaun compressaun muda ba presaun tensaun. This phenomenon is called as stress-release. Seluk tan, gradiente ba corte tenki naruk liu ho declive orijinal..

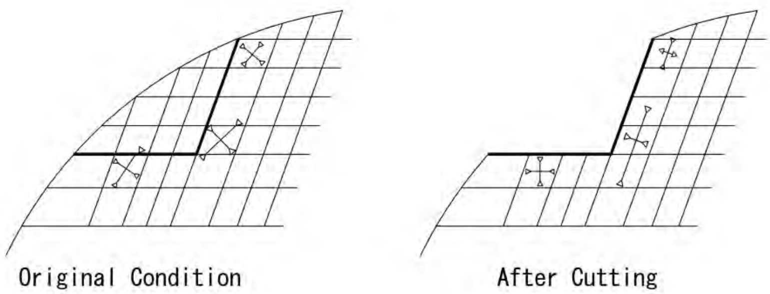


Figura 8.3 Imprensa tensaun iha corte inclinação.

Corte inclinação mak exposto ba anin hanesan isin molik. Limpasan erosi no pelapukkan akontese neneik ba neneik. Slaking halo mud stone rahun ba cada pedaços. Drenajen no protesaun de taludes mak contramedida hasoru sira ne'e hotu.

Erosaun

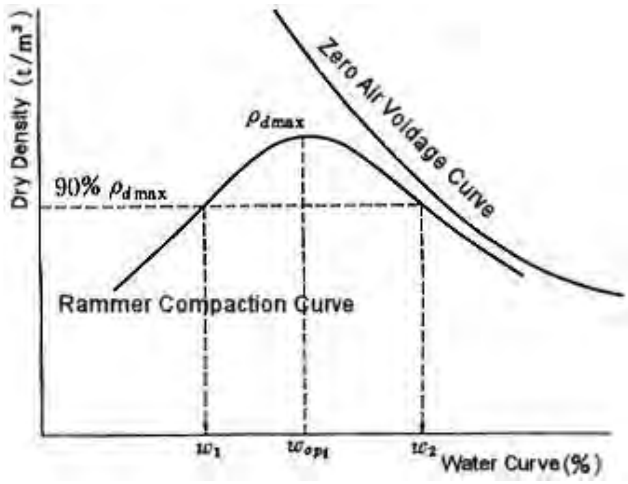
Slaking

Figura 8.4 Erosaun no intemperismo iha inclinação de corte

8.4 Inclinação rai aterru

8.4.1 Rai aterro nia isin lolon

Ita bele selesiona material aterro no prosedimentu compactação. Kondisaun ne'ebe presija ba aterro ne'ebe forte mak; material iha ninia distribuição granulométrica ne'ebe diak, konteudu be besik ho konteudu be ne'ebe optimu no energia compactação ne'ebe adequada. Aterru bele hetan densidade ne'ebe as no besik densidade maran ne'ebe masimu. Ida ne'e signifika katak aterru ne'e hetan resistência ao cisalhamento ne'ebe as no besik na ninia resistensia masimu.



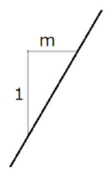
Adopta husi biblia. [5]

Figura 8.5 Kurva compactação rai

Gradiente ne'ebe adequadu ba talude mak hanesan hatudu iha Tabela 8.2. Erosaun no pelapukkan akontese iha inclinacao de aterro no hanesan mos ho inclinacao de talude.

Tabela 8.2 Gradiente ba taludes ne'ebe adequadu

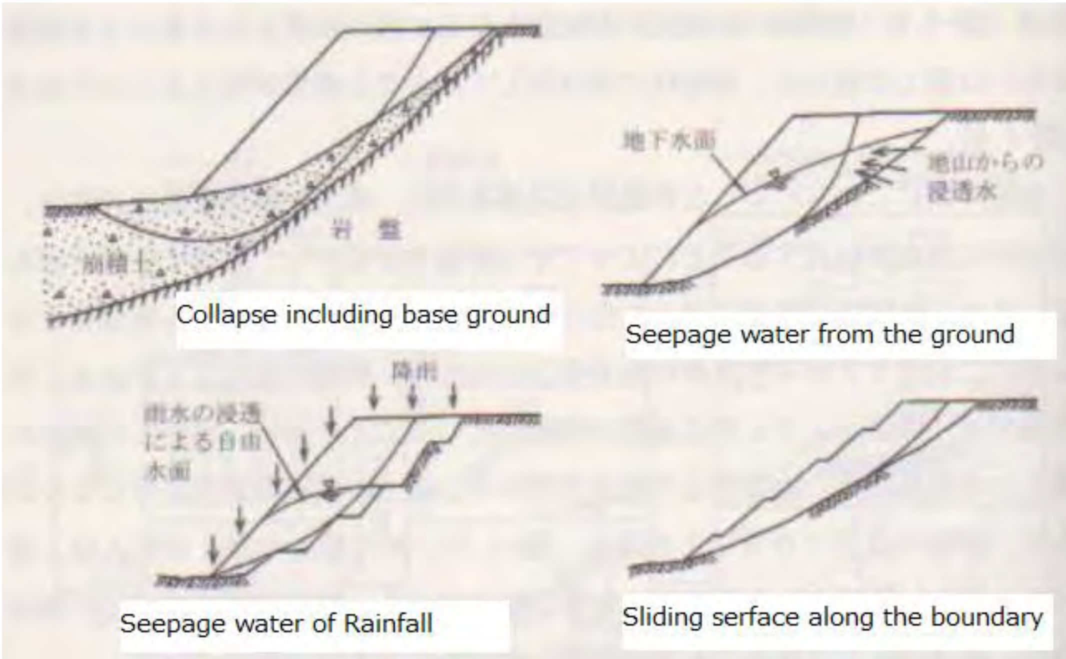
Banking materials	Height of embankment (m)	Standard gradient	Remarks
Well-graded Sand (S), gravel, and sand mixed with gravel (G)	Less than 5m	1:1.5 to 1: .8	To be applied to embankments with sufficient bearing capacity at foundation ground, which is not affected by inundation.
	5m to 15m	1:1.8 to 1:2.0	
Poorly-graded Sand (SG)	Less than 10m	1:1.8 to 1:2.0	
Rock masses (including muck)	Less than 10m	1:1.5 to 1:1.8	Typical unified soil classification are shown in ( ) for reference.
	10m to 20m	1:1.8 to 1:2.0	
Sandy soil (SF), hard clayey soils and hard clay (hard clayey soils and clay of alluvium, loam, etc.)	Less than 5m	1:1.5 to 1:1.8	In case of exception of standard slope is needed the stability calculation.
	5m to 10m	1:1.8 to 1:2.0	
Volcanic cohesive soils (V)	Less than 5m	1:1.8 to 1:2.0	



Adopta husi biblia. [5]

8.4.2 Fronteira entre rai aterru no rai fondasi

Causa husi collapso iha aterro declive dala barak mai husi limitasaun entre aterro no fondasi rai. Típicos colapso iha aterru mak hanesan hatudu iha Figura 8.6. Pontu principal hasoru colapsu mak bench cut (step cut), drenagem rai okos no drenagem superficie.



Adopta husi biblia. [2]

Figura 8.6 Típicos colapso iha declive aterru

9 Dezastre iha taludes

9.1 Klasifikasaun ba dezastre iha taludes

Figura 9.1 hatudu klasifikasaun balun husi dezastre iha taludes. Klasifikasaun ajuda ita atu hatene etapa primeiro husi saida mak akontese iha fatin dezastre. Tabela 9.1 hatudu karaktristika kada tipu. Assunto prinsipal husi matadalan ida nemak collapso Taludes T1.

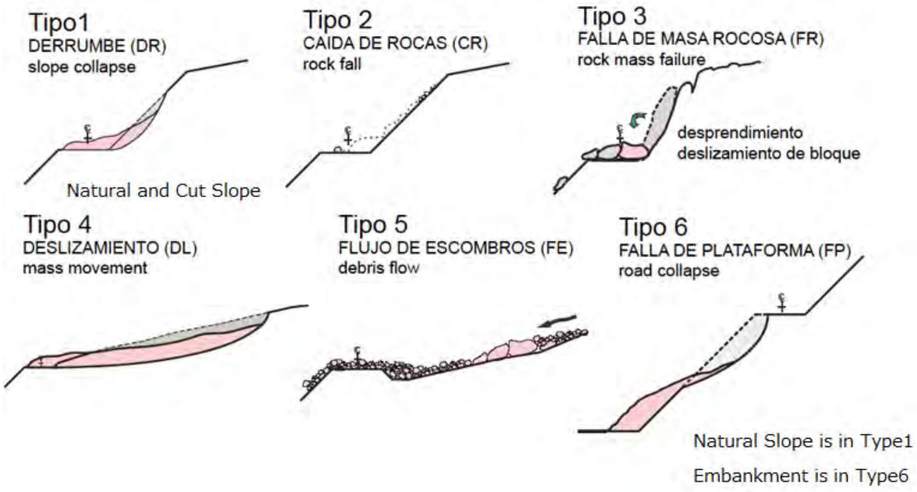


Figura 9.1 Klasifikasaun dezastre iha taludes

Tabela 9.1 Karakteristika ba kada dezastre

Disaster Type		Move -ment	Topography	Moving Material	Moisture	Scale	Speed
T 1	Slope collapse	Slide	Mild - Steep, Low - High slope	Weathered Rock, Soil	Moist	Small-Medium (<5,000m³)	Rapid
T 2	Rock fall	Fall	Steep, High slope	Rock	Dry	Very Small (<5m³)	Extremely rapid
T 3	Rock mass failure	Topple, Slide, Fall	Steep, Very high slope	Rock	Dry	Medium-Large (>100m³)	Rapid
T 4	Mass movement	Slide	Gentle slope with characteristic landform	Soil, Debris, Rock	Moist	Large (>5,000m³)	Slow
T 5	Debris flow	Flow	Stream Mountainside	Debris, Mud	Liquid form	Medium-Large (>1,000m³)	Rapid
T 6	Road collapse	Slide	Embankment slope	Fill material	Moist-Wet	Small (<1,000m³)	Rapid

T2 Fatuk monu mak fenomena comun ne'ebe ita hare iha ne'ebe deit. T3 Falha massa fatuk mak dezastre especial ho skala bo'ot no la akontese frequentamente. T4 Movimento de massa (Rai halai) mak baibain ho sakal bo'ot. Isisn lolon ne'ebe halo movimento mantem ninia forma maibe haruhan ba kada pedasuk no movimento ninia velosidade neneik los milimetru aada loron. Maibe ida ne'e ikus mai sei muda ba collapso no halai ba karaik. T5 Fluxo de resíduos ne'e konsiste husi be ho tahu ne'ebe mahar los no resíduos. Debris ho medida bo'ot konsentra hotu iha topo fluxo no ida ne'e hatudu capasidade destrutiv ne'ebe as. T6 road collapse is special because it occurs in artificial embankment.

T3 Falha massa fatuk

T5 Fluxo de resíduos

Figura 9.2 Exemplo fotografia dezastre ne'ebe raros

9.2 Principiu husi kontramedida dezastre iha rai halis

Iha ne'ebá mak prinsípiu 4 hasoru dezastre Rai halis sira hanesan hatudu iha Tabela 9.2. Kontrollu servisu no servisu dissuasão koko atu halo declive stavell diretamente. Kontrollu servisu espera katak declive atu hetan ninia stabilidade rasik. Servisu dissuasão fo forsa strutural atu hetan balanso ho forsa motriz. Servisu protesaun trafiku koko atu proteje trafiku no husik hela declive. Wainhira ita bo'ot enfrenta obstrução enorme, eziste posibilidade ba plano evita mak sai hanesan resposta ne'ebe diak.

Tabela 9.2 Prinsipiu ba kontramedida ba dezastre iha Taludes

Classification	Principle
Control work	Control work makes the ground itself be stable. This is basic means of countermeasure. Represented by adoption of adequate slope gradient, subsurface drainage and so on.
Deterrence work	Structure deters soil mass movement by proportioning force. This work is broadly classified two. One counteracts moving force by structure's own weight as retaining wall. Another counteracts by structure's tension or stiffness as anchor or pile.
Traffic Protection work	Instead of treating disaster phenomenon directly, protection work protects road / traffic solely. Represented by catch wall, rock fall protection fence, rock shed and so on.
Avoidance plan	When size of disaster phenomenon is too large to treat from technical point or cost, road avoids disaster point by route change, bridge, tunnel etc. Avoidance plan must be reasonable than countermeasure works.

9.3 Kontra medida reprezentativu

Kontra medida reprezentativu mak hanesan hatudu iha Tabela 9.3. Kada tipu dezastre iha koluna ida no kada prinsipu iha linna ida.

Tabela 9.3 Kontramedida representantivu

Classification	T1 Slope collapse	T2 Rock fall	T3 Rock mass failure	T4 Mass movement	T5 Debris flow	T6 Road collapse
Control work	Cutting with adequate slope gradient Subsurface drainage	Removing of source rock	Removing of source rock mass	Surface water drainage Shallow groundwater drainage Deep groundwater drainage Earth removal works Counter weight embankment works	Mountainside works Valley works	Embankment with adequate slope gradient Groundwater drainage
Deterrence work	Shotcrete frame Sewing bar works Anchor works	Mortar spraying Concrete pitching Cover type rock fall prevention net Shotcrete cirb Rock bolt works	Wire rope works Adhesive bonding works Rock bolt works	Pile works Anchor works	None	Retaining wall Reinforced soil retaining wall Anchor works
Protection work	Catch wall	Rock fall protection fence Pocket type rock fall protection net Rock shed	None	None	Keeping of enough flow section Debris flow shed Opened check dam	None

9.4 DNEPCC ninia kontramedida tenki introdus dala uluk

9.4.1 Targetu tipu dezastre

Targetu tipu dezastre iha inisiu tenki sai T1 collapso iha declive tamba;

T1 collapso declive frequentamente akontese iha ne'ebe deit. Kontramedida ne'ebe eziste hanesan aterro fila fali iha limitasaun no labele hetan solusauntemporariamentu.

T2 fatuk monu bele rezolve liu husi introdusaun estrutura metálica hanesan lutu protesaun fatuk monu ka prevensaun fatuk monu ho rede. Fenommena fatuk monu mak simples liu do que fenomena collapso iha declive tamba ne'e Enjineiru civil tenki rezolve problema fatuk monu ho facil do que problema collapso declive.

T3 Falha massa fatuk, T4 movimentu massa no T5 Fluxo detritos ne'ebe akontese iha pontu balun deit laos iha qualquer fatin no la frequentamente. Contra medida hasoru tipu sira ne jeralmente presija teknologia nivel altu no custo nebe as. Prioridade ba introdusaun parese menus liu husi Contra medida T1.

T6 Colapso estrada bele rezolve ho metodologia construsaun hanesan controllu densidade ho compactação ne'ebe adequada, corte bankada iha fondasi rai no drenajen subterrânea.

9.4.2 Kontramedida ne'ebe eziste ona kontra collapso declive

Contractor domestico iha maquinas pesads ba servisu terestre nune servisu terestre mak hanesan metodu ne'ebe eziste iha Timor-Leste. Kontramedida liu husi servisu terestre kontra collapso declive mak recortar. Recortar ho gradiente declive ne'ebe adequada mak reprezentativu ba servisu kontrollu nian. Iha dalan rua ba recortar; recortar ho gentler gradient no recortar ba liña kle'an liu. When the road stands near the ridge line these methods can adopt. Maibe estrada lokaliza iha area foho nune'e aplikasaun ba metodu ida ne'e sai imposibel tamba linna re-corta labele kaer linna superficie rai ate declive nia leten.

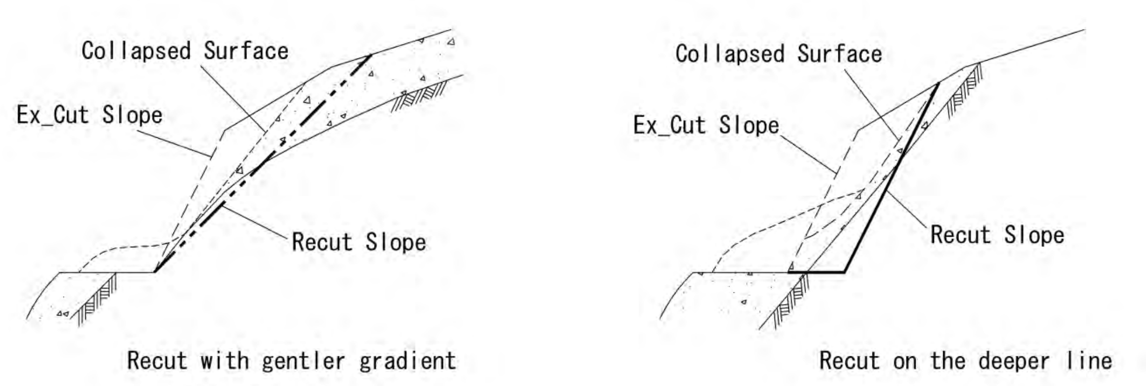
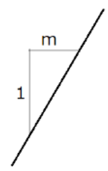


Figura 9.3 Maneira rua atu recortar

Tabela 9.4 Gradiente ne'ebe adequada ba aterro rai halis

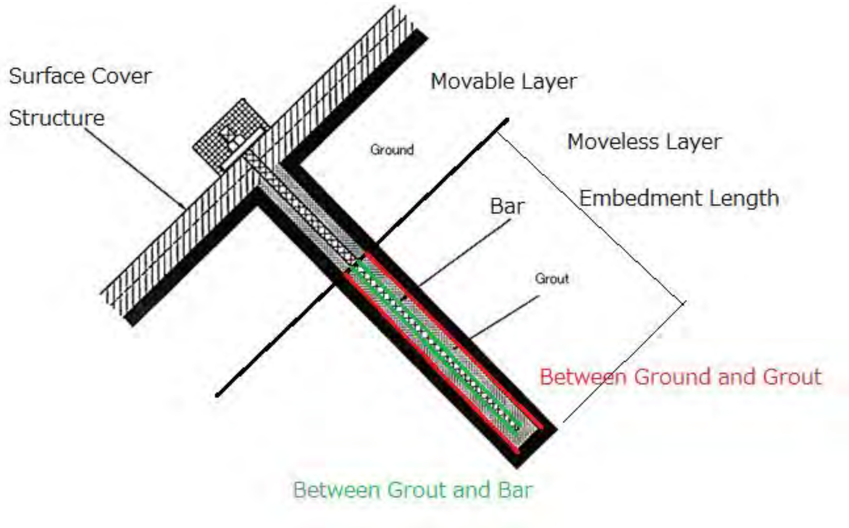
Soil classification		Cut Slope Height	Gradient
Hard rock			1:0.3 to 1:0.8
Soft rock			1:0.5 to 1:1.2
Sand	Not dense, and poorly graded		1:1.5 to
Sandy soil	Dense	Less than 5m	1:0.8 to 1:1.0
		5 to 10m	1:1.0 to 1:1.2
	Not dense	Less than 5m	1:1.0 to 1:1.2
		5 to 10m	1:1.2 to 1:1.5
Sandy soil mixed with gravel or rock masses	Dense, or well graded	Less than 10m	1:0.8 to 1:1.0
		10 to 15m	1:1.0 to 1:1.2
	Not dense, or poorly grade	Less than 10m	1:1.0 to 1:1.2
		10 to 15m	1:1.2 to 1:1.5
Clayey soil		0 to 15m	1:0.8 to 1:1.2
Clayey soil mixed with rock masses or cobble-stone		Less than 5m	1:1.0 to 1:1.2
		5 to 10m	1:1.2 to 1:1.5



Adopta husi biblia. [5]

9.4.3 Kontramedida pne'ebe prospectivu liu kontra collapso declive

Kombinasaun besi kostura no superficie cobre strutura mak representativo kontrmedida husi servisu dissuasão. Besi kostura ba iha rai ne'ebe la estabel nune'e bele estabel no kobre strutura ditribui kosturaefeitu ba fatin hotu. Metodu ida ne'e bele adopta wainhira labele adopta re-corta. Metodu ida ne'e koberta no hetan suseu ne'ebe atual iha Japaun. Fundição ne'ebe mak popular liu mak deforma reinforsa besi ba kostura besi no enkuadramento shotcrete ba superficie kobre estrutura.



Adopta husi biblia. [5]

Figura 9.4 Baze husi kostura besi no superficie kobre estrutura

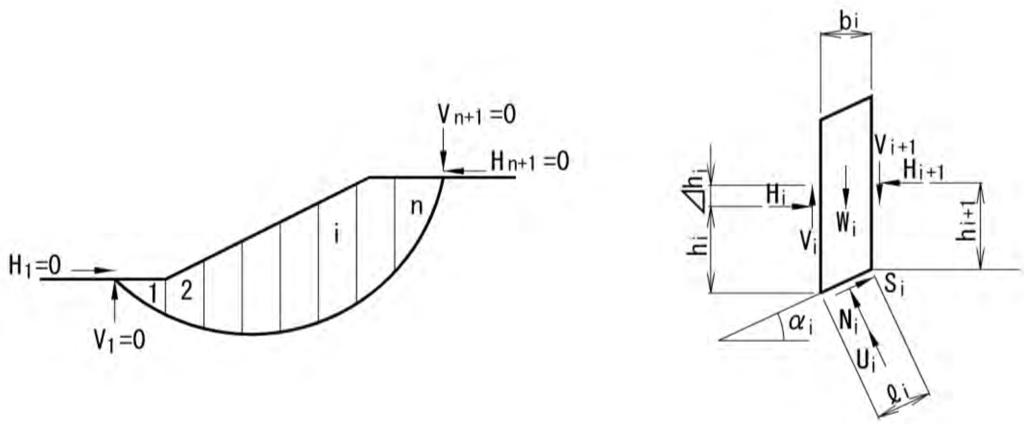
Figura 9.5 Ezemplu husi casting mais popular

10 Kakulasaun ba stabilidade taludes

10.1 Formula ba kalkulasaun

Formula kakulasaun ba stabilidade rai halis mk nesesario liu atu trata problema iha quanitativa. Ita utiliza ida ne'ebe simples liu ne'ebe hanran " Formula Simpli" hanesn hatudu tuir mai ne'e.

$$F_S = \frac{\sum[c_i l_i + (W_i - u_i b_i) cos\alpha_i tan\varphi_i]}{\sum W_i sin\alpha_i}$$



Adopta husi biblia. [2]

Figura 10.1 Esplikasan ba Formula ne'ebe simplifika tiha ona

Superficie deslizamentu mak admiti hanesan arco circular. Deslizamento nia isin fatia ba n liu husi linna fatia vestical no fatias sira ne trata hanesan rígidos isin lolon. Kondisaun assumida “forsa atuantes iha ambos tamba” ne'e mak hanaran simplifika.

10.2 Kondisaun kalkulasaun

10.2.1 Informasaun forma

Wainhira itaezekuta kalkulasaun ba stabiidade rai halis ita presiza informasaun forma; rai okos,linna superficiesuperficie be iha rai okos, dalas rai nian iha linna rai okos no linnna superficie rai muda an. peskiza seksaun transversal fo linna superficie rai okos. Investigasaun Geolojika hanesan observasaun afloramentos no perfuração, sujere linna superficie be'e rai okos no linna fronteira rai nian dalas. Linna superficie be'e rai okos tenki iha pozisaun ne'ebe as liu baibainne'e waihira akontese colapso. Estimasaun ba superficie deslizamentu liu husi forma actual colapso nian.

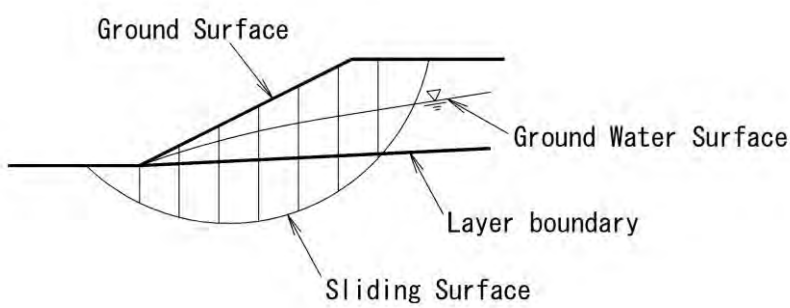


Figura 10.2 Informasaun forma

10.2.2 Karateristika rai

Karakteristik rai nian mos nesseasariu tebes ba kalkulasaun. Sira mak hanesan peo unitaria husi deslizamento nia isin no resistência ao cisalhamento husi superficie deslizamento.

Ita bele harii unidade todan ho fasil tanba valór ne'ebé hatudu nivel ne'ebé limitadu. Peso unitaria úmido γ_t lori 17 to 19 kN/m^3 no peso unitaria saturado γsat lori 18 to 20 kN/m^3.

En kontrariu configura resistensia ao cisalhamento mak problema ne'ebe deficil tebes. Iha teste atu hetan resistência ao cisalhamento mak hanesan teste Dokenbo vane cone iha terrenu no teste resistência compressão tri-axial iha laboratório. Maibé valór hosi teste distribui ho oin-oin no kompatibilidade entre kálkulu valor teste no estabilidade mak la di'ak. Tamba ne'e problema sira iha pratika kalkullu leinde métodu aplika atu estabelese dala barak forsa cisolhamento.

Kuando akontese colapsso dator seguransa estimativa hanesan 1.0. Ne'e signifika katak collapso iha balanco nune'e forsa ba deslizamento hanesan ho frosa de resistencia. Antes kalkulasaun inversu, fator resitensia cisalhamento c(coesão) ida ou ϕ (ângulo de fricção interno) tenki estabelese bazeia ba rasaun ruma. Depois, fator forse seluk ϕ or c bele hetan iha kalkulasaun tamba iha ne'eba iha formula deskuñesidu.

10.3 Excel worksheets ba kalkulasaun estabilidade rai halis

Iha projetu excel worksheet ba kalkulasaun estabilidade rai halis prepara ona ba formasaun no servisu praktikal. Ita bo'ot sira insere gradiente declive no colapso nia medida (as no profundidade vertical), worksheet kalkula circula deslizamente (raio no teta). Depois, folha servisu seluk fahe corpo de deslizamento ba fatia 6 no kalkula valor sira ne'e ho formula kalkulasaun estabilidade de declive ho tabela sumario. Ita bele hetan laos deit fator seguransa maibe cohesion c ka angulo atrito laran ϕ iha kalkulasaun inverso.

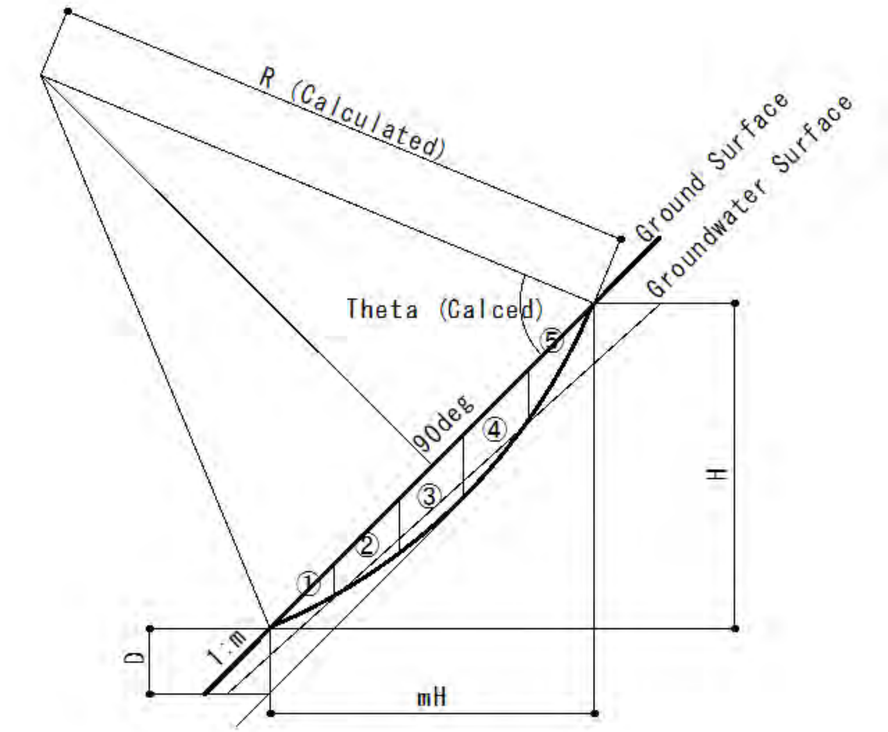


Figura 10.3 Arco círculo deslizamente iha folha excel

11 Fator ne'ebe influensia iha formula kalkulasaun stabilidade rai halis

Antes ita hasoru problema atual ita tenke hatene oinsá fatór ida-idak iha, fórmula influences kona-ba fatór seguransa.

11.1 Gradiente declive

wainhira colapso akontese iha corta declive balun,re-corta ho gradiente ne'ebe kmaan bele tama iha kondidatu kontramedida primeiro. Figura 11.1 Hatudu oinsa gradiente declive fo influensia ba fator seguransa. kuando gradiente declive mak 1:1.2 fator seguransa sai 1.05. Kuandu 1:1.5 fator seguransa sai 1.15. Gradiente de inclinação ne'ebe mak kmaan liu inesperadamente bele aumenta oituan fator seguransa.

Kondisaun kolapsu; gradiente taludes 1:1.0, saturado hotu (superficie be suteranea hanesan superficie rai), φ=30deg, c=7.23kN/m^2 (reverse calc.), γ_{sat}=20kN/m^3, size (as=5m,profundidade vertikal=2.07m)

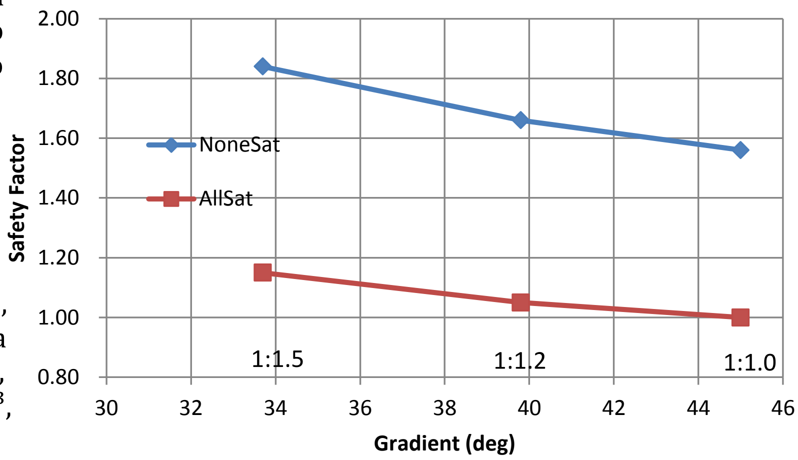
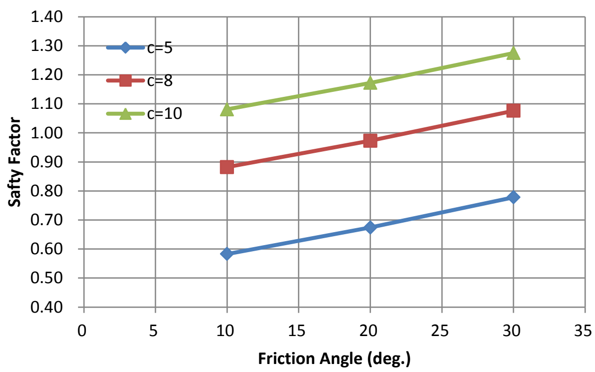


Figura 11.1 Influensia husi gradiente declive

11.2 Força de cisalhamento

Resistência ao cisalhamento husi superfície deslizamento nia mak consiste husi coesão c e ângulo fricção interno φ. Rua ne'e iha influensia diretamente ba fator seguransa C iha inflensai makas liu do que φ. Ho faktu ida ne ' ebé indika bainhira ita ezekuta kálkulu aleinde φ tenke estabelese no tenke kalkula c.



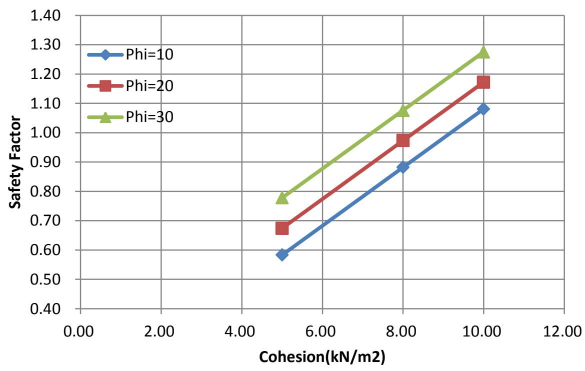
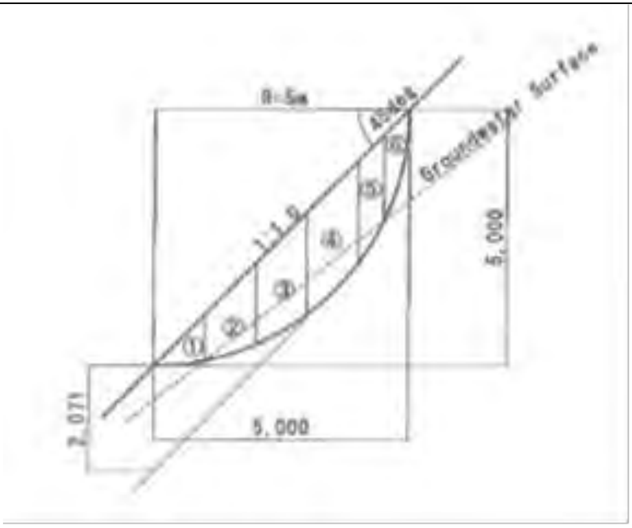


Figura 11.2 Influência resistência cisalhamento

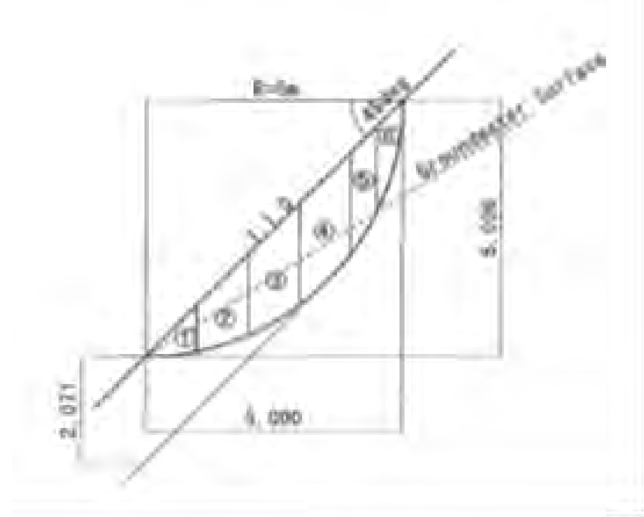
Kondisaun; gradiente taludes 1:1.0, all saturated (ground water surface equals ground surface), γ_{sat}=20kN/m^3, size (height=5m, vertical depth=2.07m)

11.3 Be iha rai okos

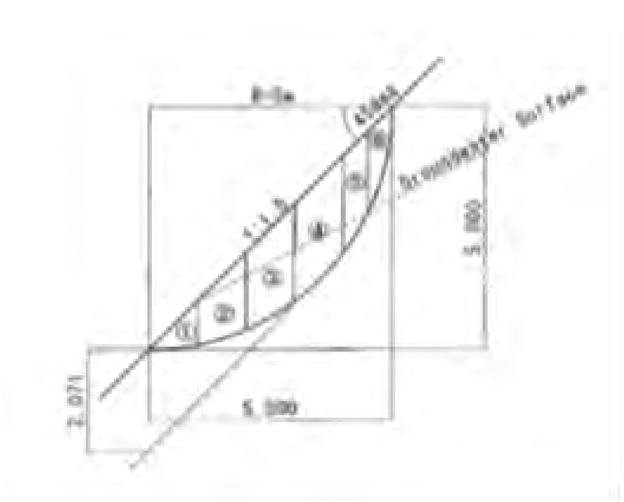
Forma be rai okos nia superficie mos fo influencia ba fator seguransa. Iha variasaun 6 ba forma be nian ne'ebe mak kalkula ona. La iha fatia ida mak iha be subteranea nia okos, Fatia sira ne'ebe mak iha besubteranea nia okos no porção média hanesan hatudu iha Figura 11.3.



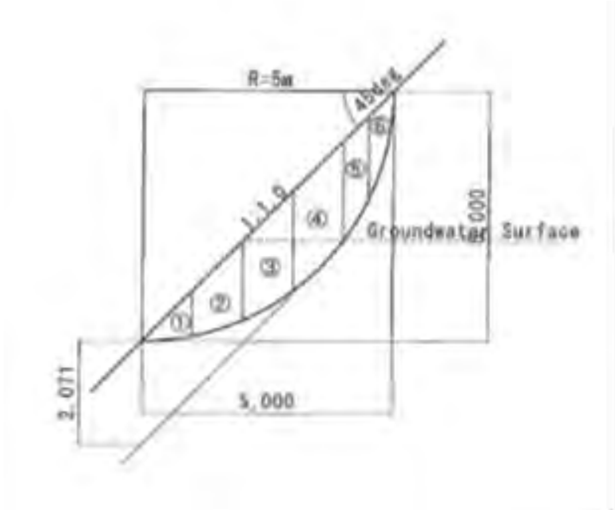
Be rai okos S1 to'o S5



Be rai okos G0 to'o S5



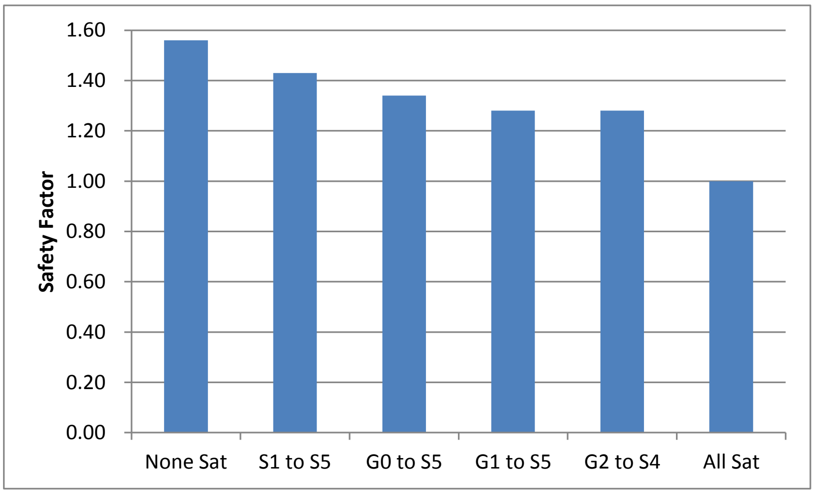
Be rai okos G1 to'o S5



Be rai okos G2 to'o S4

Figura 11.3 Variasaun husi forma be rai okos

Rezultadu hatudu iha Figura 11.4. Fator seguransa diminui wainhira nivel be iha rai okos sae. Parte inferior husi deslizamento nia isin funciona ba resistensia. Wainhira flutuaçãohusi be rai okos atua parte forsa resistensia liu husi diminui fricção nune'e fator seguransa bele tun. Drenajem poço lateral bele sai hanesan kontramedida ne'ebe efektivu wainhira coloca iha posição ne'ebe adequada.



Groundwater	Safety Factor
None Sat	1.56
S1 to S5	1.43
G0 to S5	1.34
G1 to S5	1.28
G2 to S4	1.28
All Sat	1.00

Figura 11.4 Influencia husi be rai okos

12 Ezemplu dezennu ba kontramedida hasoru colapso de declive raso

12.1 Prosedimentu Dezennu

Figura 12.1 aprezenta prosedimentu dezennu husi sewing bar no supeficie ne'ebe cobertura ho strutura.

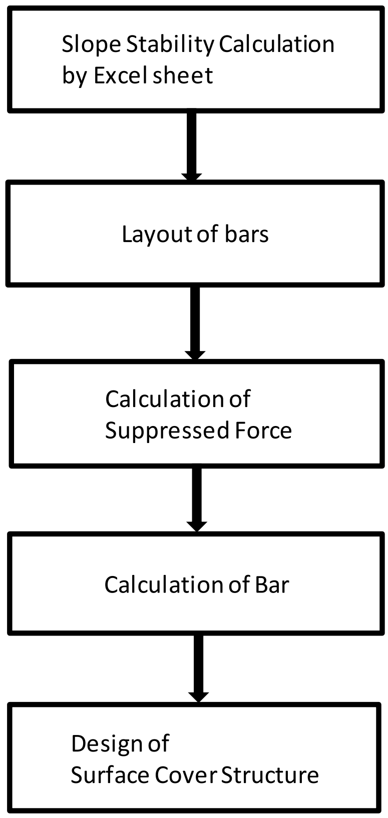


Figura 12.1 Dezennu prosedimentu ba sewing bar no superficie covertura strutura

12.2 Kalkulasaun stabilidade rai halis

Iha ezemplu kalkulasaun stabilidade rai halis mak hanesan hatudu iha karaik ne'e.

Input data of Slope Stabilty Calculation

Shape of ground surface	Height	m	10.00
	Gradient ratio		1.20
Movable layer depth	ML depth	m	2.603
Groundwater depth	Grandwater level is as same as ground surface.		
Unit weight	Wet UW	kN/m3	18.0
	Saturated UW	kN/m3	20.0
	Water UW	kN/m3	9.8
Calculation Type	Calc Type		B
Input slip surface strenth	IP cohesion	kN/m2	
	IP IF angle	deg	30.0
Exsiting safety factor	ES Fs		1.00

Summary Table

Element	Angle	Length	Area	Weight	WcosAlph	WsinAlph
	Alpha	l		W	-ul	
#	deg	m	m2	kN	kN	kN
1	15.5	2.490	1.603	32.06	15.19	8.55
2	24.5	2.638	4.291	85.82	36.02	35.65
3	34.3	2.905	5.812	116.23	39.07	65.50
4	45.5	3.423	5.718	114.36	24.14	81.55
5	55.2	2.105	2.157	43.14	0.00	35.44
6	63.7	2.712	0.860	17.21	0.00	15.43
Total		16.273			114.42	242.12

A. Given c and Phi, Target is Fs

IP cohesion	kN/m2	0
IP IF angle	deg	30
Fs		-

B. Given Phi and Fs, Target is c

IP IF angle	deg	30
ES Fs		1
c	kN/m2	**10.82**

C. Given c and Fs, Target is Phi

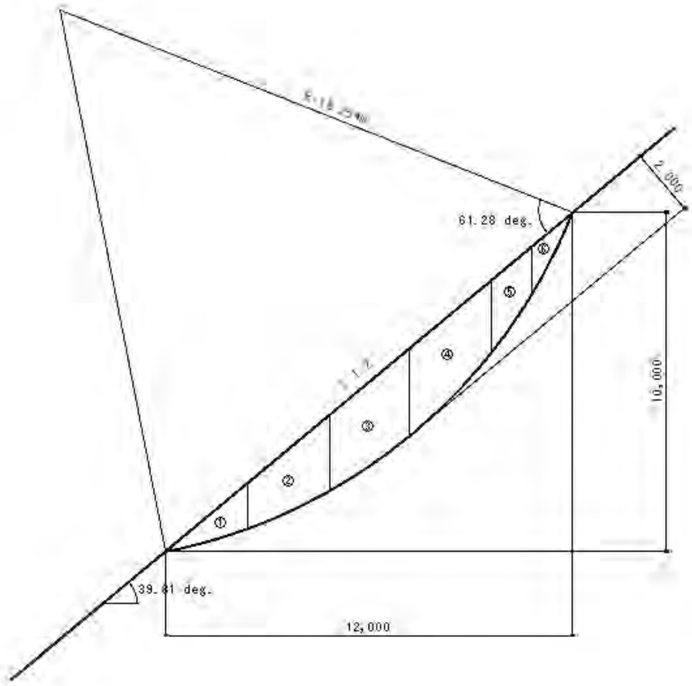


Figura 12.2 seksaun transversal ba kalkulasaun stabilidade rai halis

12.3 Layout besi nian

Intervalu kada besi mak hnaesan relasaun copremisio entre diametru besi no numeru besi nian. Intervallu besi ne'ebe do'ok malu halo diametru besi ne'ebe bo'ot no quantidade besi ne'ebe oituan. Intervallu badak lori rezultado ne'ebe kontrario. Generalidade intervallu besi distribui 1.5 m to'o 3 m. 2m bele aplika ba kazu sira ne'ebe luan.

Hanesan Ezempli intervallu Horizontal "m" 2 metru no numeru besi ne'ebe kesi iha colapso "n" igual 7.

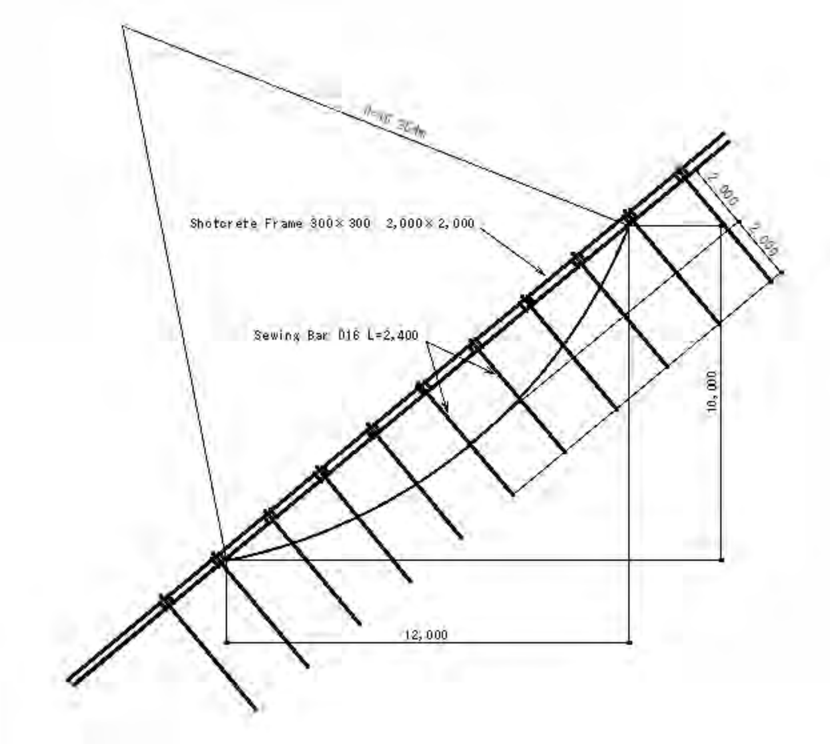


Figura 12.2 Layout besi nian

12.4 Kalkulasaun forsa suprimida

Forsa Suprimida kalkula ho formula tuir mai ne'e.

$$F_{SA} = \frac{\sum (c_i l_i + (W_i - u_i b_i)\cos\alpha_i \tan\varphi_i)}{\sum W_i \sin\alpha_i} = 1.00$$

$$F_{SP} = \frac{\sum (c_i l_i + (W_i - u_i b_i)\cos\alpha_i \tan\varphi_i) + P_T \tan\varphi_i}{\sum W_i \sin\alpha_i} = 1.20$$

$$F_{SP} - F_{SA} = \frac{P_T \tan\varphi_i}{\sum W_i \sin\alpha_i} = \Delta F_S = 0.20$$

$$P_T = \frac{\Delta F_S \sum W_i \sin\alpha_i}{\tan\varphi_i}$$

$$P_{eB} = \frac{m}{n} P_T$$

F_{SA}: Actual Safety Factor

F_{SP}: Planed Safety Factor

ΔF_S: Additional Safety Factor 0.2 commonly

P_T: Total Suppressed Force

m: Horizontal Interval of Sewing Bars

n: Number of Sewing Bars on the Collapse

P_{eB}: Suppressed Force of each Sewing Bar

We suppose collapse occurs on F_{SA}=1.00.

It means limit of the balance between resistance and sliding forces.

Iha ezemplu kalkulasaun ezekuta hanesan tuir mai ne'e. Ita hetan ΣWsinα=242.12kN liu husi tabela sumariu husi dadus Excel.

$$P_T = \frac{\Delta F_S \sum W \sin\alpha}{\tan\varphi} = \frac{0.2\times242.12}{\tan 30} = 83.87kN$$

$$P_{eB} = \frac{m}{n} P_T = \frac{2}{7}\times 83.87 = 23.96kN$$

12.5 Kalkulasaun ba besi

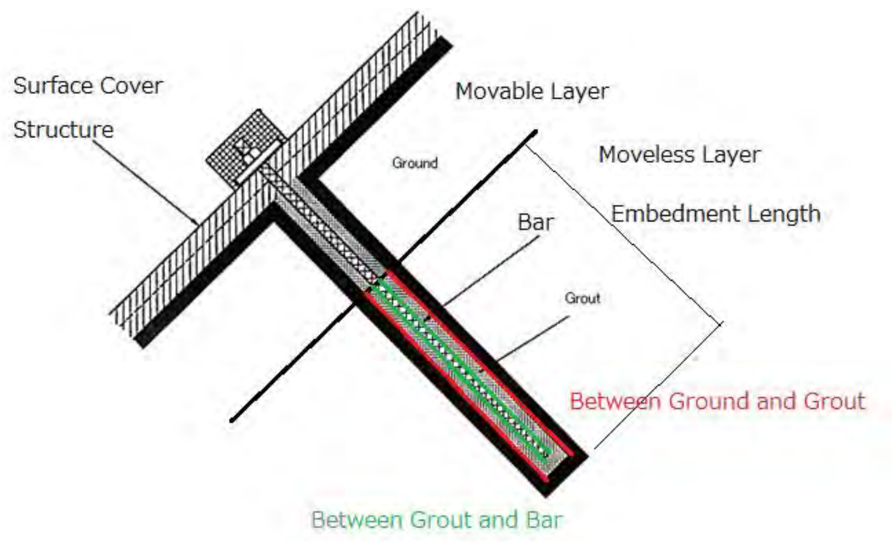
12.5.1 Selesaun ba homan besi

Reinforsa besi D16 mak selesiona ba homan besi. Iha posibilidade besi sira ne hetan korosi no lakon parte balun iha seksau transversal iha futuru. Diametru 1mm mak margem ba seksaun transversal $A=176mm^2$. Estresse tensão kalkula hanesan tuir mai ne'e. Valor menus liu valor ne'ebe permiti.

$$\sigma = \frac{P_{eB}}{A} = \frac{23.96\times10^3}{176} = 136 < 200N/mm^2$$

12.5.2 Embedment length

Besi sira ne'e fixo ona iha dalas ne'ebe labele muda. Ida ne'e hanaran embutir. Se embutir nia naruk passa ona pontu kontrollu 2 nune'e besi bele tahan terhadap penarikkan. They are friction between ground and grout and friction between grout and bar.



Adopta husi biblia. [5]

Figura 12.3 Pontu verifikasaun husi aterru nia naruk

12.5.2.1 Kalkulasaun embutir nia naruk entre ground no grout

Embutir nia naruk ne'ebe mak nessesariu liu entre ground no grout mak kalkula ho formula tuir mai ne'e.

$$l_b = \frac{P_{eB}F_{sb}}{\pi\cdot d\cdot\tau} = \frac{23.96\times10^3\times2.0}{\pi\times65\times0.14} = 1676mm \rightarrow 2.0m$$

l_b: Presija embutir nia naruk entre ground no grout atu labele dada an

Fsb: Fator seguransa ba hasai; valor padraun 2.0

d: Diâmetro de perfuraçãor; 65mm mak diâmetro ne'ebe popular

τ: Resistensia fricção kulit final

Kondisaun hipoteza: dalas ba gravel valor-N=20

Entaun τ= 0.14 N/mm²

Valor padraun ba resistencia fricção ba isin kulit final hatudu iha Tabela 12.1.

Tabela 12.1 Estimasaun fricção kulit final

Ground type			USFR N/mm²
Base rock	Hard rock		1.2
	Soft rock		0.8
	Weathered rock		0.5
	Hard pan		0.5
Gravel Layer	N-value	10	0.08
		20	0.14
		30	0.20
		40	0.28
		50	0.36
Sandy soil	N-value	10	0.08
		20	0.14
		30	0.18
		40	0.23
		50	0.24
Clayey soil			0.8×C

Adopta husi biblia. [1]

12.5.2.2 Kalkulasaun embutir nia naruk entre grout no besi

Embutir nia naruk ne'ebe persija entre grout no besi mak hanesan kalkula tiha ona iha formula tuir mai ne'e.

$$l'_b = \frac{P_{eB}}{\pi \cdot D \cdot \tau_{0a}} = \frac{23.96 \times 10^3}{\pi \times 15.9 \times 1.4} = 343mm < 1676mm$$

l'_b: embutir nia naruk entre grout no besi atu labele dada an

D: Diâmetro besi, D16 → D=15.9mm

τ_{0a}: Resistência final à fricção da pele, τ_{0a}=1.4N/mm²

Valor padraun ne'ebe permite presaun aderência entre grout no besi ne'ebe deforma mak hanesan hatudu iha Tabela 12.1.

Tabela 12.2 Presaun aderênci ne'ebe mak permite entre grout no besi

DRSG σ_{ck}(N/mm²)	18	24	30	Over 40
AAS τ_{0a}(N/mm²)	1.4	1.6	1.8	2.0

DRSG: Design reference strength of grout

AAS: Allowable adhesion stress

Adopta husi biblia. [1]

12.6 Dezennu husi superficie cofre strutura

Iha ezemplu enkuadramentu shotcrete aplika hanesan superficie cobre estrutura. Figura 12.4 hatudu prosedimentu dezennu.

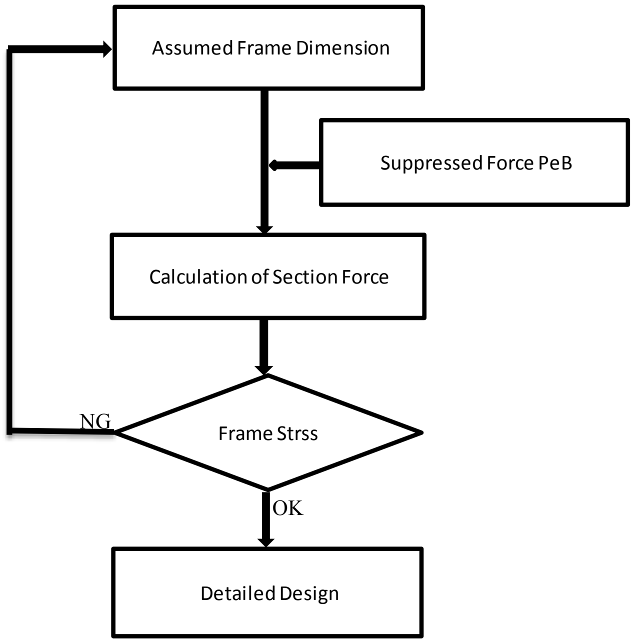


Figura 12.4 Procedimentu dezennu enkuadramentu shotcrete

Iha ezemplo asume ona dimensaun ba quadro mak;

quadro intervallu 2.0 × 2.0m no quadro seksaun transversal 300 × 300mm.

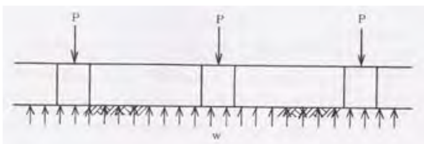
12.6.1 Kalkulasaun ba força de seção

Enkuadramentu ba seksaun forsa kalkula hanesan formula tuir mai ne'e.

$$w_x = w_y = \frac{P}{l_x + l_y - b} = \frac{23.96}{2.0 + 2.0 - 0.3} = 6.48\, kN/m$$

$$M_{max} = \frac{1}{10} wl^2 = \frac{1}{10} \times 6.48 \times 2.0^2 = 2.59kNm$$

$$S_{max} = \frac{3}{5} wl = \frac{3}{5} \times 6.48 \times 2.0 = 7.78kN$$



P: Tensaun costura besi

w: Reação de subleito uniformemente distribuída

l: Quadro intervallu

b: Quadro nia largura

M_{max}: Momento máximo de flexão

S_{max}: Força máxima de cisalhamento

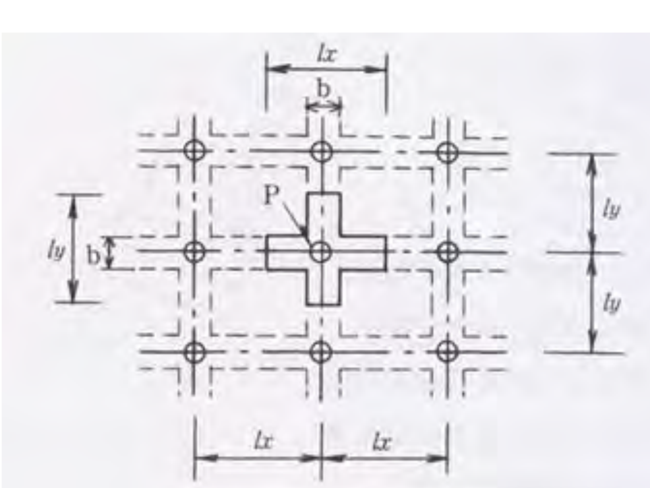


Figura 12.5 Modelo ba kalkulasaun quadro

12.6.2 Verifika ba tensaun frames

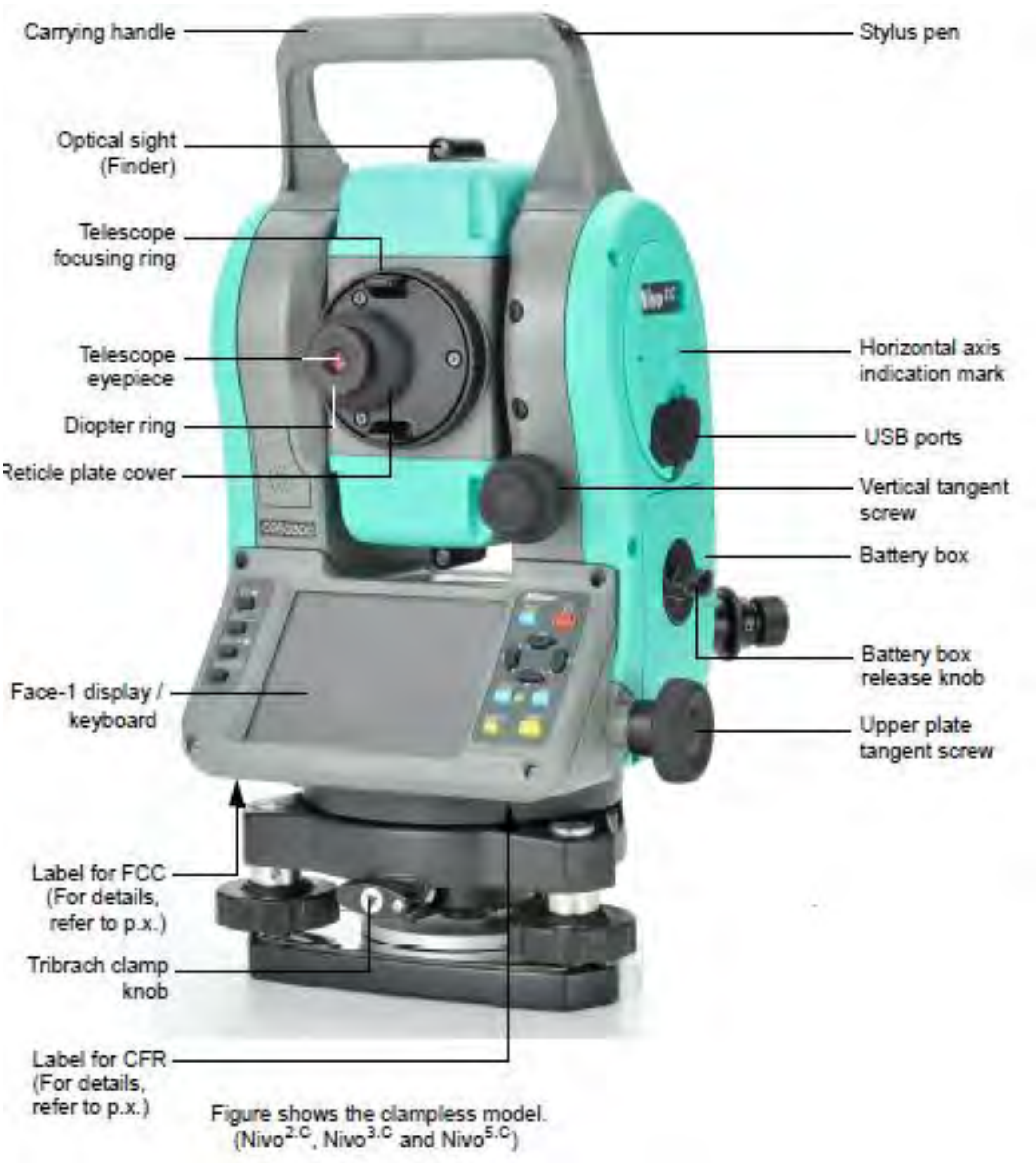
Verifika enkuadramentu presaun ne'ebe mak implementa iha kondisaun hanesan seksaun transversal rektangular,konkretu reinforsa uniku no metodu dezenu presaun ne'ebe permite. pressaun tolu ne'e hotu passa kontrollu hanesan tuir mai ne'e.

Frame cross section					
Item		Unit	Value	Memo	
Member width		cm	30.0		
Member height		cm	30.0		
effective height		cm	23.5		
Cross-section area of reinforcing bar		mm2	253.4	D13 * 2 Standard Layout	
Result of calculation					
Item		Unit	Calculated	Allowed	Judgement
Stress	Compression of concrete	N/mm2	1.24	6.00	OK
	Tension of R.F. bar	N/mm2	47.95	180.00	OK
	Avelage shear	N/mm2	0.110	0.400	OK

Annex A
(informativu)

Oinsa atu Utiliza Total Station

A.1 Parte naran



Adopta husi biblia. [3]

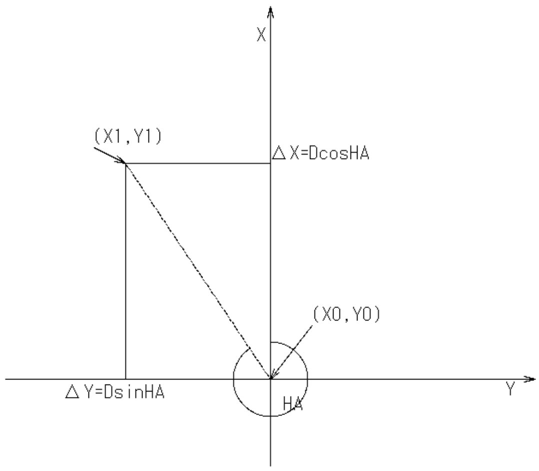
Adopta husi biblia. [3]

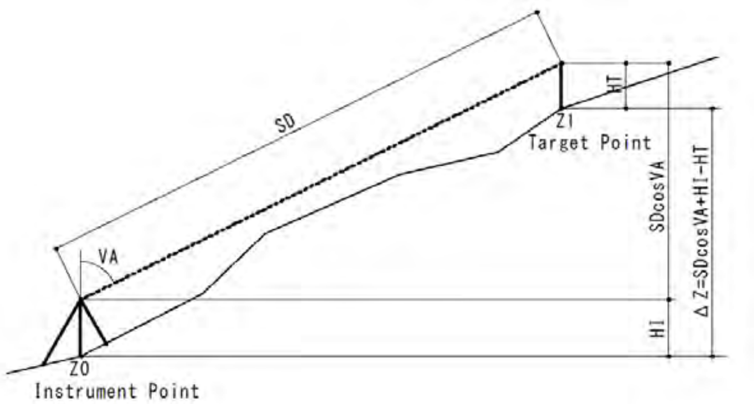
A.2 Valor saida mak sukat husi Total Station

Total station sukat angulo horizontal, vertical no distansia declive. Iha liafuan seluk, hotu-hotu iha instrumentu ida atu sai hanesan alvu koordenasaun dala ida de'it.

- HA: Horizontal Angle
- VA: Vertical Angle
- SDx: Slope Distance

Koordenasaun ba targetu bele kalkula liu husi HA, VA no SDx hanesan hatudu iha Figura tuir mai.





A.3 Configura instrumentu

Configura instrumentu katak sentraliza no nivelar.

- Centering: The TS must be set just on the station point mark.
- Leveling: Upper plate (tribranch) must be set as level.

[Prosedimentu]

① Agrimensor konfigura tripod Ulun ho nivelado no ba iha central se posivel.

② Nia tula instrumentu iha tripod nia leten.

③ Nia insere parafuso montagem tripod nian ba iha intrumentu.

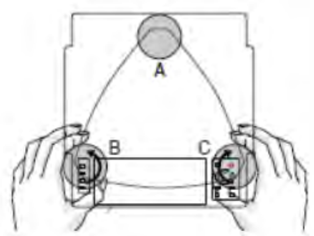
④ Nia nivela instrumentu atu ajusta tripod nia naruk depois de ida ne'e mak utiliza parafuso nivelamento.

⑤ Nia muda instrumentu iha tripod nia leten ho kore parafugo montagem atu nune'e bele centraliza liu husi verifika prumo óptico.

⑥ Nia repete nivelado no centralizacao ate kondisaun rua ne permite ba circula.

⑦ Se iha pontu sentrál ida deit iha levantamentu simples hanesan seksaun transversal ida, entaun centralização bele ignora tiha.

[Oinsa atu uza parafusos nivelamento]



- Two leveling screws are turned at one time by both thumbs and first fingers to different direction. It means both thumbs go inside or go outside. Slow and Gentle.
- Left thumb reads level bobble.

A.4 Prosedimentu geral ba peskiza simples

① Agrimensor estabele pontu estasaun rua ida ba instrumentu no seluk ba visaun ba parte kotuk.

② Nia konfigura instrumentu iha pontu stasaun, sukat instrumentu nia as.

③ Nia konsentra iha visaun parte kotuk f, no define HA=0. Tuir mai X axis mak estabele husi pontu stasaun ba iha pontu fila fali ba kotuk.

④ Nia fo instrusaun ba ida ne'ebe kaer tiang atu tau tiang iha pontu targetu primeiru.

⑤ Nia konsentra ba los deit iha reflector ka targetu no haneha buataun hodi sukat distansia declive.

⑥ Nia hanehan butaun hodi gr, target height and the values HA, VA, SD on the field note.

⑦ Fila fali ba prosedimentu ④ to'o ⑥ ba pontu targetu hotu-hotu.

⑧ Se iha ne'eba iha pontu stasaun ida deit iha peskiza simples hanesan seksaun transversal ida deit, entaun prosedimentu ① to'o ③ bele ignora tiha.

A.5 Kalkula koordenasaun liu husi notas kampo

Projetu ne'e fornese dadus excel ba kalkulasaun coordenasaun liu husi dados iha kampo.

[Tabela entrada]

Station Name	Instrument Height	Target			Horizontal Angle			Vertical Angle			Slope Distance
		Name	Number	Height							
—	m	—	—	m	deg	minute	second	deg	minute	second	m
Room1	1.21	Coener A	1	0.95	35	32	3	91	58	24	8.273
	1.21	Coener B	2	1.07	318	44	48	93	23	23	2.451
	1.21	Clock	3	2.49	27	35	8	70	10	41	3.768
	1.21	Corner C	4	3.23	50	7	2	74	33	18	7.598
	1.21	Corner D	5	3.23	95	35	41	75	21	31	7.991

[Tabela de saída]

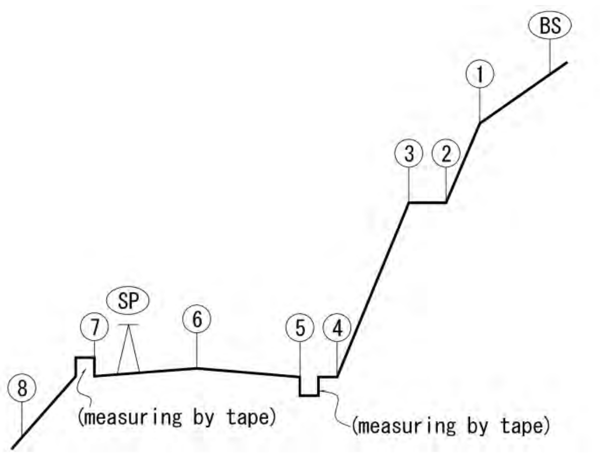
Target Number	X	Y	Z
	m	m	m
1	6.728	4.805	-0.025
2	1.840	-1.614	-0.005
3	3.142	1.642	-0.002
4	4.696	5.620	0.003
5	-0.754	7.695	0.000

A.6 Pontu targetu husi peskiza seksaun transversal

Pontu saida mak ita persij wainhira ita dezennu seksaun transversal? Resposta mak pontu ida ne'ebe wainhira gradiente superficie rai nian muda an.

Batas material mos presija, aspal, konkretu, rai no seluk tan.

Strutura kiik sira hanesan,drenajem,parede de guarda no seluk tan bele sukat ho fita exceto pontu ida deit laos levantamentu ba hotu-hotu.



A.7 Pontu stasaun

Papel pontu stasaun mak atu liga fatin no dezennu. Peskizador halo materia peskiza. Enjineriu design halo dezennu ho materia peskiza. Kontratante konstrui hamutuk tuir dezenu. Se laiha pontu stasaun iha terennu maka contractor labele deside servisu nia posição.

Iha tipu 2 ba pontu stasaun, ida mak stasaun temporario no seluk tan mak stasaun permanente. Stasaun tempario halo husi patok ai no hanehan ba pavementu. En kontrariu estasaun permanente halo ho patok konkretu ne'ebe dura ka bloku atu asegura niia pazisaun. Stasaun permanente dalaruma sai hanesan pontu de referensia.

Annex B
(informativu)

Oinsa atu utiliza Dokenbo

B.1 Informasaun jeral sobre Dokenbo

- What is Dokenbo?

Equipment for Soil layer prospection
consists of
1)Cone 2)Rod 450mm 3)Rod 500mm × 9
4)Handle 5)Vane cone 6)Load meter
7)Dial torque wrench 8)Open-end wrench × 2
9)Connection sleeve 10)Carry bag

Kanji Letters	Pronunciation	Meaning	Abbreviation
土層	doso	Soil Layer	Do
強度	kyoudo	Strength	
検査	kensa	Prospection	Ken
棒	bou	Rod	Bo

[Desenvolvedor e Patente]

Public Works Research Institute PWRI iha Japaun mak dezenvolve Dokenbo no hetan patente iha Japaun. Ema hotu bele utiliza Dokenbo maibe so ida ne'ebe mak permite mak bele halo Dokenbo.

B.2 Uzu Dokenbo

① Soil layer depth prospection
② Penetration test by spring load meter
③ Shear strength test by dial torque wrench with vane cone

B.3 Cuidado importante

Dokenbo iha bandu rigorozu rua;

The rods connects each other by right-screw.

Therefore,

Never turn anticlockwise

when the Dokenbo is in the soil layer.

If you do connection screw is released and apical end is lost in the soil layer.

Dokenbo is designed for static use.

Therefore,

Never hit top by hammer

to penetration.

If you do Dokenbo would buckle up or get broken.

B.4 Prospecção dalas rai nia profundidade

B.4.1 Prosedimentu

- Apical end is the cone, top end is the handle.
- Set Dokenbo on prospect point, push the handle statically and slowly by investigator's own power.
- Dokenbo penetrates no more, then rod length from the surface is depth of soil layer. Investigator can read using 10cm scale mark on the rod.

B.4.2 Distribuisaun kona-ba pontu perspektiva

- Random way; Investigator choices prospect points where soil layer seems deep. Maximum depth represents soil layer depth of the target slope.
- Regular way; Prospect points are distributed along preset line such as cross section line, contour line or fall line. All prospect points must have position information such as coordinate values.

B.5 Teste penetrasaun

B.5.1 Prosedimentu

① Investigator penetrates Dokenbo till measurement depth.

② Investigator push Dokenbo through load meter slowly, when Dokenbo goes into action then investigator reads load meter.

③ Investigator fills data on 'Data Sheet for Dokenbo Penetration Test'.

B.5.2 Dadus folha

- There are two ways of DPT. One is Normal Test.
- Weight of Rods is counted in calculation of penetration strength qdk.

Data Sheet for Dokenbo Penetration Test							
Subject:						Date:	Weather:
Survey Point:						Investigator:	
Ground Condition: Water Content:							
Normal Test	Area of Cone (m2):		1.76E-04			Mass of Cone and Apex Rod (kg):	0.310
Final Penetration Depth (m):						Mass of Raguler Rod (kg):	0.308
Depth D m	Load Mater Value W N	kN	Number of Rod n	Penetration Strength qdk kN/m2	Remark	Depth m	Penetration Strength (kN/m2) 400 800 1200 1600 2000
1.00	100	0.100	1	603			
1.00	300	0.300	1	1,739			
4.50	300	0.300	9	1,876			

$$q_{dk} = \frac{W + (m_0 + n \cdot m) \cdot g}{A}$$

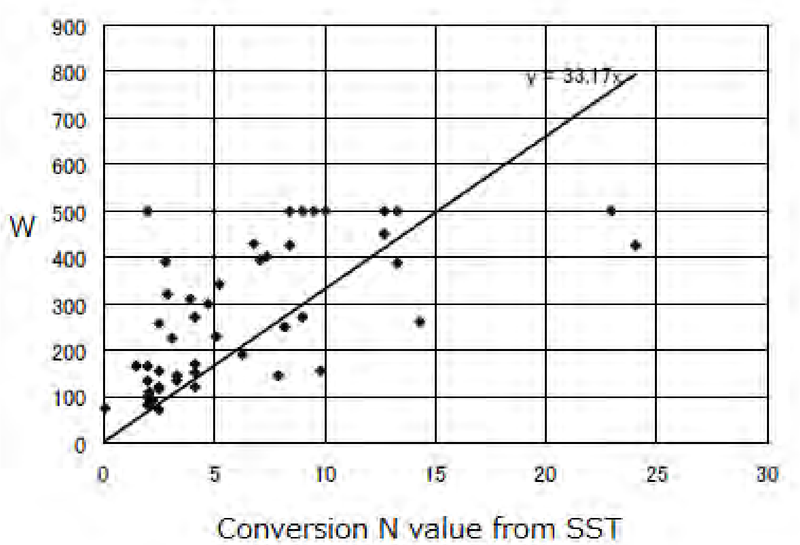
- Another is simplified Test.
- Weight of rods is not counted in calculation of apparent penetration strength qdk'.

Data Sheet for Dokenbo Penetration Test							
Subject:						Date:	Weather:
Survey Point:						Investigator:	
Ground Condition: Water Content:							
Simplified Test	Area of Cone (m2):		1.76E-04			Mass of Cone and Apex Rod (kg):	
Final Penetration Depth (m):						Mass of Ragulaer Rod (kg):	
Depth D m	Load Mater Value W N	kN	Number of Rod n	Penetration Streneth qdk' kN/m2	Remark	Depth m	Penetration Strength (kN/m2) 400 800 1200 1600 2000
1.00	100	0.100	1	568			
1.00	300	0.300	1	1,706			
4.50	300	0.300	9	1,706			

$$q_{dk}' = \frac{W}{A}$$

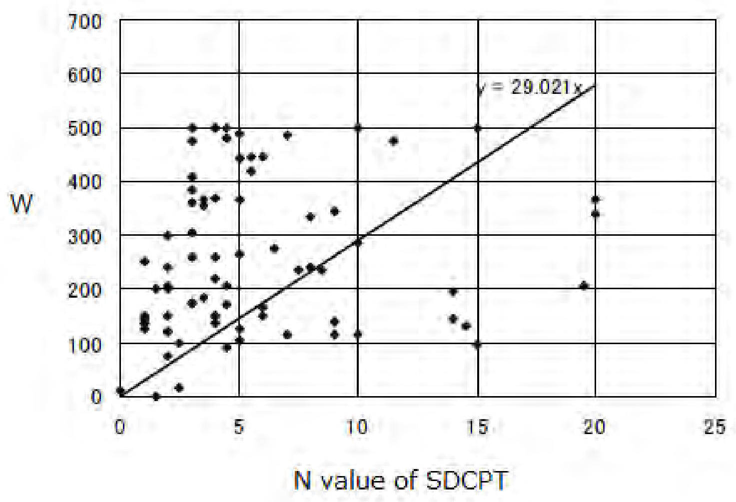
B.5.3 Korelasaun husi rezultadu teste sira seluk

Grafiku tuir mai hatudu korelasaun husi observasaun valor entre Dokenbo W no konversaun valr N hiso Teste Swedish Sounding. Dokenbo bele aproximamente penetra rai N≤10 ba kraik W≤300N.



Adopta husi biblia. [4]

Grafiku tuir mai hatudu korelasaun husi valor observasaun entre Valor Dokenbo W no N liu husi Teste de Penetração Dinâmica Cone Simplificado Dokenbo bele penetra aproximadamente N≤10 rai okos W≤300N.



Adopta husi biblia. [4]

B.6 Teste de resistência ao cisalhamento

B.6.1 Membru komponente

① Vane cone and Apex rod
② Rods
③ Dial torque wrench
④ Load meter and connection sleeve

① Load Meter
② Dial Torque Wrench
Maximum load of LM is 300N (30.5kgf)
Maximum torque of DTW Is 7Nm (0.71kgfm)

B.6.2 Prosedimentu

Teste ida ne'e presija ema nain 2, operador mak sai hanesan lider ba teste ne'e no ida hanehan ne'e mak hanesan asistente.

① Operador penetra dokenbo to atinji profundidade ne'ebe targetu tiha ona ho vaneless normal.

② Ida hanehan ne' e hanehan dokenbo ho neneik ho dial torque wrench searah jarum jam iha load mater nia okos ne'ebe indika 0. Valor masimo tenki registu hanesan Torque liu husi skin friction **T0**.

③ Operador troka cone normal ho vane cone.

④ Operador estabelese Dokenbo dala ida tan iha profundidade ne'ebe hanesan no tau tan todan balun atu penetra vane deit ba rai la nakfera.

⑤ Operador tula todan vertical ne'ebe planea tiha ona **Wi** liu husi mater todan.

⑥ The turner turns Dokenbo slowly with the dial torque wrench for clockwise under the load mater indicates vertical load **Wi**. Valor máximo torque mak **Ti**.

⑦ Ida hanehan ne'e rejistu teste profundidade, **Wi** no **Ti** iha folha de dados.

⑧ Operador dada sai Dokenbo no verifika kondisaun Vane Cone.

⑨ Ida hanehan dokenbo ne hakerek ninia observasaun kona rai, influencia husi gravel, no seluk tan.

⑩ Repete hela deit prosedimentu ida ne'e ate hetan 5 conjuntos ba Wi no Ti.pelo menos dala 3 husi Wi no Ti. Kada tste tenki ezecuta iha rai ne'ebe la nakfera no klean liu oituan husi etapa antes ne'e.

Wainhira koak penetrasaun labele hamrik mesak maka prosedimentu ba teste ne'e tenki muda hanesan tir mai ne'e.

① Operador koko atu estabelese vane cone ho klean ne'ebe hanesan iha koak foun besik koak teste skin friction.

② Operador sei la hasai Dokenbo ba kada etapa iha teste ne atu nune bele kontinua teste seluk hodi kompleta sets 5 husi **Wi** no **Ti**.

③ Operador estabele vane cone ho nia klean 3 to'o 5cm depois etapa antes ne'e atu bele hetan rai ne'ebe la at.

B.6.3 Prosesu atu hetan resistência cisalhamento

Iha dalan rua atu hetan resistência cisalhamento husi rezultadu teste. Ida mak formula empirik no seluk tan mak formula korelasaun. Dalan ba formula korelasaun presija parseiru 3 husi teste CU traxial compressive no teste dokenbo. Tamba ne'e atadalan ne so introdus deit formula empirica.

Formula empirica kesi reziltadu teste resistência ao cisalhamento haneasn tuir mai ne'e.

$$\sigma = 2.4\times10^2 \cdot W_{VC}$$
$$\tau = 1.5\times10^4 \cdot T_{VC}$$
$$W_{VC} = W + (m_0 + n\cdot m)\cdot g$$
$$T_{VC} = T - T_0$$

① Investigator makes chart of Sigma and Tau.
② He makes linear regression formula.
③ Y-intercept is **Cohesion**.
④ Gradient is tangent Phi.
⑤ Phi is **Internal friction angle**.

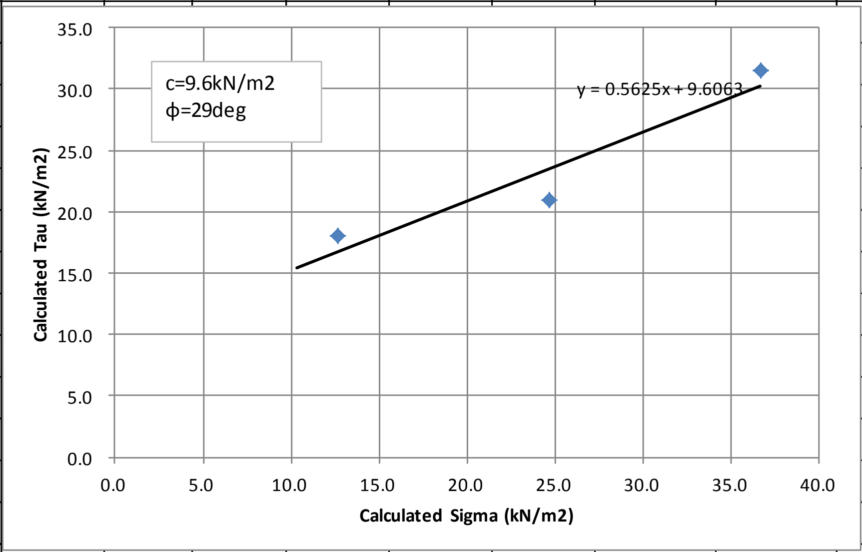
B.6.4 Ficha de dados

Projeto ne'e fornese data sheet ba teste de resistência ao cisalhamento Dokenbo. Ezemplu mak hatudu iha kraik ho grafiku σ no τ.

Data Sheet for Dokenbo Shear Strength Test

Subject:	Aituto Landslide Monitoring OJT	Date:	1-Dec-17	Weather:	Fine
Survey Point:	Around No.3 BH	Investigator:	Minegishi and Trainee		
Ground Condition: Water Content:	Colluvium, clayey soil mixed with angulated gravel, gravel mean size is 10 to 30 cm.				
Empiric Formula	Height of Vane (m) 7.00E-03	Mass of Vane Cone and Apex Rod (kg):	0.310		
Final Test Depth (m):		Mass of Ragulaer Rod (kg):	0.308		

Depth D	Load Mater Value W	Number of Rod n	Vertical Load on Vane Wvc	Torque by Skin T0	Dial Torque Wrench T	Torque on Vane Tvc	Calculated Normal Stress Sigma	Calculated Shear Stress Tau	Remark
m	cN		kN	Nm	Nm	kNm	kN/m2	kN/m2	
0.30	5,000	0	0.053	0.0	1.2	0.0012	12.7	18.0	
0.35	10,000	0	0.103	0.0	1.4	0.0014	24.7	21.0	
0.40	15,000	0	0.153	0.0	2.1	0.0021	36.7	31.5	
0.45	20,000	0	0.203	0.0					Dokenbo go into motion by vertical load.



Remark:
Matrix is clayey soil.
However the result indicates sandy soil characteristics.
Without check of maximum vertical load, we failed the test when vertical load at 20,000cN.

Annex C
(informativu)

Folha servisu ba kalkulasaun stabilidade ba gravidade moru retensaun.

C.1 Traçado

Folla servisu ezecuta kalkulasaun stabilidade moru retensaun, ne'ebe konsite husi folla 4: In_put, Moru, Presaun rai, no Sumariu.

- Forma Moru mak trapezoidal ho ponto nos 4. Timbunan mak horizontal.
- Koordinat orijin mak moru nia tumit, moru nia parte oin mak diresaun x axis plus no parte leten moru mak diresaun y axis plyus.
- Presaun rai nian kalkula ho formula Coulomb.
- Earthquake is out of coverage.

C.2 Folha servisu

[In_put]

Name of Conditions			Symbol	Nuit	Valu	
Wall	Shape	Node1	X, Y	m	0.000	0.000
		Node2	X, Y	m	1.800	0.000
		Node3	X, Y	m	0.600	3.000
		Node4	X, Y	m	0.000	3.000
	Unit weight		γc	kN/m3	23	
Backfill	Unit weight		γs	kN/m3	19	
	Internal friction angle		φ	deg.	30	
Foundation	Allowable bearing capacity		Qa	kN/m2	200	
	Friction coefficent walll and foundation		μ	ND	0.6	
Road	Surcharge on the Road		q	kN/m2	10	

[Moru]

Element	Area A (m2)	Weight V (kN)	Arm length x (m)	Moment M (kNm)
1	2.70	62.1	0.800	49.7
2	0.90	20.7	0.200	4.1
Total		82.8		53.8

[Presaun rai]

α degree	β degree	φ degree	δ degree	KA
0.0	0.0	30.0	20.000	0.297

Active Earth Pressure Coefficient	Backfill Unit Weight	Wall Height	Surcharge on the Road	Load Name	Load	Friction Angle of Wallback	Vertical Load	Arm Length	Moment	Horizontal Load	Arm Length	Moment
KA	γ kN/m3	h m	q kN/m2		PA kN	δ degree	V kN	x m	M kNm	H kN	y m	M kNm
0.297	19	3.000		Earth Pressure	25.4	20.000	8.7	0.000	0.0	23.9	1.000	23.9
0.297		3.000	10	EP by Surcharge	8.9	20.000	3.0	0.000	0.0	8.4	1.500	12.6
						Total	11.7		0.0	32.3		36.5
											ΣM=	36.5

[Sumariu]

Summary table for loads and Moments

Load Name	Vertical Load kN	Horizontal Load kN	Moment kNm
Wall Weight	82.8		53.8
Earth Pressure	11.7	32.3	36.5
Total	94.5	32.3	90.3

Three check points of stability index

1) Over-turnig

X-coordinate of resultant	X=	0.956	m
X-coordinate of bottom center	B/2=	0.900	m
Eccentricity of resultant	e=	0.056	m
Allowable eccentricity	B/6=	0.300	m
Judgment		**OK**	

2) Sliding

Total vertical load	ΣV=	94.5
Total hrizontal load	ΣH=	32.3
Friction coefficient	μ	0.6
Safety factor of sliding	Fs=	1.76
Judgment		**OK**

3) Bearing capacity

Reaction stress at wall's toe	qt=	62.3
Reaction stress at wall's heel	qh=	49.6
Allowable stress (Bearing capacity)	qa=	200.0
Judgment		**OK**

Annex D
(informativu)

Folha servisu excel ba kalkulasaun estabilidade declive

D.1 Traçado

Worksheet ezekuta kalkulasaun stabilidade rai halis, konsiste husi sheet 3: In_put, Cal_EUT no Calc

- Kolapsu inklinasaun presume hanesan deslizamento sirkular.
- Taludes mak parte tetuk ne'ebe nia gradiente uniforme.
- Medida deslizamento mak fo liu husi altura no profundidade deslizamento.
- Deslizamento nia isin automatikamente fahe ba 6.
- Be subteranea mak parte tetuk, bele halo sulin liu ba iha node point.
- Formula simplifikadu aplika ba iha kalkulasaun fator seguransa.
- Iha ne'eba iha Tipi 3 ba kalkulasaun kalkula kombinasaun liu husi kondisaun no targetu.

$$F_S = \frac{\sum\left(c_i l_i + (W_i - u_i b_i)\cos\alpha_i \tan\phi_i\right)}{\sum W_i \sin\alpha_i}$$

Tipu Kalkulasaun	Fó Kondisaun	Targetu
A	c, ϕ	Fs
B	ϕ , Fs	c
C	c, Fs	ϕ

D.2 Folha servisu

[In_put]

Input data of Slope Stabilty Calculation

Shape of ground surface	Height	m	10.00
	Gradient ratio		1.20
Movable layer depth	ML depth	m	2.603
Groundwater depth	Grandwater level is as same as ground surface.		
Unit weight	Wet UW	kN/m3	18.0
	Saturated UW	kN/m3	20.0
	Water UW	kN/m3	9.8
Calculation Type	Calc Type		B
Input slip surface strength	IP cohesion	kN/m2	
	IP IF angle	deg	30.0
Exsiting safety factor	ES Fs		1.00

[Cal_EUT] kalkulasaun ba equasaun slip circular

Theta_d	Theta	Sine Theta	Cosine Thet	Left	Right	DFR
85	1.4835299	0.9961947	0.0871557	0.0436609	0.2560328	-0.212371844
45	0.7853982	0.7071068	0.7071068	0.4142136	0.2560328	0.158180775
70	1.2217305	0.9396926	0.3420201	0.176327	0.2560328	-0.079705806
60	1.0471976	0.8660254	0.5	0.2679492	0.2560328	0.011916406
65	1.134464	0.9063078	0.4226183	0.2216947	0.2560328	-0.034338124
62	1.0821041	0.8829476	0.4694716	0.249328	0.2560328	-0.006704784
61	1.0646508	0.8746197	0.4848096	0.2586176	0.2560328	0.002584797
61.3	1.0698868	0.8771462	0.4802235	0.2558264	0.2560328	-0.000206412
61.2	1.0681415	0.8763067	0.4817537	0.2567564	0.2560328	0.000723573
61.28	1.0695378	0.8769785	0.4805296	0.2560123	0.2560328	-2.04485E-05
61.27	1.0693632	0.8768946	0.4806827	0.2561053	0.2560328	7.25397E-05
61.28	1.0695378	0.8769785	0.4805296	0.2560123	0.2560328	-2.04485E-05

Slip circular			
	mH/2		6
	H/2		5
	R-t		14.2544
	xc		-3.1254
	yc		15.9505
	R		16.2541

[Calc]

Summary Table

Element	Angle	Length	Area	Weight	WcosAlph	WsinAlph
	Alpha	l		W	-ul	
#	deg	m	m2	kN	kN	kN
1	15.5	2.490	1.603	32.06	15.19	8.55
2	24.5	2.638	4.291	85.82	36.02	35.65
3	34.3	2.905	5.812	116.23	39.07	65.50
4	45.5	3.423	5.718	114.36	24.14	81.55
5	55.2	2.105	2.157	43.14	0.00	35.44
6	63.7	2.712	0.860	17.21	0.00	15.43
Total		16.273			114.42	242.12

A. Given c and Phi, Target is Fs

IP cohesion	kN/m2	0
IP IF angle	deg	30
Fs		-

B. Given Phi and Fs, Target is c

IP IF angle	deg	30
ES Fs		1
c	kN/m2	**10.82**

C. Given c and Fs, Target is Phi

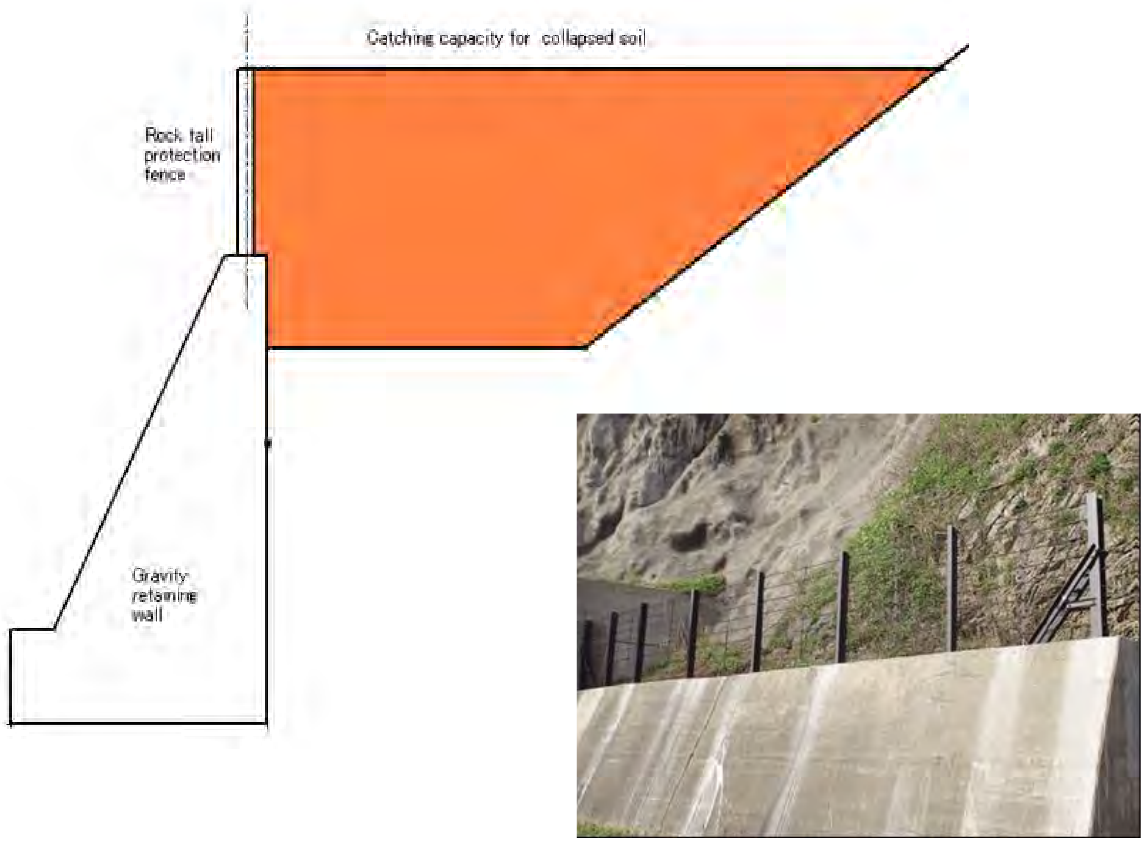
IP cohesion	kN/m2	0
ES Fs		1
Phi		-

Annex E
(informativu)

Moru captura

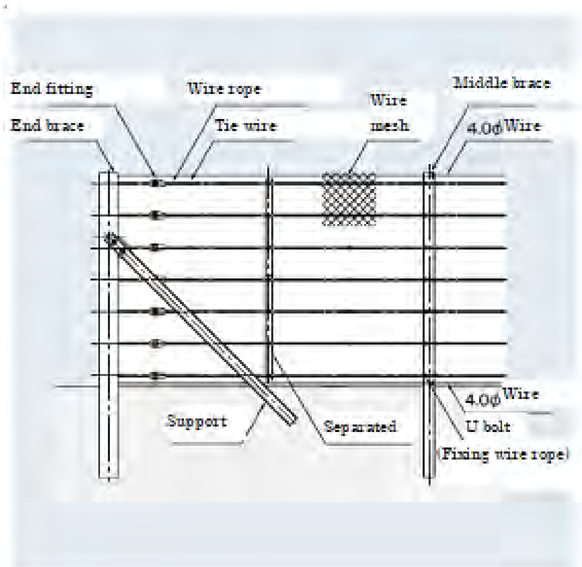
E.1 Informação geral de parede de captura

Moru kaptasaun ne'ebe mak introdus iha ne'e mak kombinasaun gravidade moru retensaun no rock fall protection fence. Kapasidade kaptasaun decide bazea ba massa colapso rai nian. Moru ne'e iha durabilidade hasoru impactu forsa rai ne'ebe collapso.



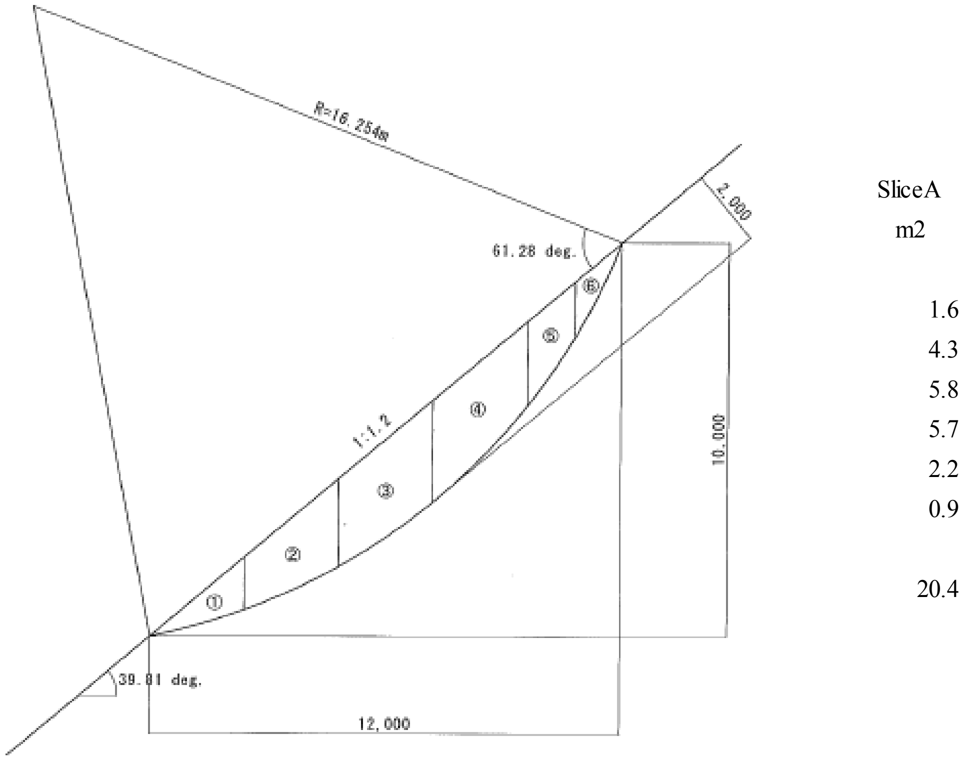
[Karakteritika]

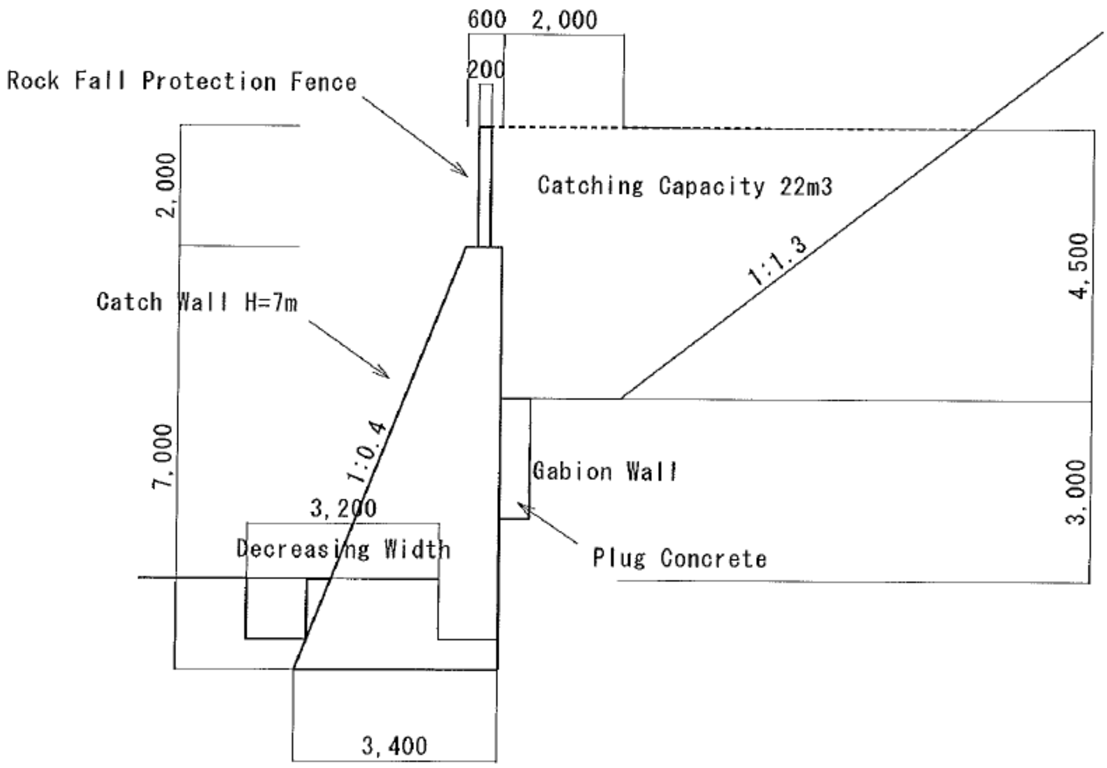
- Klasifika ba tráfiku servisu protesaun
- Lutu ho baja bele redus todan iha porção superior
- Kapasidade kaptasaun tenki boot liu rai ne'ebe hetan collapso
- Moru tenke fó forsa ba impaktu hosi collapso rai



E.2 Kapasidade captura

Kapasidade kaptasaun deside bazea ba massa colapso rai nian. Iha ezempli ida ne'e skala kona ba collapso rai halis mak hnaesan stimava tha ona hanesan ho dezennu. Massa (seksaun transversal) mak 20.4m^2. Kapasidade kaptasaun sai 22m^2 kuando as adisional 4.5m hanesan tuir mai ne'e. Lotu ho Fatuk H=2m ne'ebe babain adopta ba kombinasaun.





E.3 Prosedimentu dezennu

① Elevasaun as moru nia decide tiha ona 2 m tun, husi moru leten.

② Forma Moru nian mos bele selesiona husi Tipu 1 husi dezennu comun.

③ Forma ne'ebe orijinal mos adotável.

④ Kalkulasaun ba impacto ba forsa.

⑤ Hanesan mos ho kalkulasaun gravidade moruretensaun babain.

E.4 Kalkulasaun stabilidade

[Kondisaun kalkulasaun]

Kalkulasaun ba kondisaun kona ba moru kaptura konsiste husi valor lokal ne'ebe mak decide bazea ba cazu no valor padraun ida ne'ebe babain uza.

Calculation Conditions of Catch Wall

Items	Symbol	Unit	Local Value	Standard Value
Items for Calculation of Impact Force				
Possible Collapsing Height	H	m	40	
Slope Gradient	θu	deg.	38	
Gradient between Slope-end and Wall	θd	deg.	0	
Distance between Slope-end and Wall	Xb	m	2	
Height of Moving Soil	hsm	m		1.0
Density of Moving Soil	ρs	t/m^3		1.8
Specific Weight of Moving Soil	σ	DL		2.6
Volumetric Concentration of Moving Soil	c	DL		0.5
Acceleration of Gravity	g	m/s^2		9.8
Coefficient of Fluid Resistance	fb	DL		0.025
Coefficient of Impact Force absorption	α'	DL		0.5
Internal Friction Angle of Moving Soil	Φd	deg.	35	
General Items				
Unit Weight of Wall Concrete	γc	kN/m^3		22.56
Unit Weight of Backfill Soil	γb	kN/m^3	18	
Unit Weight of Moving Soil	γ	kN/m^3	18	
Internal Friction Angle of Backfill Soil	Φb	deg.	35	
Friction Angle between Wall and Soil	δ	deg.	23.3	2/3Φb

[Valor permitido ne'ebe iha verifikasaun stabilidade]

Verifikasaun stabilidade implementa iha situasaun tolu hanesan, situasaun normal, atuasaun forsa impacto (colapso ne'ebe akontese) no atuasaun colapso presaun rai (depois de akontese). Kada situasaun iha diferente valor ne'ebe permite hanesan tuir mai ne.

Allowable Value on Stability Check

	Over-turning Eccentric Length e is	Sliding Safety Factor is	Bearing Capacity Reaction Force is
Normal	Smaller than B/6 Middle Third	Bigger than 1.5	Smaller than qu/3=300 kN/m²
Impact Force Acting	Smaller than B/3	Bigger than 1.0	Smaller than qu=900 kN/m²
Collapsed Soil Earth Pressure Acting	Smaller than B/3	Bigger than 1.2	Smaller than qu/2=450 kN/m²

[Kalkulasaun ba forsa impacto]

Forsa impacto kalkula ho equasaun tuir mai ne'e. Fornese Excel worksheets.

$$\mathrm{F} = \alpha' F_{sm}$$

F: Impact Pressure on the Wall (kN/m²)

F_{sm}: Pressure by Moving Soil

α': Coefficient of Impact Pressure absorption

$$F_{sm} = \rho_s g h_{sm} \left[\left\{ \frac{b_u}{a} \left(1 - exp\left(\frac{-2aH}{h_{sm}\sin\theta_u} \right) \right) cos^2(\theta_u - \theta_d) \right\} exp\left(\frac{-2aX_b}{h_{sm}} \right) + \frac{b_d}{a} \left(1 - exp\left(\frac{-2aX_b}{h_{sm}} \right) \right) \right]$$

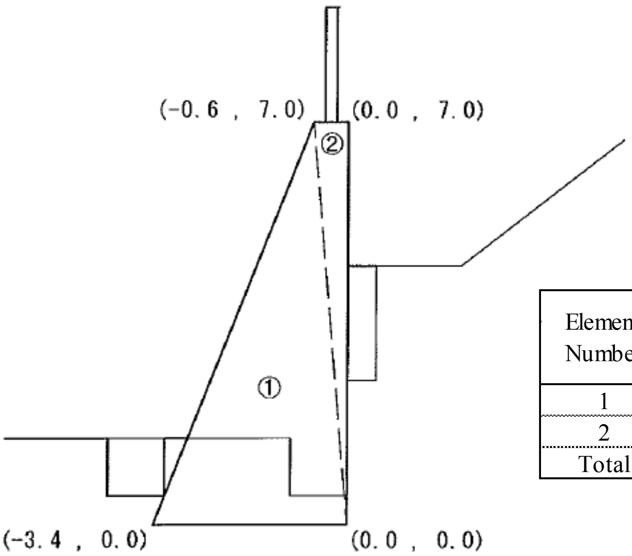
$$\mathrm{a} = \frac{2}{(\sigma-1)c+1} f_b$$

$$b_u = \cos\theta_u \left\{ \tan\theta_u - \frac{(\sigma-1)c}{(\sigma-1)c+1} \tan\varphi_d \right\}$$

$$b_d = \cos\theta_d \left\{ \tan\theta_d - \frac{(\sigma-1)c}{(\sigma-1)c+1} \tan\varphi_d \right\}$$

Item	Symbol	Unit	Value
Coefficient	a	DL	0.027778
	bu	DL	0.370430
	bd	DL	-0.311203
Pressure of Moving Soil	Fsm	kN/m2	106.39
Impact Pressure on the Wall	F	kN/m2	53.20
Impact Pressure Acting Area	Asm	m2	1.00
Impact Force	Fc	kN	53.2

[Moru nia todan no sentru gravidade]



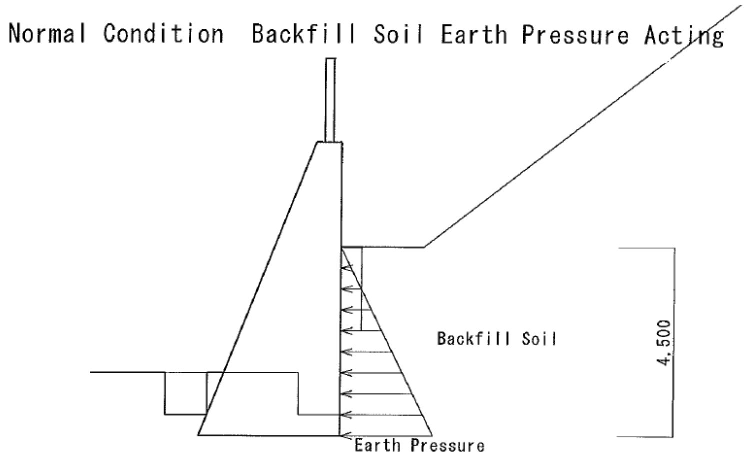
Element Number	Area A (m2)	Weight V (kN)	Arm Length x (m)	Moment M (kNm)
1	11.90	268.5	-1.333	-357.9
2	2.10	47.4	-0.200	-9.5
Total		315.9		-367.4

[Presaun rai activa Coulomb]

Presaun rai nan kalkula ho formula Coulomb. Ida mak presaun rai nia iha situasaun normal. Seluk tan mak situasaun atua presaun rai ne'ebe collapso.

α degree	β degree	φ degree	δ degree	KA	γ kN/m3	h m	PA1 kN/m	q kN/m2	PA2 kN/m	ΣPA kN/m	PAH kN/m	PAV kN/m
0.0	0.0	35.0	23.333	0.244	18	4.5	44.47	0	0.00	44.47	40.8	17.6
0.0	0.0	35.0	23.333	0.244	18	9	177.88	0	0.00	177.88	163.3	70.4

[Kalkulasaun stabilidade iha situasaun normal]



Summary of Load and Moment

Condition	Normal				
Loads	Vertical Loads V (kN)	Arm Length x (m)	Horizontal Loads H (kN)	Arm Length y (m)	Moment M (kNm)
Wall Body	315.9		0.0		-367.4
Earth Pressure	17.6	0.000	-40.8	1.500	-61.2
	333.5		-40.8		-428.6

Three Check Points of Stability Index

1) Over-turning

X coordinate of ΣV	X=	-1.285
X coordinate of Wall Toe	Xt=	-3.400
X coordinate of Wall Heel	Xh=	0.000
Width of Base	Bh=	3.400
X coordinate of Limit for ΣV	Xa=	-2.833
Judgment		**OK**
Eccentric Length	e=	-0.415
Middle-third/2		0.567
Shape of Reaction Force		**Trapezoidal Shape**

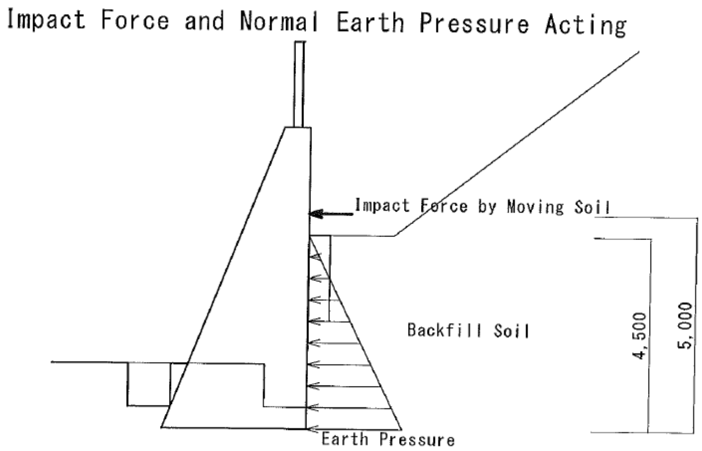
2) Sliding

Friction Coefficient	μ=	0.6
Sliding Safety Factor	Fs=	4.90
Needed Safety Factor	Fsn=	1.50
Judgment		**OK**

3) Bearing Capacity of Foundation Ground

Reaction Force at Wall Toe	qt=	26.3
Reaction Force at Wall Heel	qh=	169.9
Allowable Bearing Capacity	qa=	300
Judgment		**OK**

[Kálkulu estabilidade ne'ebé iha impaktu forsa situasaun atua]



Summary of Load and Moment

Condition	Impact Force Acting				
Loads	Vertical Loads V (kN)	Arm Length x (m)	Horizontal Loads H (kN)	Arm Length y (m)	Moment M (kNm)
Wall Body	315.9		0.0		-367.4
Earth Pressure	17.6	0.000	-40.8	1.500	-61.2
Impact Force			-53.2	5.000	-266.0
	333.5		-94.0		-694.6

Three Check Points of Stability Index

1) Over-turning

X coordinate of ΣV	X=	-2.083
X coordinate of Wall Toe	Xt=	-3.400
X coordinate of Wall Heel	Xh=	0.000
Width of Base	Bh=	3.400
X coordinate of Limit for ΣV	Xa=	-2.833
Judgment		**OK**
Eccentric Length	e=	0.383
Middle-third/2		0.567
Shape of Reaction Force		**Trapezoidal Shape**

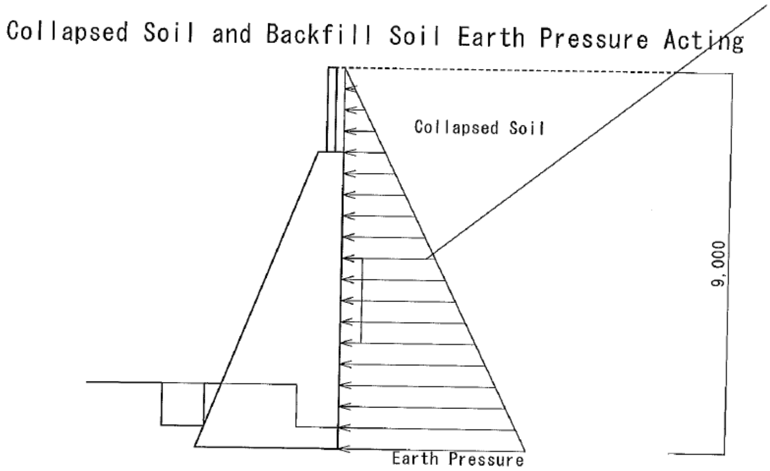
2) Sliding

Friction Coefficient	μ=	0.6
Sliding Safety Factor	Fs=	2.13
Needed Safety Factor	Fsn=	1.00
Judgment		**OK**

3) Bearing Capacity of Foundation Ground

Reaction Force at Wall Toe	qt=	164.4
Reaction Force at Wall Heel	qh=	31.8
Allowable Bearing Capacity	qa=	900
Judgment		**OK**

[Kalkullu estabilidade iha colapso presaun rai nian ne'ebe atua]



Summary of Load and Moment

Condition	Collapsed Soil Earth Pressure Acting				
Loads	Vertical Loads V (kN)	Arm Length x (m)	Horizontal Loads H (kN)	Arm Length y (m)	Moment M (kNm)
Wall Body	315.9		0.0		-367.4
All Earth P.	70.4	0.000	-163.3	3.000	-489.9
	386.3		-163.3		-857.3

Three Check Points of Stability Index

1) Over-turning

X coordinate of ΣV	X=	-2.219
X coordinate of Wall Toe	Xt=	-3.400
X coordinate of Wall Heel	Xh=	0.000
Width of Base	Bh=	3.400
X coordinate of Limit for ΣV	Xa=	-2.833
Judgment		**OK**
Eccentric Length	e=	0.519
Middle-third/2		0.567
Shape of Reaction Force		**Trapezoidal Shape**

2) Sliding

Friction Coefficient	μ=	0.6
Sliding Safety Factor	Fs=	1.42
Needed Safety Factor	Fsn=	1.20
Judgment		**OK**

3) Bearing Capacity of Foundation Ground

Reaction Force at Wall Toe	qt=	217.7
Reaction Force at Wall Heel	qh=	9.6
Allowable Bearing Capacity	qa=	450
Judgment		**OK**

E.5 Komparasaun ho kontramedida sira seluk

Ezemplu dezennu parede kaptura ida ne'e mak kontramedida kompetitiva atu kombina ho costura barra no estrutura konkretu ne'ebe apresenta iha artigo 12. Tabela komparasaun mak hanesan hatudu tuir mai ne'e.

Item	A. Sewing Bar and Shotcrete Frame	B. Catch Wall
Principle Classification	Deterrence Work	Traffic Protection Work
Out line	The bar sews the collapsing soil to unmoving ground, the frame distributes the bar force to collapsing soil.	Catch wall protects traffic from collapsed debris by own catching capacity. Catch wall must bear impact force by the debris
Quantity per 10m	Shotcrete frame: 370m Sewing Bar: 100, 400m	Wall concrete: 140m3 Rock fence: 10m
D.C. cost per 10m In Japan	USD 86,000.-	USD 36,000.-
Others	No loss	Road width 3.2m loss
Maintenance	Nothing	Debris shall be removed after collapse.
Selection	No demerits but high cost.	Low cost but some demerits.

Karakteristika Parede kaptura bele resume hanesan karaik ne'e.

- Moru kaptura nia custo menus liu do que kontramedida seluk iha cazu barak.
- Nivel balu kona-ba spaso ba halo baze ba moru mak presiza declive nia ain. Tamba ne'e moru kaptura la adequada atu koloka iha fatin ne'ebe kolo'ot hanesan foot of steep slope.
- Nivel balu husi kapasidade carga husi rai okos mak presiza halo tuir dalan slope sorin. Ida-ne'e obrigasaun absoluta.
- Detrito sira tenki hamos depois collapso atu fo ftin ba collapso tuir mai.
- Se targetu collapso declive mak expansivo ba parte superior declive nian, forsa ba impacto bele sae tamba ptencial moru captasaun ne'ebe as. Posibilidade altura kolapso iha kondisaun dezennu tenki deside ho konsiderasaun ne'ebe klean.

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Democratic Republic of Timor-Leste

Ministry of Public Works

Directorate General of Public Works

National Directorate of Roads, Bridges and Flood Control

Road Guidelines — Slope Protection — Landslide Investigation

Guia de Estrada — Proteção de Taludes — Investigação de Deslizamentos

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Contents

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REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTÉRIO DAS OBRAS PÚBLICAS
GABINETE DO VICE MINISTRO
Av. Nicolau Lobato, Mandarin, Dili, Timor-Leste

Foreword

In the interest of constructing high quality and economically viable government infrastructure to serve the nation, these guidelines for landslide investigation were prepared by the JICA Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste (CDRS) in collaboration with the *Direcção Nacional de Estradas, Pontes e Controlo de Cheias* (DNEPCC, 'National Directorate of Roads, Bridges and Flood Control') of the *Ministério das Obras Públicas* ('Ministry of Public Works'). We would like to thank JICA for their continuing support.

September, 2019

Eng. Nicolau Lino Freitas Belo
Vice Minister for Public Works
Ministry of Public Works

19-09-2019

Foreword by JICA

Japan International Cooperation Agency (JICA) has been conducting a technical cooperation project for development of capacity regarding road services, which is called as CDRS, in order to facilitate the DNEPCC in properly managing and maintaining the road infrastructure that is the basis of social and economic activities. To this end, JICA has been dispatching a team of experts from March 2016 to December 2019. As a result of collaborative works with counterparts of the DNEPCC, these guidelines for design of landslide investigation have been finalized. I hope that these guidelines will contribute to infrastructure development and maintenance and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials of the Government of the Democratic Republic of Timor-Leste for their close cooperation with the expert team.

September, 2019

Masafumi NAGAISHI
Chief Representative of JICA Timor-Leste Office
Japan International Cooperation Agency

Acknowledgements

The Project for Capacity Development of Road Services in the Democratic Republic of Timor-Leste wishes to thank all parties involved in preparing and revising these Landslide Investigation guidelines.

In support of the project, the officials of the (former) Ministry of Development and Institutional Reform: M. R. M. Cruz, J. L. C. C. P. Mestre and J. Santos; and the officials of the Ministry of Public Works: C. M. Henrique and especially R. H. F. Guterres; are hereby acknowledged.

In contributing to the preparation of this document, the officials of the DNEPCC: M. R. C. Monteiro, J. P. Amaral, J. M. G. Sousa, J. G. Carlvalho, I. M. L. Gutteres, N. Lobato, L. Luis, M. Soares and J. L. Kehy; and the International Labour Organization's (ILO) technical assistance team of the Roads for Development Support Program (R4D-SP): A. O. Asare, K. H. Myaing, S. Done, U. Yat and L. Thakuri; are hereby acknowledged.

Feedback:

Any positive feedback for possible incorporation into future editions would be appreciated. Please send such comments or feedback to the below address.

Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
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Introduction

Timor-Leste is a mountainous country, so most of the major roads are constructed by cutting hillsides. However, because of such topographic condition, it is difficult to construct the cut slopes with stable gradient, and slope failures occur at many places. In addition, landslides, which are much larger than slope failures, also damage the roads in Timor-Leste.

Landslides are large-scale movement phenomena of the ground, and their movements are so slow, that it is generally difficult to recognize their existence at the initial stage of the activity. Moreover, once they start to move, it is extremely difficult to prevent their movement. Therefore, different methods from general slope protection are required for the investigation and the countermeasure of landslides.

In this chapter, the result of the investigation on Aituto Landslide in Ainaro Municipality, conducted by the CDRS Project, is introduced as an example of the landslide investigation.

Road Guidelines — Slope Protection — Landslide Investigation

1 What is a landslide?

1.1 Definition of the term "landslide"

In many countries of the world, the term "landslide" is also used for various disasters of slopes. In these guidelines, the term "landslide" refers generally to mass movement phenomenon that keep the block shape and it moves very slow (0.01~10mm/day). Additionally, one of the characteristics of mass movement is that the inclination of slope angle is a relatively low angle (about 5-20 degrees) comparative to other slope failures. However, in some situation, moving speed increases and develops the large collapse. Some characteristic features commonly appear like Figure 2.

1.2 Mechanism

The mechanism of mass movement is considered as below.

1) When groundwater rises, balance between sliding force and resistance force breaks since pore water pressure rises and effective stress drops.

2) Road earthwork such as cut on foot of moving block or embankment on head of moving block breaks balance between sliding force and resistance force.

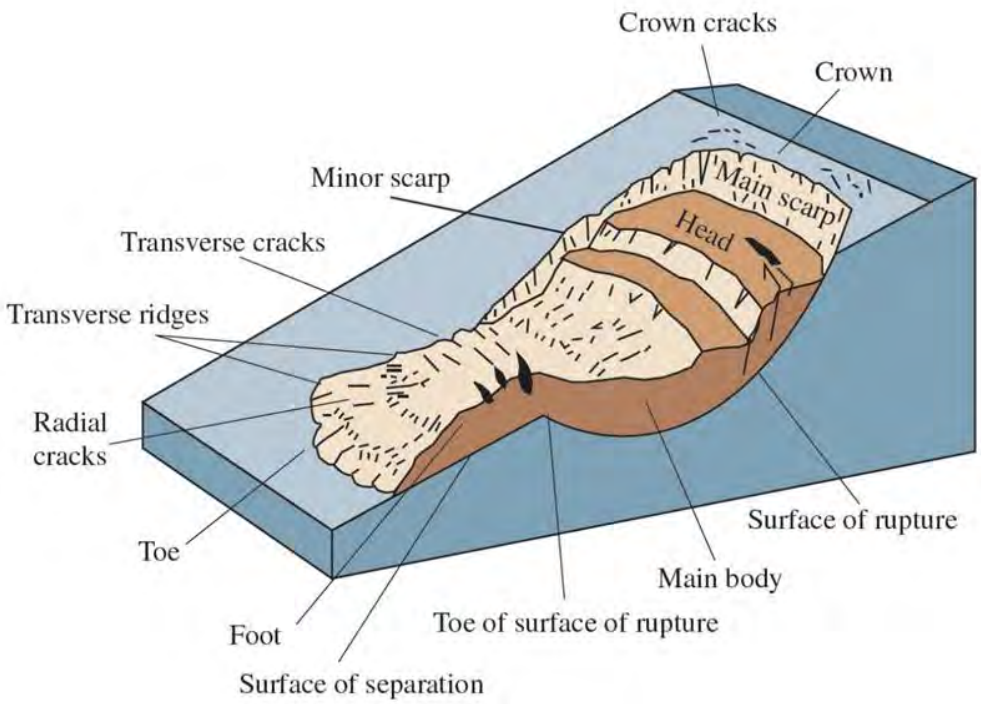

Figure 1 — An idealized Rotational landslide showing commonly used nomenclature for labeling the parts of a landslide.

2 What are the landslide warning signs?

From the perspective of the road inspector role, DRBFC suspects the landslide warning sign as the visible phenomenon. The typical phenomenon is introduced as follows,

2.1 Crack

Generally, the crack is generated by the tensile strength near the crown. It is difficult to detect the crack in the forest area. But if the cracks are generated in the road surface or house, the inspector can suspect the early landslide phenomenon.

Figure 2 — Crack in the road surface and shoulder (Landslide in Sri Lanka)

Figure 3 — Crack at the house near Landslide area (Landslide in Sri Lanka)

2.2 Tree Bending

When the slope movement by landslide is generated, the trunk of tree becomes too bent due to recover to the sun direction. In case that the degree of inclination of the tree is increasing, it assumes that the movement is probably on active.

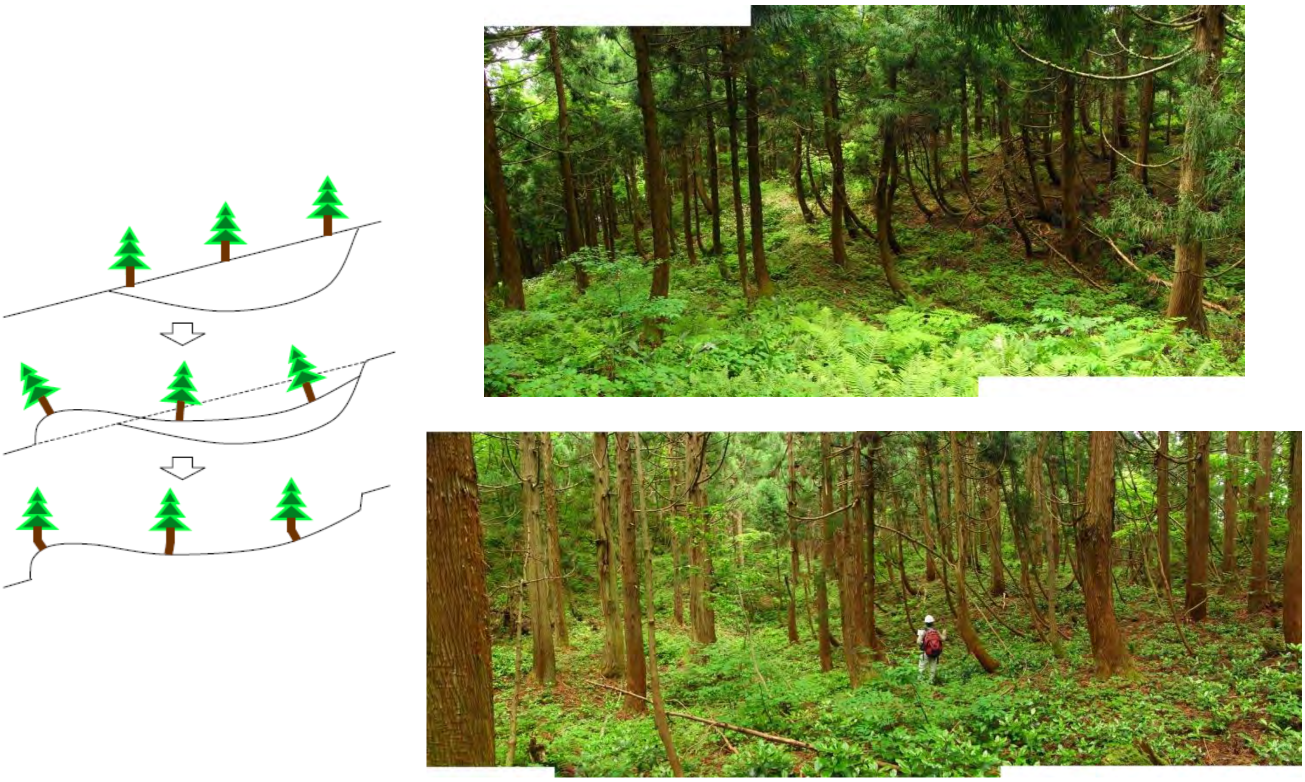

Figure 4 — Tree bending in Landslide (Landslide in Japan)

2.2.1 Focus on Aituto Landslide

2.2.1.1 Location of Aituto landslide

Aituto landslide is located near the boundary of 3 municipalities, such as Ainaro, Manufahi, Aileu, and village of Aituto is administratively under Ainaro district. Aituto is in the central part of the steep mountainous range which exceeds 2,000 m in altitude.

The landslide occurred with an altitude of around 1,700 m of the southern slope of the ridgeline that continues in the east-west direction.

Figure 5 — Location of Aituto landslide

2.2.1.2 How Aituto landslide was recognized

During the widening works of A05, collapse of the cut slope occurred, and existence of a large-scale landslide was suspected behind the slope. Due to above phenomenon, the widening work was suspended.

From the above reason, the geological survey with drilling works was launched. The drilling started in last November and completed in the beginning of December. The casings for the monitoring with inclinometer were also installed to some of the drill holes.

Figure 6 — Collapse due to the cut slope

3 Flow chart of landslide investigation

If the landslide phenomenon is recognized, it is necessary to conduct the investigation to obtain the geological condition, scale of landslide and activity. The result from investigation, the countermeasure is proposed.

This flow chart shows how the investigation on Aituto landslide had been conducted. For the investigation on the other landslide, it will be effective if the operations are followed to these procedures.

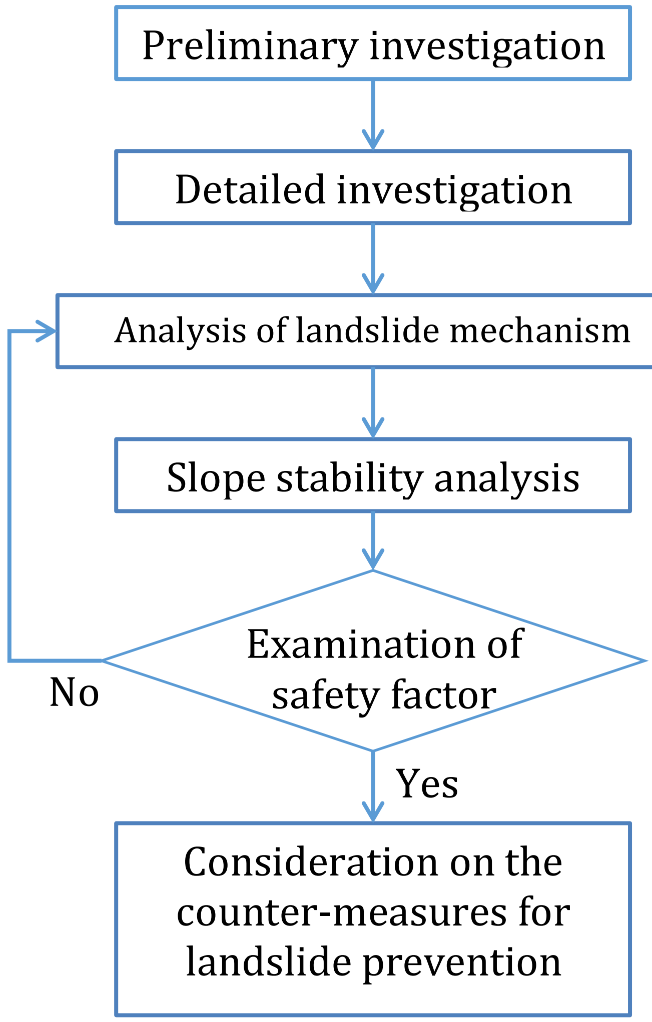

Figure 7 — Flow chart of landslide investigation

4 Preliminary investigation

The method of investigation differs depending on the large-scale landslide described above, such as rotational landslide, translational landslide, block slide, and other slope failures.

The purposes of the topographic investigation are to understand following items

1) The overall topographic feature of the site slopes

2) Understanding the topographic characteristics of the site slope

3) Estimating the regional geologic structure of the site

The flow chart is shown as follows.

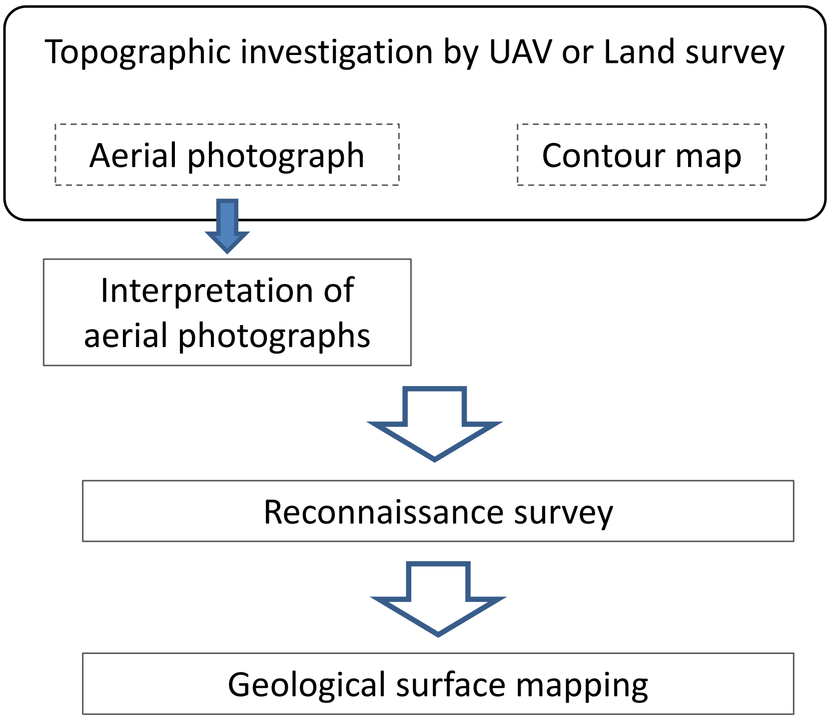

Figure 8 — Flow chart of Preliminary investigation

4.1 Topographic investigation

Figure 9 — UAV (drone)

The purpose of topographic investigation is to obtain the information of topography. The main outputs are contour map and aerial photographs. A contour line of the contour map is a line formed by a group of points of the same height. And a contour map is drawn to represent the topography of some region by contour lines of fixed intervals.

There are two types of investigation method; UAV (Drone) survey and Land survey. The land survey is the man-power method using by total station and GNSS measurement. The UAV survey is used by UAV measurement, and new technology to get the topographic information. The advantage of UAV method is efficiently collected the accuracy and wide area data. One the other hand, it is difficult to take data under the circumstances of forest area that prevent from the topographic surface. The standard specification and operation method of UAV is in Annex A.

4.1.1 Focus on Aituto Landslide

4.1.1.1 Aerial photograph

Examples of aerial photographs taken from UAV are shown in Figure 14. The resolution of Ortho satellite image is 3.85 cm/pixel and, the original digital elevation model (DEM) for generating the counter map is 15.4 cm.

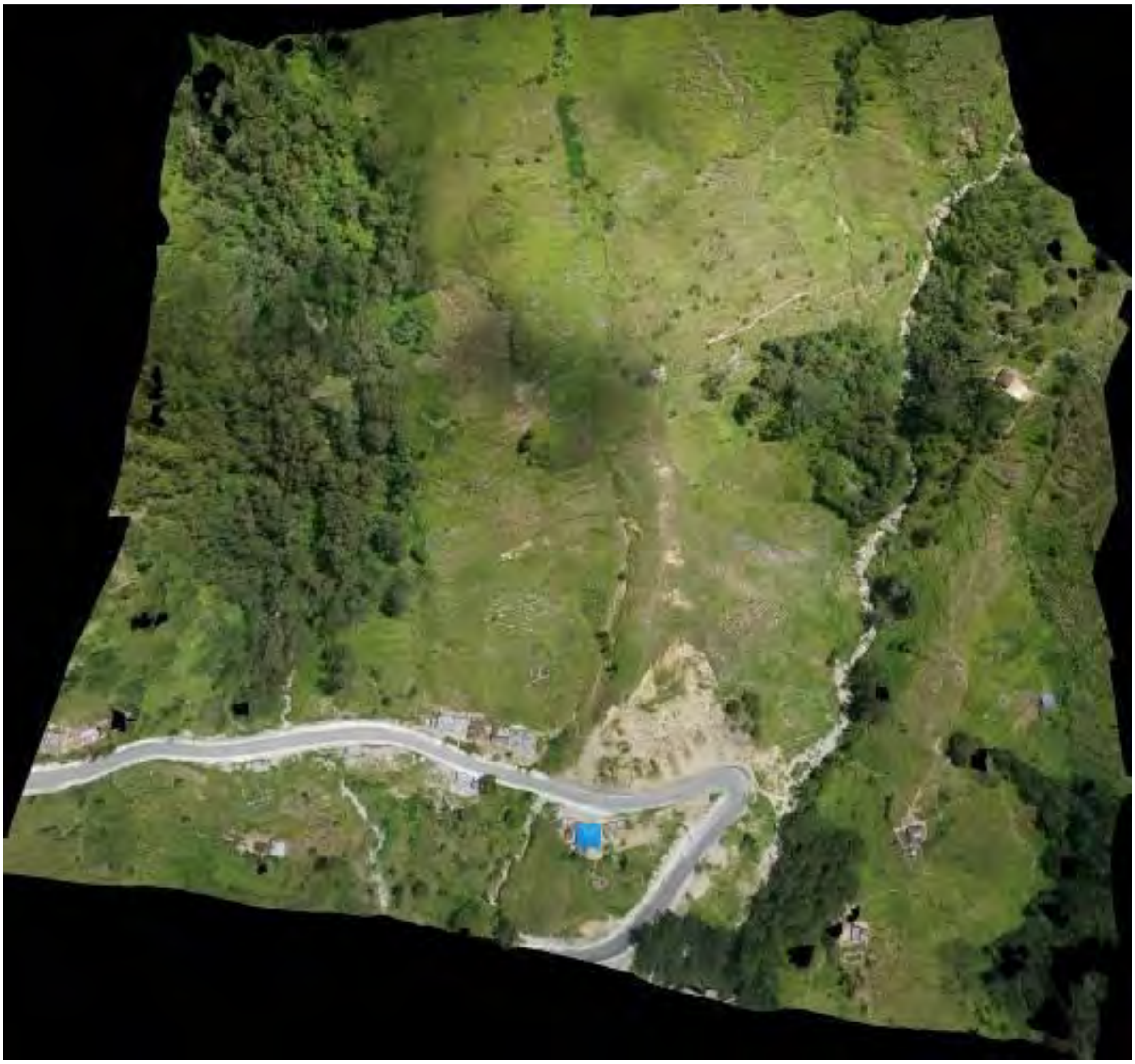

Figure 10 — Aerial photographs taken from the UAV (Drone)

4.1.1.2 Contour map

According to the result of topographic investigation, the contour map can be generated.

A contour line is a line formed by a group of points of the same height. And a contour map is drawn to represent the topography of some region by contour lines of fixed intervals. Contour maps are also used to draw cross-sections for geological profiles and topographical sections for the slope stability analysis.

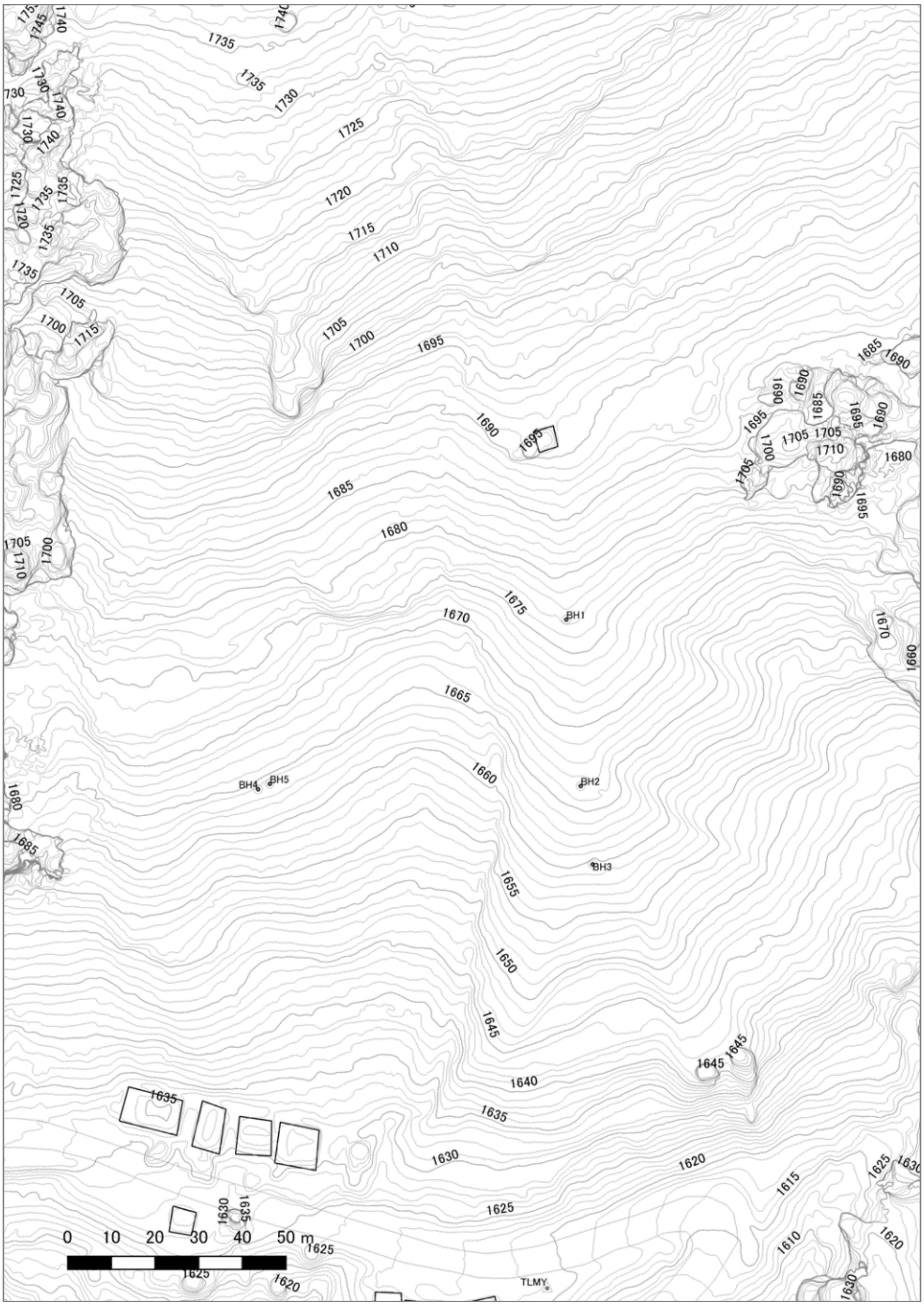

Figure 11 — The contour map created using aerial photographs taken by the UAV

4.2 Interpretation of aerial photographs

The shapes of the landslide blocks can be identified by stereoscopically viewing a set of aerial photographs taken from neighbouring points. The shapes of identified landslide blocks should be traced to the contour map and used to consider the plan of geological investigation.

Figure 12 — Stereoscopic viewing of a pair of aerial photographs

4.2.1 Focus on Aituto Landslide

According to the stereoscopic interpretation of aerial photograph, the trace of outline of landslide is prepared. Based on the traced map, the plan of geological investigation will be started.

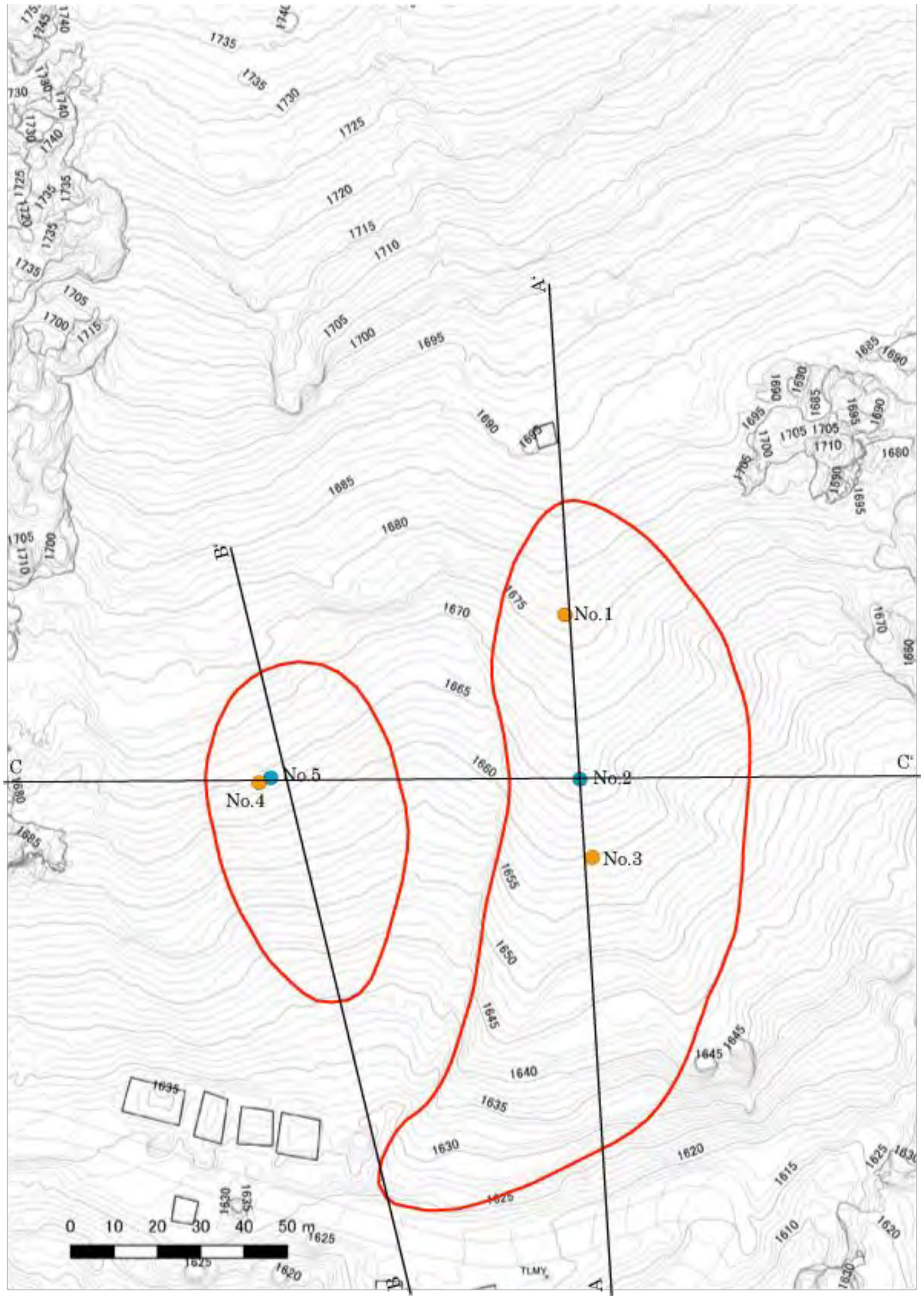

Figure 13 — Trace of outlines of landslide blocks which is interpreted with aerial photographs

4.3 Reconnaissance survey

The reconnaissance survey is conducted at the initial stage of the investigation. Purposes of the reconnaissance survey is to

1) Understand the aerial extent and a general direction of movement of the landslide

2) Assess the geology and geologic structure

3) Estimate the cause of the sliding

4) Predict future movement

4.4 Geological surface mapping

Geological surface mapping had been carried out using the contour map to understand the geology and geologic structure of the site. Scarps, cracks and other characteristic features of landslide were also recorded on the map.

4.4.1 Focus on Aituto Landslide

4.4.1.1 Geological condition of the site

4.4.1.1.1 Talus deposits

The surface of the site is covered with talus deposits. These deposits consist of gravels of limestone of various sizes, and soft brown soil is filling the gravels.

Figure 14 — Outcrop of the talus deposits

4.4.1.1.2 Bedrock

Based on the observation of out-crops, geological condition of the landslide blocks is analysed. The bedrock of the site is consists of alternation of limestone layers and mudstone layers. At the outcrop, strata of mudstone are often sheared into fragile layers. These soft layers are supposed to compose the surface of rapture.

Figure 15 — Outcrop of the bedrock

4.4.1.1.3 Sheared zone

On the southwestern corner of Block A, soft mudstones outcrop along the road. These strata are considered to have been fractured by the fault.

Figure 16 — Outcrop of the sheared zone

4.4.1.1.4 The result of geological surface mapping had been summarized as the route map.

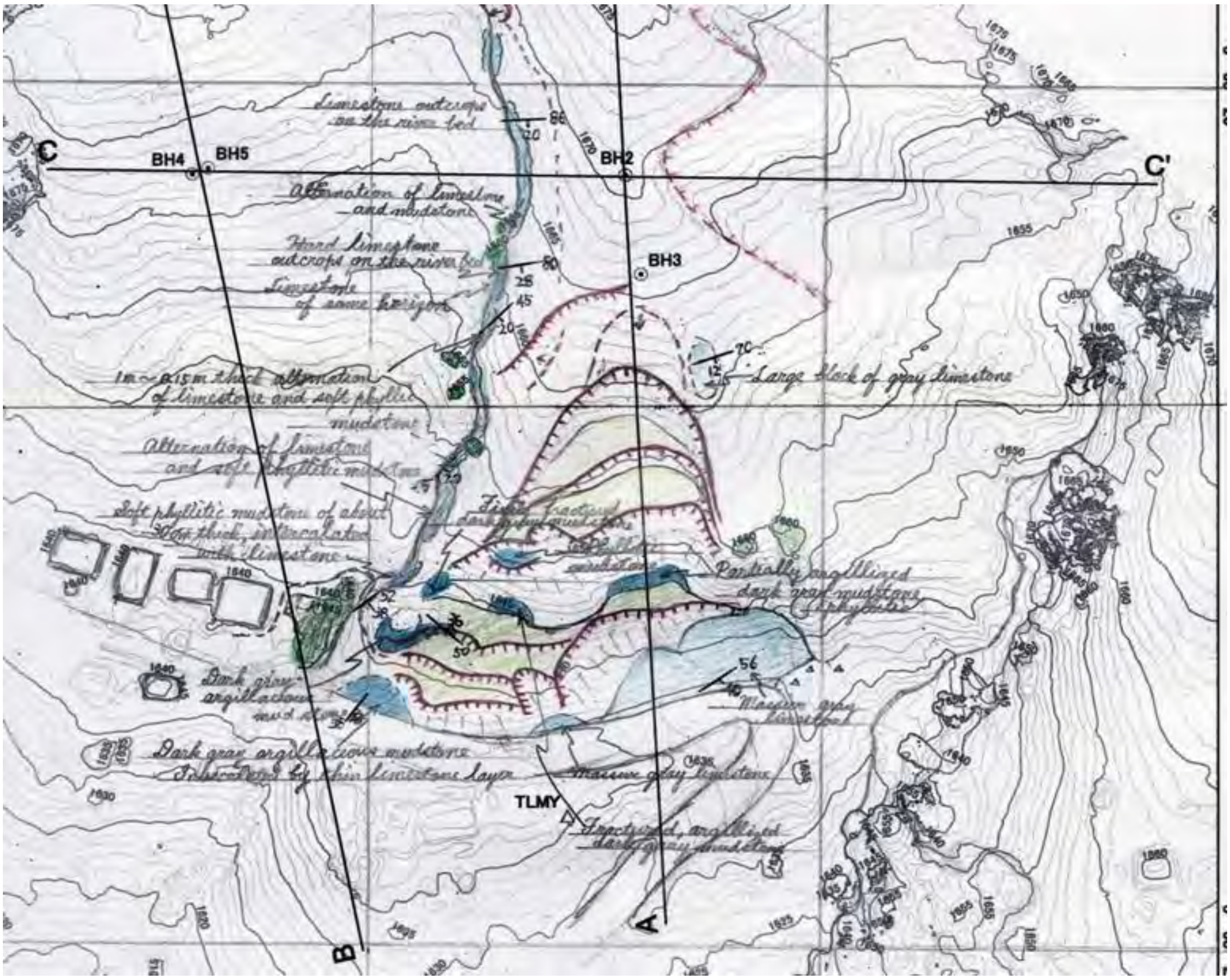

Figure 17 — Route map of Aituto landslide

5 Detailed investigation

Based on the results of the preliminary investigation, a plan of the detailed investigation was drafted. Detailed investigation should be carried out by selecting appropriate investigation methods and instruments.

5.1 Simple method to measure movement

In the case that any tension crack is observed on the site, following method will be effective to know the movement of the ground.

Drive stakes across a tension crack along the direction of movement. Then attach horizontal board to the stakes, and saw through the board. Any movement across the tension crack can be determined by measuring the space between the sawed portions of the board.

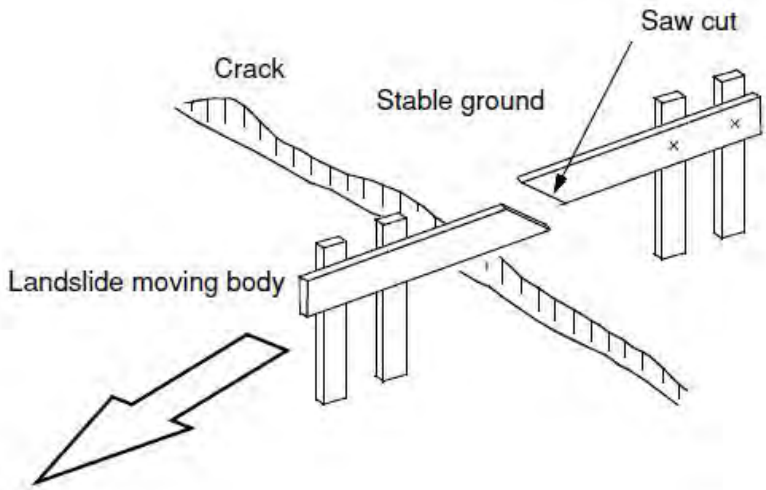

Figure 18 — Simple method to measure movement

5.2 Drilling works

Drilling works had been carried out to obtain geological information of the underground. The depth of the surface of rapture was assumed based on observation of the recovered core samples. The technical specification is attached as Annex 2.

The following information is recorded as drilling logs:

- o Geologic and soil description
- o Colour, Hardness and Lithology
- o Degree of weathering
- o Alterations and fractures
- o Strike and dip of bedding and joints
- o Initial and stabilized groundwater levels
- o Rate of core recovery.

Figure 19 — Simple of undisturbed core sample in mass movement

5.3 Confirmation of the surface of rupture by inclinometer measurement

To detect displacement of the sliding mass, monitoring with the inclinometer is the useful tool. Measurement the inclination of casings with the inclinometer should be performed periodically, and the cumulative displacement of the casing should be analysed to detect the depth of the surface of rupture.

The guidelines for installation of inclinometer casings are attached as Annex 3 and Annex 4.

Manuals for the inclinometer and the logger are attached as Annex 5 and Annex 6.

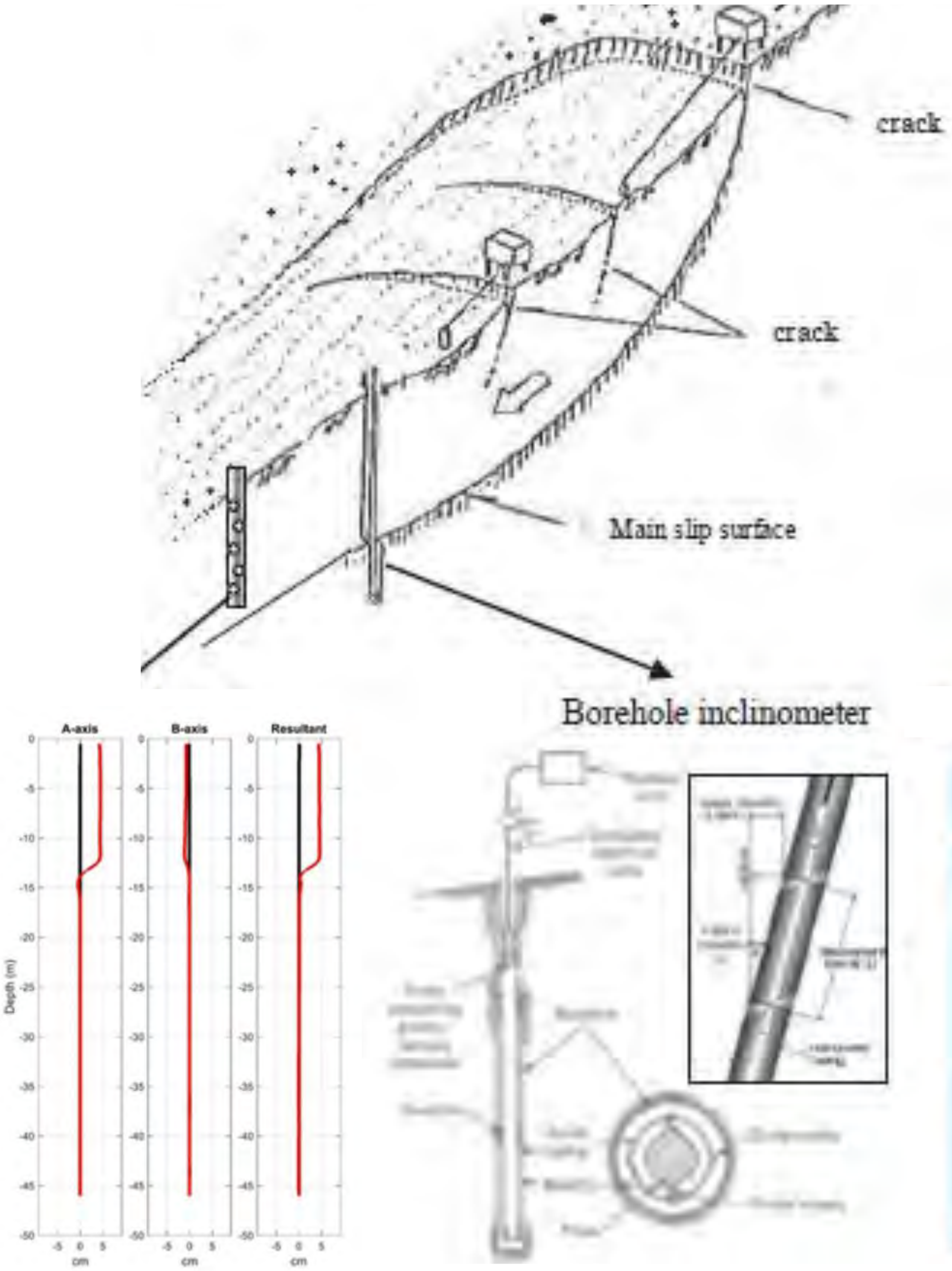

Figure 20 — General image of Inclinometer

5.3.1 Focus on Aituto Landslide

5.3.1.1 Records of the inclinometer

The inclinometer being carried out at drilling No.1, No.3 and No.4. Groundwater level is also being observed at drilling No.2 and No.5.

Figure 21 — Insertion of the probe of the inclinometer into the casings

Figure 22 — Reading of values of inclination of the probe with the logger

The record of the inclinometer of drilling No.1, No.3 and No.4 are shown in Figure 26, 27 and 28.

At Drilling No. 1, there are signs of displacement at three depths (refer Figure 26). In the case that one of these signs will be recognized more clearly, the surface of rupture of the cross-section should be revised.

At Drilling No. 3, there are signs of displacement at a depth of 4.0 m (refer Figure 26). Therefore, careful attention will be required in the future. Currently, no sign of displacement can be seen in Drilling No. 3(refer Figure 28).

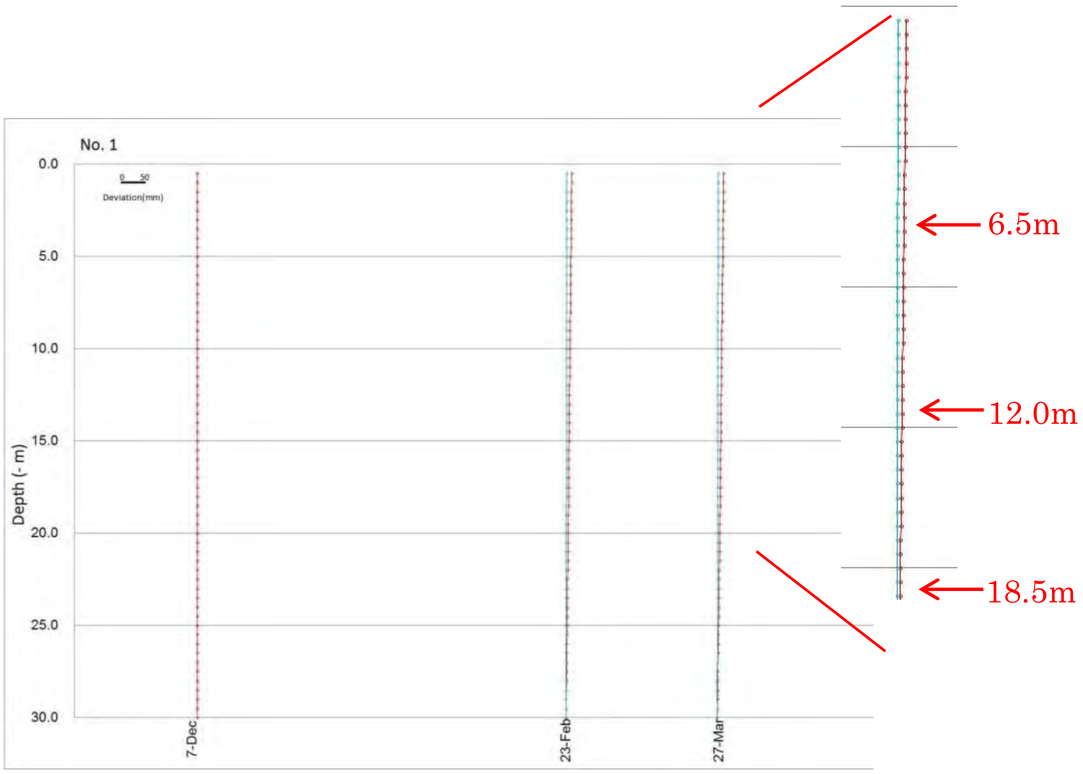

Figure 23 — Record of the inclinometer for the Drilling No.1

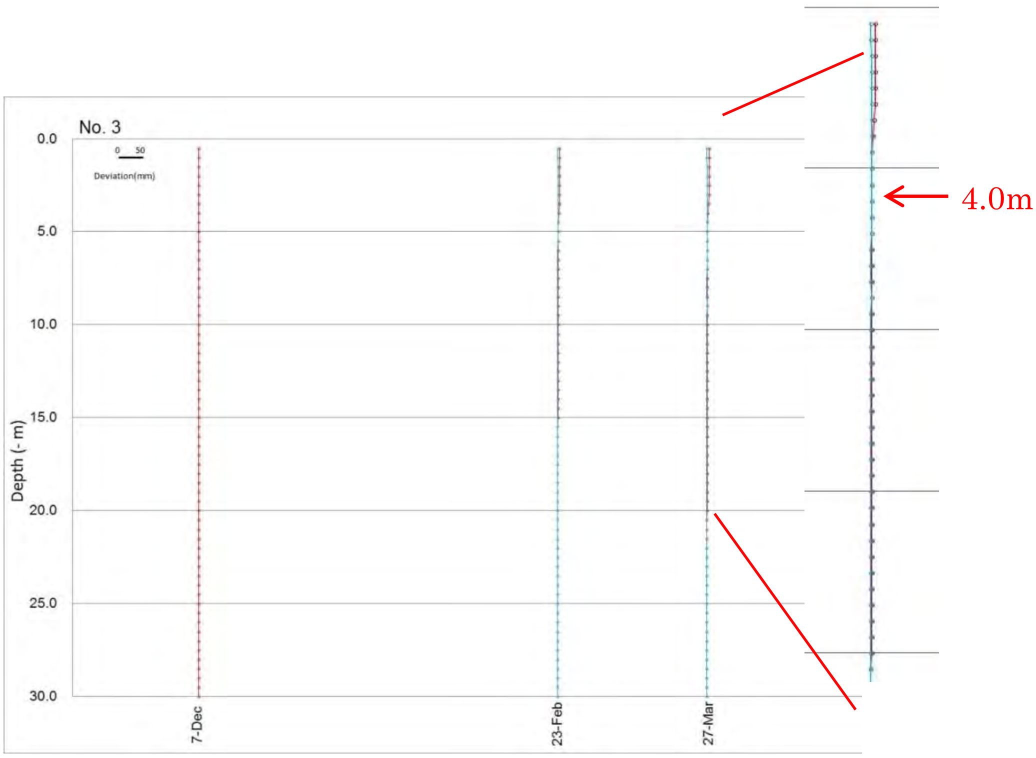

Figure — 24 Record of the inclinometer for the Drilling No.3

6 Analysis of mechanism of the landslide

Based on the results of the investigations, the geological condition of landslide was summarized, and also the mechanism of the sliding was analysed.

6.1 Development of geological profile

Based of contour maps, cross-sections for geological profiles and topographical sections for the slope stability are analysed.

6.1.1 Focus on Aituto Landslide

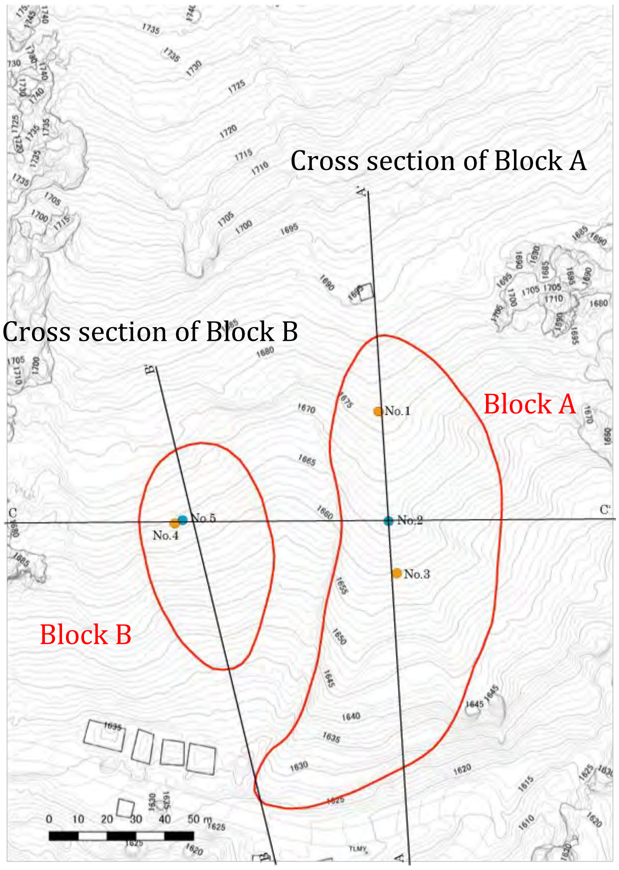

Figure 25 — Cross-section line of plane figure

6.1.1.1 Geological cross-section of Block A

Around the Aituto landslide, the bed-rock consists of alternation of limestone layers and mudstone layers. Along the surface of the bedrock, rocks are altered by weathering, so these parts are defined as the weathered zone. In these weathered zone, strata of mudstone are sheared into fragile layers, and open cracks are developed in limestone layers.

The surface of rupture is assumed near the bottom of the weathered zone. Other circular ruptures are also assumed at the lower edge of the block.

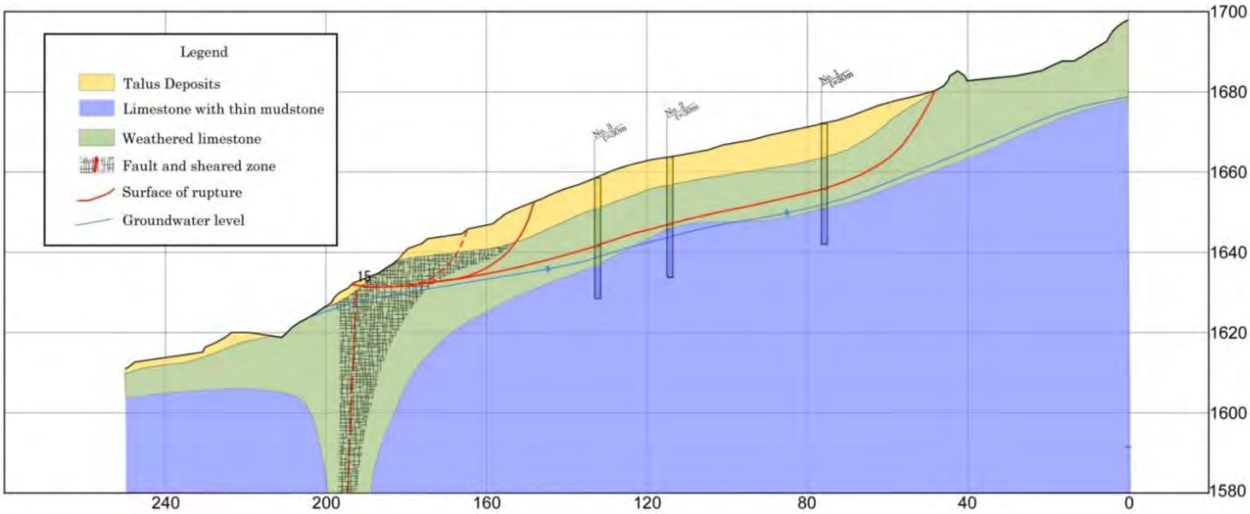

Figure 26 — Geological cross-section of Block A

6.1.1.2 Geological cross-section of Block B

In block B, a shallow sliding mass is assumed in the layer of the talus deposits.

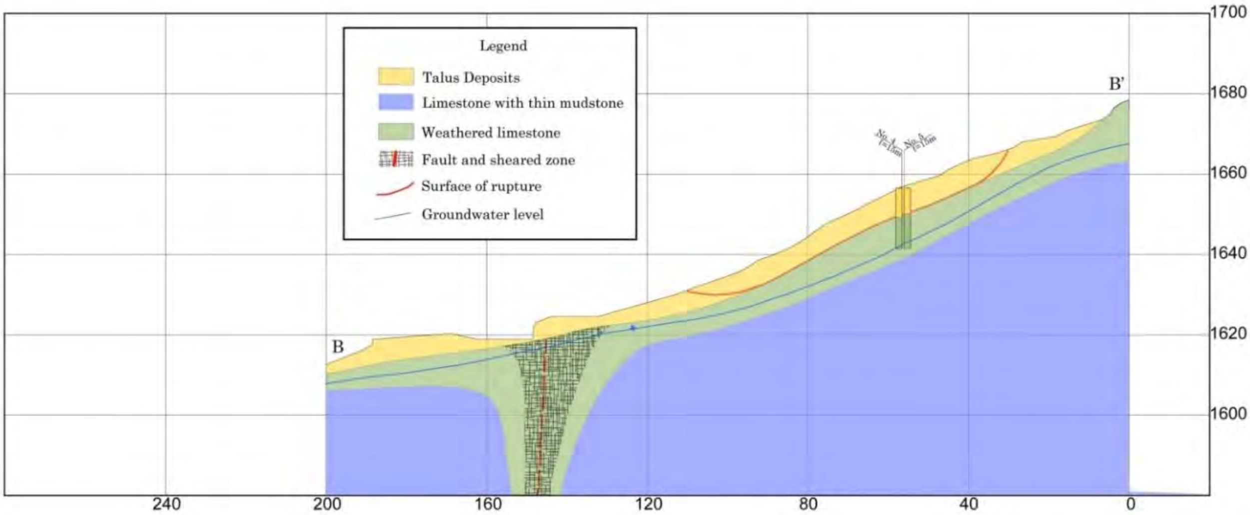

Figure 27 — Geological cross-section of Block B

6.2 Slope stability analysis

Stability of the landslide are calculated based on the cross-section. Constants used for calculation are determined empirically in Japan.

6.2.1 Equation for calculating the safety factor

Fellenius Method (1927) is applied for the calculation of the safety factor.

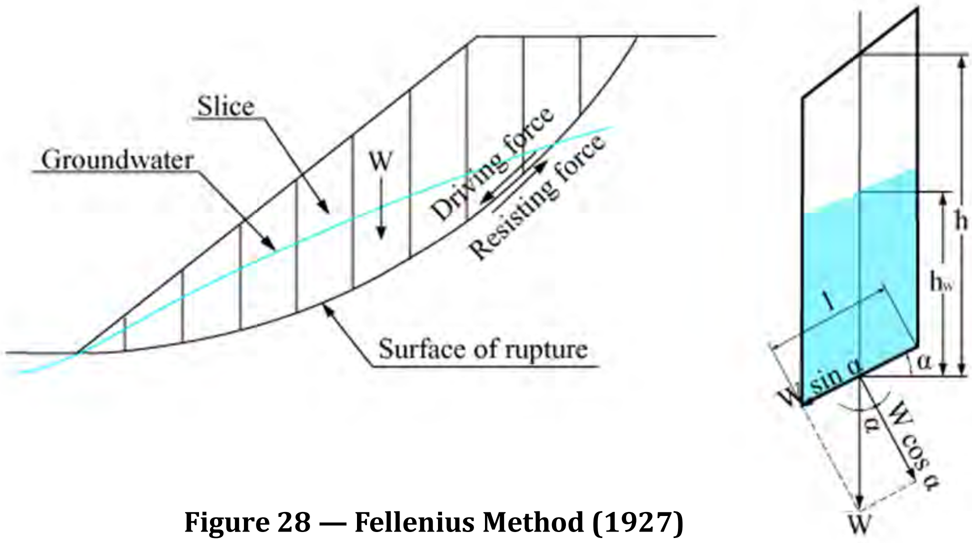

Figure 28 — Fellenius Method (1927)

The landslide mass is divided into several slices, and resistance force and driving force is calculated for each slice.

$$Fs = \frac{Resistance\ force}{Driving\ force}$$

$$Driving\ force = W \sin \alpha$$

$$Resistance\ force = cl + (W \cos \alpha - ul) \tan \emptyset$$

Then calculate the ratio of the total resistance force and the total driving force as safety factor (Fs).

$$Fs = \frac{\sum\{cl + (W \cos \alpha - ul) \tan \emptyset\}}{\sum W \sin \alpha}$$

c : $Cohesion\ of\ surface\ of\ rupture\ (kN/m^2)$

$\emptyset$: $Angle\ of\ Internal\ Friction\ of Surface\ of\ rupture\ (°)$

u : $Average\ pore\ water\ pressure\ of\ slice\ (kN/m^2)$

$u = h_w \cdot \gamma_w$

h_w : $Height\ of\ groundwater\ from\ surface\ of\ rupture (m)$

γ_w : $Unit\ weight\ of\ water\ (kN/m^3)$

l : $Length\ of\ surface\ of\ rupture\ of\ slice\ (m)$

W : $Unit\ weight\ of\ slice\ (kN/m)$

α : $Gradient\ of surface\ of\ rupture\ of slice\ (°)$

6.2.2 Focus on Aituto Landslide

Prepared excel file for slope stability analysis. The Excel file is prepared for the slope stability analysis.

6.2.2.1 Cross-section of the sliding mass for slope stability analysis

Cross-sections of Block A and Block B are shown in Figure 30 and 31.

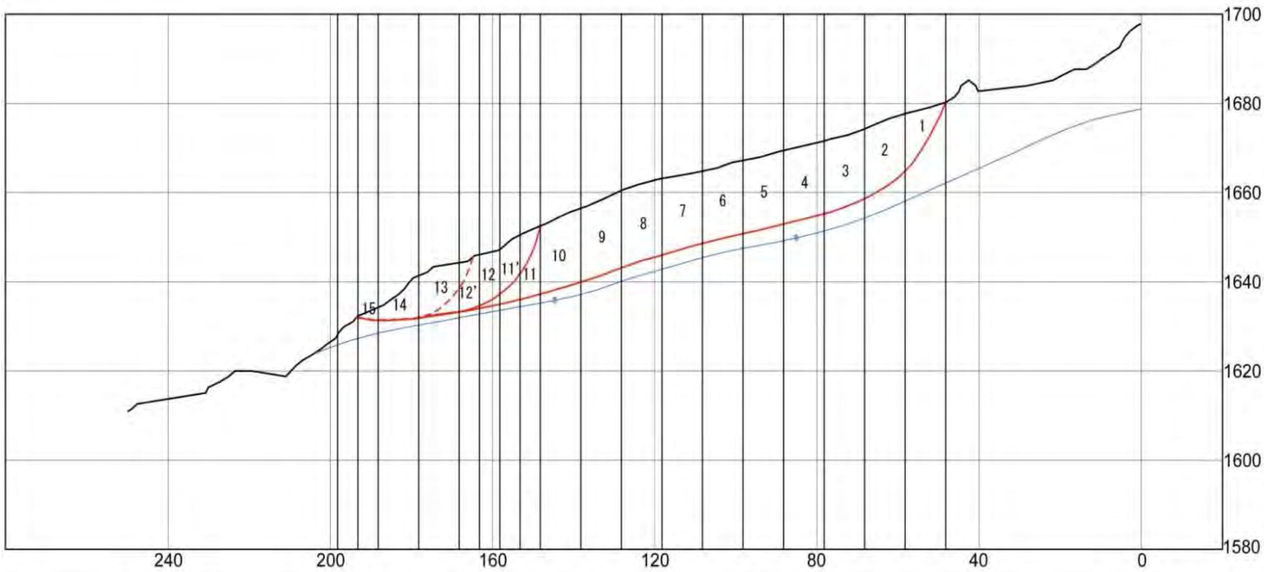

Figure 29 — Cross-section of Block A for slope stability analysis

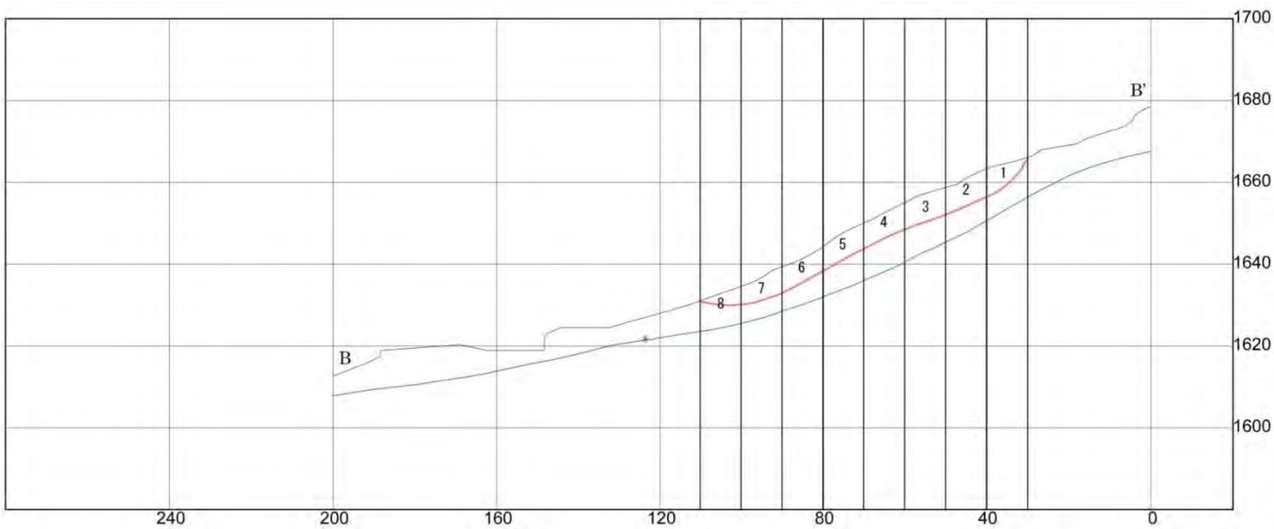

Figure 30 — Cross-section of Block B for slope stability analysis

In the cross-section used for the slope stability analysis, surface of rapture had been assumed based on the observation of drilling cores. In the case that any deformation will be detected with the inclinometer, these cross sections should be modified.

Landslide	Section	Unit weight of earth γ(kN/m³)		Cohesion of surface of rupture (kN/m²)		Angle of Internal Friction of surface rupture (°)		Unit Weight of water(kN/m³)
Aituto	A-A'	γ= 20.00		c= 17.00		Φ= 12.50	Φ(radian)= 0.21817	γ_w= 10.00

Slice No.	cumulative distance (m)	Elevation (m) ground surface	Elevation (m) surface of rupture	Elevation (m) Ground-water	Width of slice b(m)	Average elevation (m) ground surface	Average elevation (m) surface of rupture	Average elevation (m) Ground-water	Area of slice A(m²)	Unit weight of earth γ(kN/m³)	Weight of earth W(kN/m)	Gradient of surface of rupture of slice α (radian)	Gradient of surface of rupture of slice α (°)	cosα	sinα	Wcosα	Wsinα
	0.0	1680.2	1680.2	1662.0													
1					10.0	1678.95	1672.50	1659.98	64.53	20.00	1290.50	0.99	56.96	0.5452279	0.8382879	703.617	1081.810
	10.0	1677.7	1664.8	1658.0													
2					10.0	1676.01	1661.74	1656.16	142.73	20.00	2854.60	0.55	31.57	0.8519946	0.5235507	2432.104	1494.528
	20.0	1674.3	1658.7	1654.3													
3					10.0	1672.96	1656.91	1652.91	160.52	20.00	3210.40	0.34	19.43	0.9430617	0.3326179	3027.605	1067.836
	30.0	1671.6	1655.1	1651.5													
4					10.0	1670.61	1654.08	1650.26	165.22	20.00	3304.40	0.21	11.95	0.9783177	0.2071099	3232.753	684.374
	40.0	1669.6	1653.0	1649.0													
5					10.0	1668.39	1651.81	1648.28	165.81	20.00	3316.20	0.24	13.71	0.9714985	0.2370456	3221.683	786.091
	50.0	1667.2	1650.6	1647.5													
6					10.0	1665.93	1649.59	1646.41	163.45	20.00	3269.10	0.20	11.30	0.9805995	0.1960218	3205.678	640.815
	60.0	1664.7	1648.6	1645.3													
7					10.0	1663.98	1647.28	1644.04	166.98	20.00	3339.60	0.26	14.66	0.9674444	0.2530835	3230.877	845.198
	70.0	1663.3	1646.0	1642.8													
8					10.0	1661.90	1644.50	1641.44	174.03	20.00	3480.70	0.29	16.38	0.959396	0.2820624	3339.370	981.775
	80.0	1660.6	1643.0	1640.1													
9					10.0	1658.51	1641.34	1638.58	171.68	20.00	3433.70	0.33	18.68	0.9473199	0.3202889	3252.812	1099.776
	90.0	1656.5	1639.6	1637.1													
10					10.0	1654.45	1638.46	1636.11	159.93	20.00	3198.50	0.23	13.39	0.9728052	0.2316249	3111.517	740.852
	100.0	1652.4	1637.3	1635.2													
11					5.0	1651.57	1636.69	1634.81	74.38	20.00	1487.55	0.23	12.92	0.9746828	0.2235922	1449.889	332.605
	105.0	1650.7	1636.1	1634.5													
11'					5.0	1648.88	1635.53	1634.00	66.74	20.00	1334.70	0.23	13.24	0.9734376	0.2289525	1299.247	305.583
	110.0	1647.1	1634.9	1633.5													
12					5.0	1646.70	1634.34	1633.24	61.81	20.00	1236.20	0.24	13.55	0.9721663	0.2342921	1201.792	289.632
	115.0	1646.4	1633.7	1632.9													
12'					5.0	1645.35	1633.52	1632.48	59.17	20.00	1183.30	0.09	5.02	0.9961677	0.0874635	1178.765	103.496
	120.0	1644.4	1633.3	1632.0													
13					10.0	1642.83	1632.59	1631.08	102.31	20.00	2046.10	0.14	8.04	0.9901642	0.1399102	2025.975	286.270
	130.0	1641.3	1631.9	1630.1													
14					10.0	1637.92	1631.54	1629.31	63.81	20.00	1276.10	0.07	4.04	0.9975171	0.0704247	1272.932	89.869
	140.0	1634.5	1631.2	1628.5													
15					5.0	1633.45	1631.77	1628.01	8.39	20.00	167.70	0.23	13.22	0.973481	0.228768	163.253	38.364
	145.0	1632.4	1632.4	1627.5													
																37349.870	10868.873

Figure 31 — The Excel file for slope stability analysis

Elevation of ground surface, surface of rapture and groundwater level are read from the cross-sections, and imputed. Unit weight of earth, cohesion of surface of rupture, unit weight of water had been imputed as constants. In Japan, the value of cohesion is assumed based on the thickness of the sliding mass (refer Table 1).

Table 1 — Assumptive value of cohesion

Thickness of landslide (m)	*Cohesion* C (kN/m²)
5	5.0
10	10.0
15	15.0
20	20.0
25	25.0

$$Fs = \frac{\Sigma\{c \cdot l + (W\cos\alpha - u \cdot l)\tan\Phi\}}{\Sigma w \sin\alpha} = 1.0100232$$

Average pore pressure of slice u(kN/m^2)	Length of surface of rupture of slice l(m)	Height of groundwater from surface of rupture h_w (m)	Unit pore pressure of water $u=h_w \cdot \gamma_w$ (kN/m2)	u·l (kN/m)	Wcosα-u·l	tanΦ	(Wcosα-u·l)tanΦ	c (kN/m^2)	c·l (kN/m)
0.00	18.34	0.00	0.00	0.000	703.617	0.221694663	155.988	17.00	311.796
0.00	11.74	0.00	0.00	0.000	2432.104	0.221694663	539.184	17.00	199.532
0.00	10.60	0.00	0.00	0.000	3027.605	0.221694663	671.204	17.00	180.264
0.00	10.22	0.00	0.00	0.000	3232.753	0.221694663	716.684	17.00	173.768
0.00	10.29	0.00	0.00	0.000	3221.683	0.221694663	714.230	17.00	174.987
0.00	10.20	0.00	0.00	0.000	3205.678	0.221694663	710.682	17.00	173.363
0.00	10.34	0.00	0.00	0.000	3230.877	0.221694663	716.268	17.00	175.721
0.00	10.42	0.00	0.00	0.000	3339.370	0.221694663	740.320	17.00	177.195
0.00	10.56	0.00	0.00	0.000	3252.812	0.221694663	721.131	17.00	179.454
0.00	10.28	0.00	0.00	0.000	3111.517	0.221694663	689.807	17.00	174.752
0.00	5.13	0.00	0.00	0.000	1449.889	0.221694663	321.433	17.00	87.208
0.00	5.14	0.00	0.00	0.000	1299.247	0.221694663	288.036	17.00	87.319
0.00	5.14	0.00	0.00	0.000	1201.792	0.221694663	266.431	17.00	87.434
0.00	5.02	0.00	0.00	0.000	1178.765	0.221694663	261.326	17.00	85.327
0.00	10.10	0.00	0.00	0.000	2025.975	0.221694663	449.148	17.00	171.689
0.00	10.02	0.00	0.00	0.000	1272.932	0.221694663	282.202	17.00	170.423
0.00	5.14	0.00	0.00	0.000	163.253	0.221694663	36.192	17.00	87.316
							8280.267		2697.547

Figure 32 — The Excel file for slope stability analysis

6.2.2.2 Results of slope stability analysis

Then several value of angle of internal friction for surface of rupture is imputed as parameters to make Fs close to 1.0. Keep in mind that the safety factor is a relative value and not an absolute value.

The results of slope stability analysis are summarized in Table 2.

Table 2 — Results of the slope stability analysis

Variables used in the calculation	Block A	Block B
Unit weight of earth, γ (kN/m^3)	20.0	18.0
Cohesion of surface of rupture (kN/m^2)	17.0	7.0
Angle of Internal Friction of surface rupture (°)	12.5	20.2
Unit Weight of water (kN/m^3)	10.0	10.0
Safety Factor	1.01	1.004

6.2.2.3 Examination of safety factor

When topographic condition or groundwater level will change, the safety factor of the landslide block will also change.

6.2.2.3.1 Examination of safety factor for Block A

Because the bedrock of the downslope of Block A is so fragile due to shearing by the fault that the collapse will possibly occur in the future (refer Figure 33). If collapse occurs at the lower part of the slope, the safety factor of Block A drops from 1.01 to 0.91, which is extremely unstable (refer figure 34).

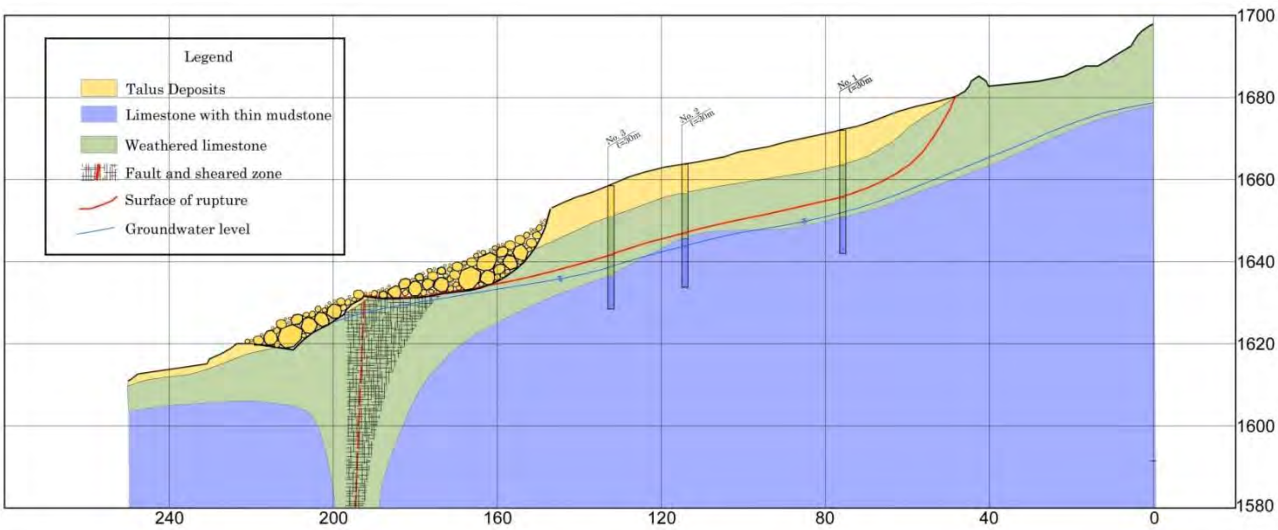

Figure 33 — Assumed geological cross-section of Block A after the collapse

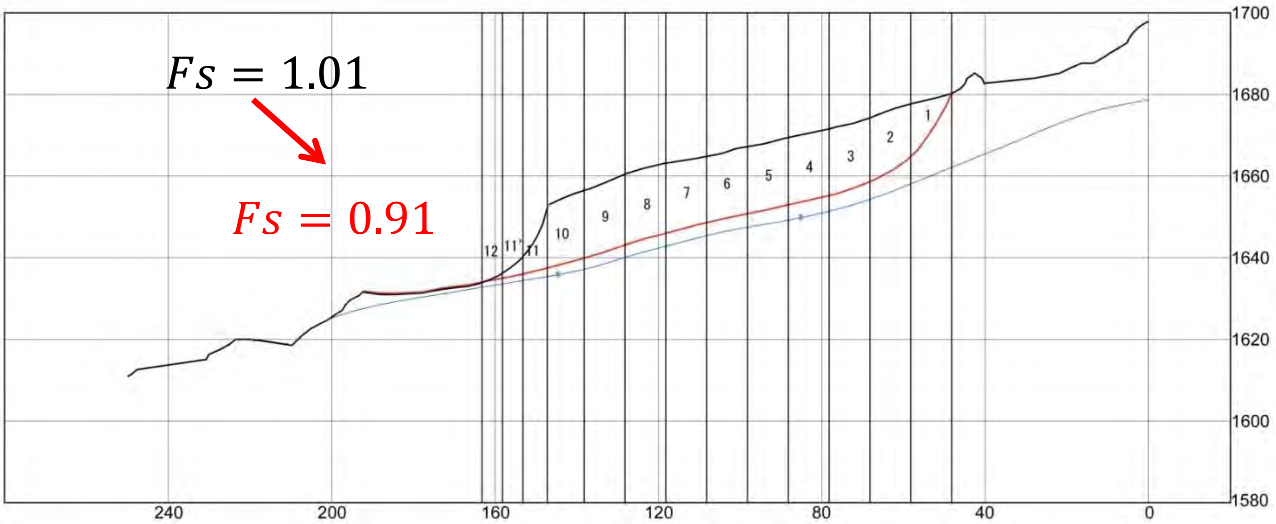

Figure 34 — Cross-section of Block A for the calculation of Fs after the collapse

Assuming that the groundwater level in block A has increased by 7 m as a whole, the safety factor will drop from 1.01 to 0.91, so Block A will possibly start to slide (refer Figure 35).

Currently, it is not probable that the days when daily precipitation exceeding 100 mm will continue even around Aituto. However, climate change due to global warming has become world-widely noticeable. If the groundwater level rises at Aituto landslide in the future, drainage with horizontal drilling will be effective.

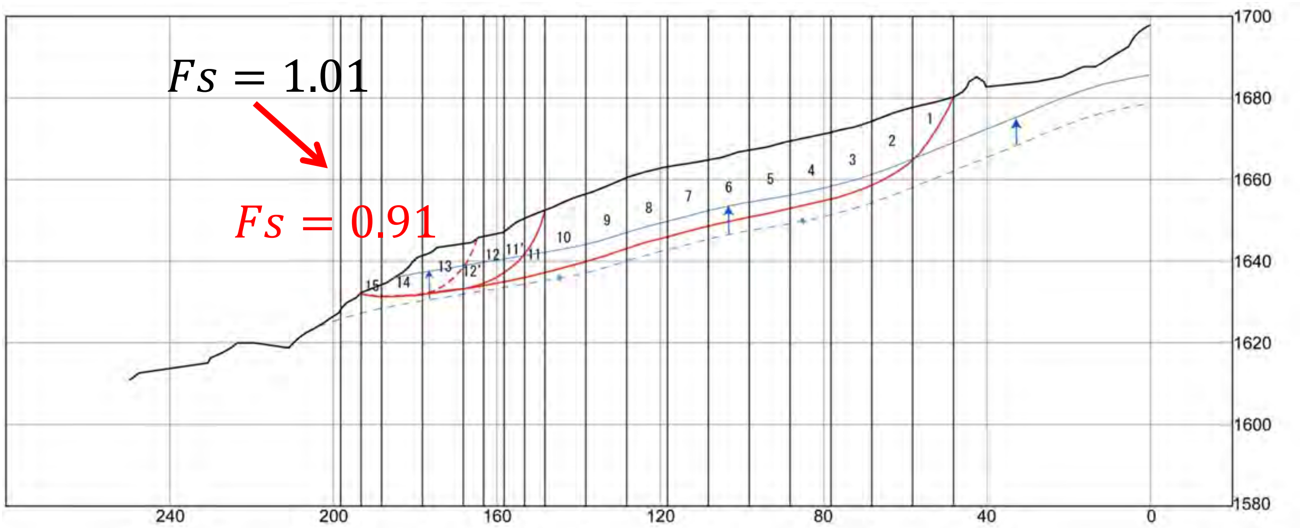

Figure 35 — Cross-section of Block A for the calculation of Fs after the groundwater level has increased by 7 m as a whole

7 Consideration on the countermeasures for landslide prevention

Generally, Mass movement is the he large scale of phenomenon that the scale is reaching tens to hundred of thousands of cubic meters. According to the scale, in many cases, it takes the huge cost to spend the countermeasure. Therefore, sufficient investigation and analysis are important to accurate design based on these knowledges.

The mass movement of countermeasure is classified as control and prevention works. The control works is the works by changing the condition of geotechnical shape or groundwater level. The representative control works is drainage works and earth removal of mass movement head. The prevention works is to resist the sliding force of mass movement by structural force. The representative structures are pile works and anchor works. The more detailed countermeasure work and structure design is introduced in ANNX G as the referenced document.

Table 2 — Classification of countermeasure

Classification	Countermeasure	Point of view
Control work	Surface water drainage: channel, infiltration prevention works Shallow groundwater drainage: drainage conduit, open drainage conduit, lateral boring Deep groundwater drainage: lateral boring, drainage well, drainage tunnel Earth removal works Counterweight embankment works	Drainage works try to lower the water table, which is a strong contributory factor. The earth removal work lightens the slope's head to reduce the sliding force. The counterweight embankment work is embankment on the foot to increase the weight of slip resistance.
Prevention work	Pile works Anchor works	Pile works contain mass movement installing piles that go through the surface of mass movement, in rows perpendicular to the direction of movement. Anchor works fix steel materials with high strength to the stationary ground and installs structures to catch pressure in head of tensile member, to contain the mass movement with stress of tensile member.
Protection work	-	Basically, they are not established due to gigantic force of mass movement

If mass movement is too large to solve within realistic control works or prevention works avoidance plans such as tunnels or bridges shall be considered.

7.1 Focus on Aituto Landslide

According to the result of the slope stability analysis, the counter measure for Aituto Landslide is proposed. The selected countermeasures are retaining wall and embankment that are limitation of technically available in Timor-Leste. Generally, the most effective measure for mass movement is to be keep the deterioration of groundwater level, and shallow and deep groundwater drainages are representative counter measurement that are require the lateral boring technology in slope gradient area. These countermeasures will also be installed as the effective measurement in Aituto landslide.

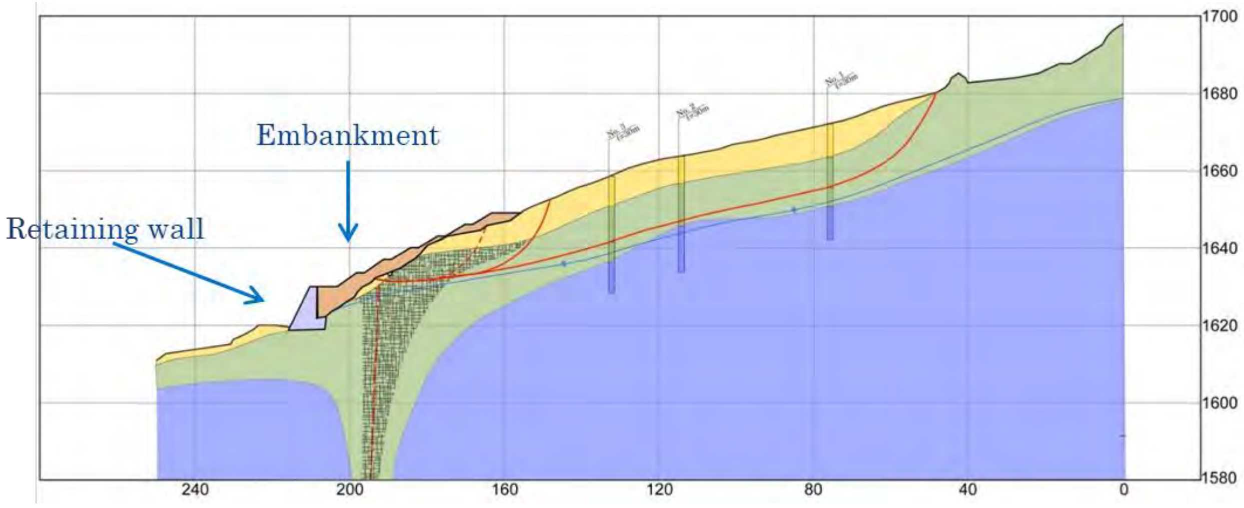

Figure 36 — Cross-section of Block A for the calculation of Fs after the groundwater level has increased by 7 m as a whole

8 Conclusion

In this report, the investigation conducted on Aituto landslide has been explained following its flow of the procedure. In Timor-Lest, most of the land is occupied by steep mountains, therefore, many landslides may exist. However, investigation, observation, or design of countermeasures for landslides, haven't been carried out.

According to this investigation, carried out by CDRS Project, will be an example of the study for the other landslides. It will be our pleasure if the personnel of DRBFC and concerning organization will refer this report.

And concerning the Block A, examination of safety factor shows if collapse occurs at the lower part of the slope, the safety factor of Block A drops from 1.01 to 0.91, so the block will become extremely unstable. Therefor it is very important for DRBFC to continue the monitoring with the inclinometer and keep watching on the displacement of the block.

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Annex A
(informative)

Standard specification and operation method of UAV

Contents

A-1. Outline of UAV Survey (General)

A-1.1. The Process of UAV Survey

The flow chart shows main process of UAV survey

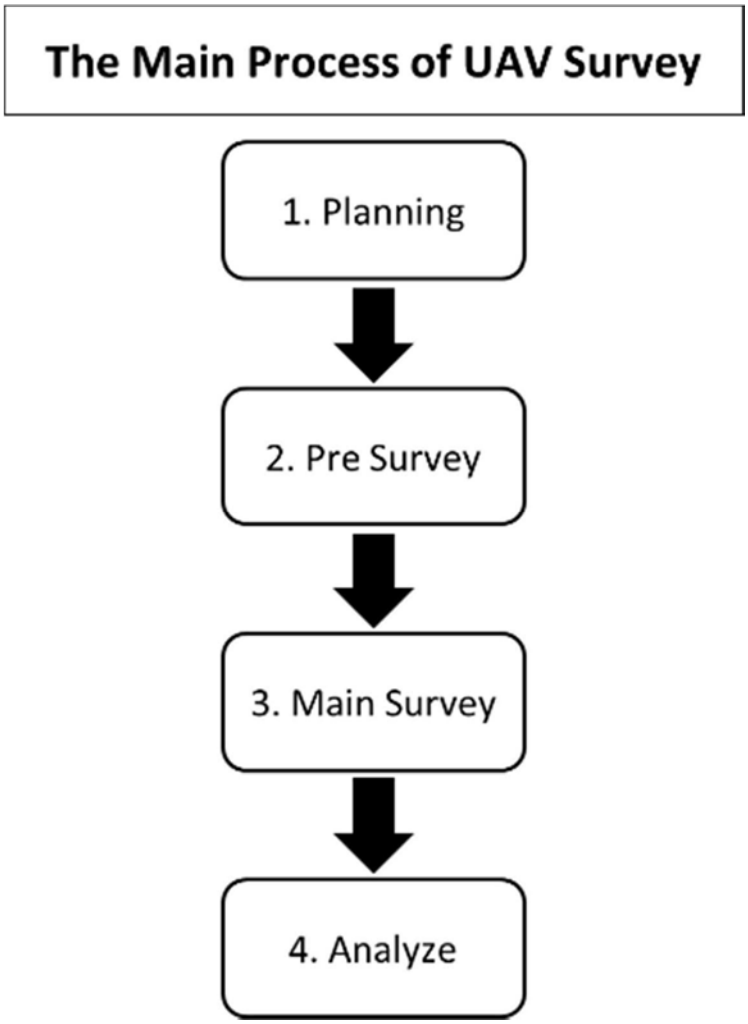


Figure1. The Flow Chart of UAV Survey

A-1.2. Activities for each process

Show the activity for each process and rough date for each activity (about 800m×800m).

Process 1. Planning (at the office) 1~2 Days

Planning survey area, flight route, place of bench marks, and point for takeoff and landing from existing drawing.

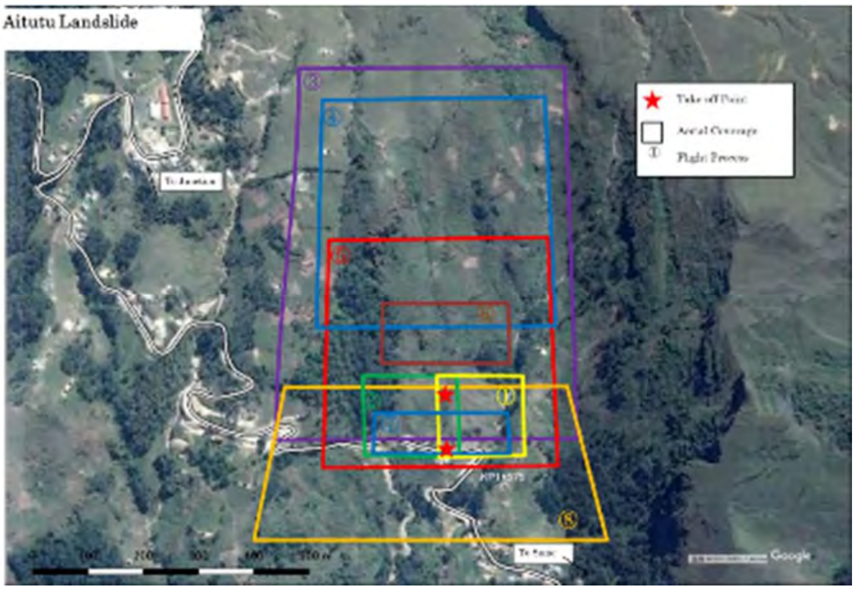


Figure2. Planning Area (First Plan)

Process2. Pre Survey（at the site）1~2 Days

Examination of plan made at [Process 1] at the site and change the plan if it need.

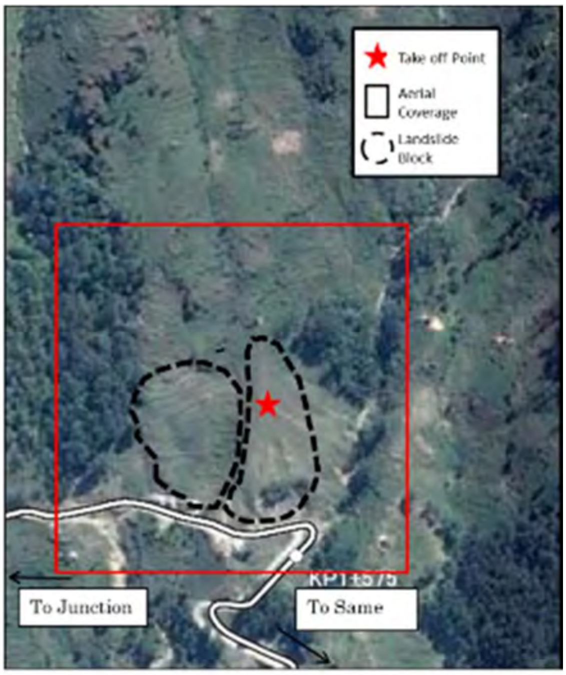


Figure3. Planning Area (Revised)

Process3. Main Survey（at the site）1~2 Days (without bench mark survey)

Taking aerial photo by UAV and survey the coordination of bench marks by various survey method.

Process4. Analyze（at the office）1 Week

Analyzing the data and make contour map, ortho photo and etc.

A-1.3. Outputs

Ortho photo、Contour map、3D aerial view、DEM etc.

A-2. The Process of UAV Survey CDRS Operated.

A-2.1. Planning

A-2.1.1. Outline

First, CDRS Planned the survey area (Figure.4). We made flight plan of UAV based on survey area (Figure.5).

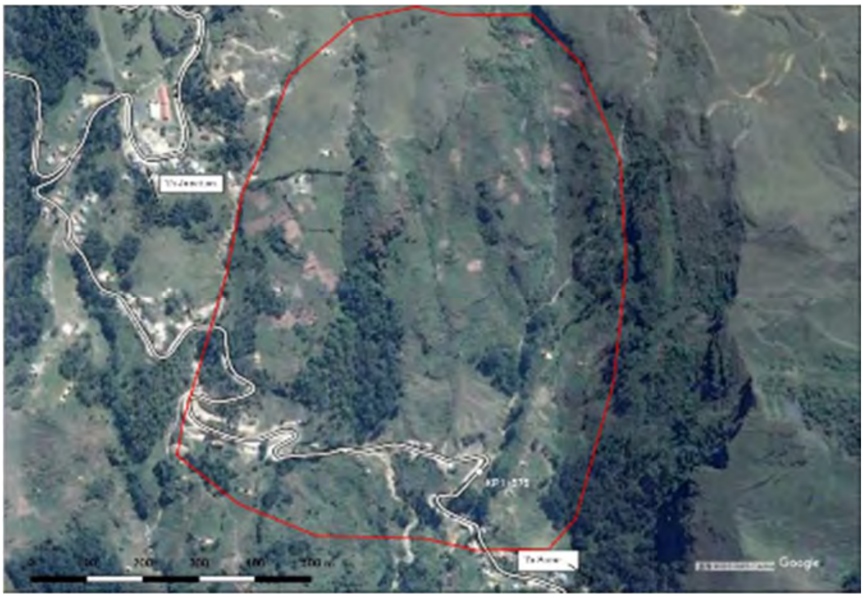


Figure.4 Survey Area (at the first)

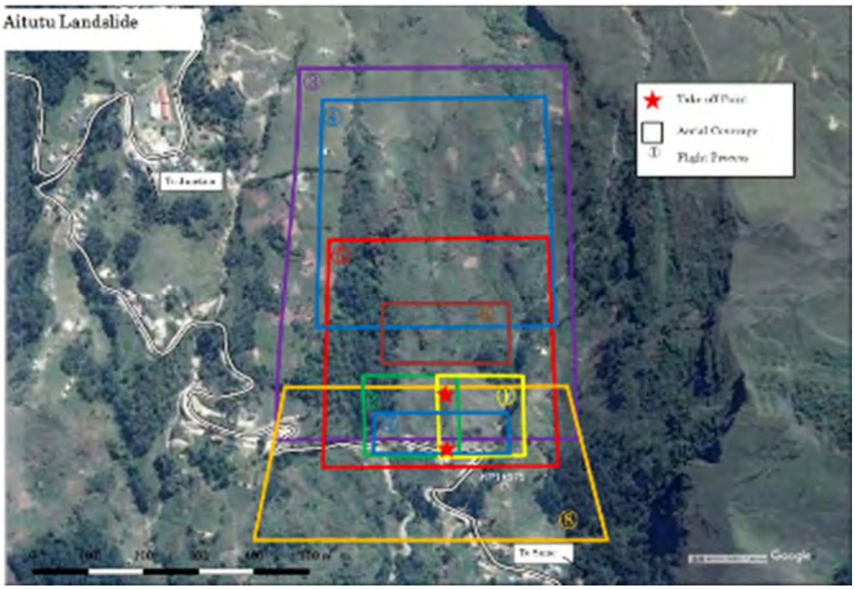


Figure.5 Flight Plan (at the first)

A-2.1.2. Important Point

When planning the flight route, the important thing is the height and rate of overlap each aerial photo. If the flight height is low, the accuracy will be high but need to take many photo and severer for with camera shake. Conversely, if the flight height is high, the number of photo is fewer and effect of camera shake decrease than low height but the accuracy also decrease. The number of photo is the biggest influence to the time for analyze. The table shown is the relationship of the flight height and analyze. The rate of overlap is have to more than 60% to analyze.

Table1. The Relation of Flight Height and Accuracy

Flight height	Higher	Lower
The Accuracy of Output	Lower	Higher
The Number of Flight time	Few	Many
Effect of Camera Shake	Lenient	Severer
The Number of Photo	Fewer	More

The place of Bench Mark, the purpose is input coordination (X,Y,Z) to analyze output. It needs more than 3 Bench Marks to adjust X,Y,Z coordination. The number of Bench Mark is depended the survey area and accuracy. It is better that the Bench Mark is established every corner and regular interval of survey area for X,Y coordination, the highest point, medium height point and the lowest point of survey area for Z coordination. The accuracy of outputs is the most effected the Bench Mark coordination.

Decide the place of takeoff and landing point, the most important thing is perspective. If the point is covered by tree, UAV can't receive GPS signal and also the risk of accident (UAV hit the tree) is very high. While the flight, operator must see the UAV. If operator can't see UAV, can't deal with accident.

To make flight route, there are many application. CDRS use "Mission Planner" it is free soft. Everyone can download from http://ardupilot.org/planner/
Input survey area, camera states, rate of overlap and flight height, this soft make flight route automatically.

Example of Taking Photo Overlap

GOOD	BAD
Overlapping	Not Overlapping
	
	

Figure. 6 Example of Talking Photo Overlap

Example of Place of Bench Mark

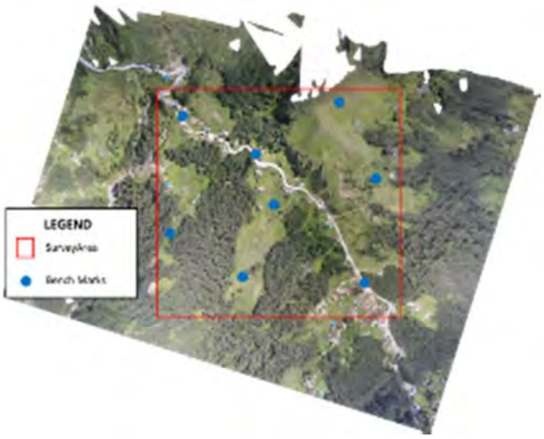
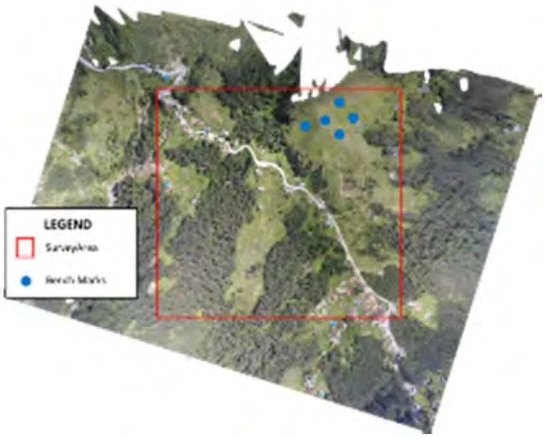
GOOD	BAD
Bench Marks are put balanced	Bench Marks are not put balanced
	

Figure. 7 Example of Bench Mark Arrangement

A-2.2. Pre Survey

A-2.2.1 Outline

After planning, we went to site to confirm situation of the site with the expert of landslide. The expert of landslide judge the landslide area (Figure.8). We revise flight plan (Figure.9)

Figure.8 Landslide Area (Expert Judge)

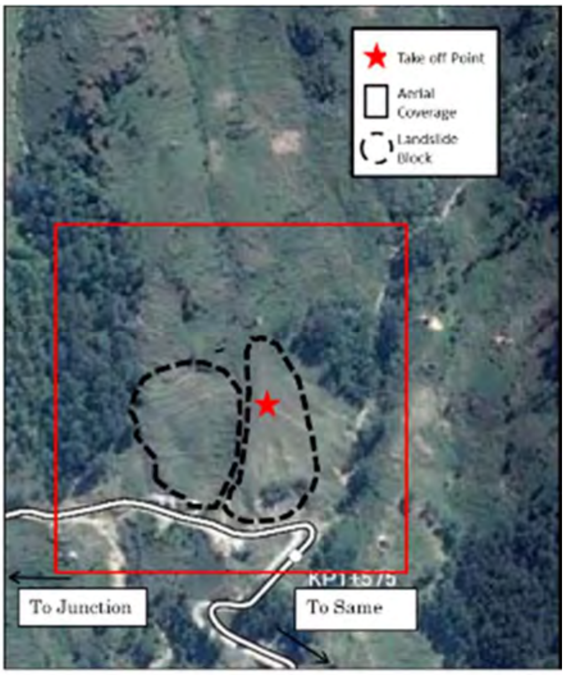


Figure.9 Survey Aria by UAV

A- 2.2.2. Important Point

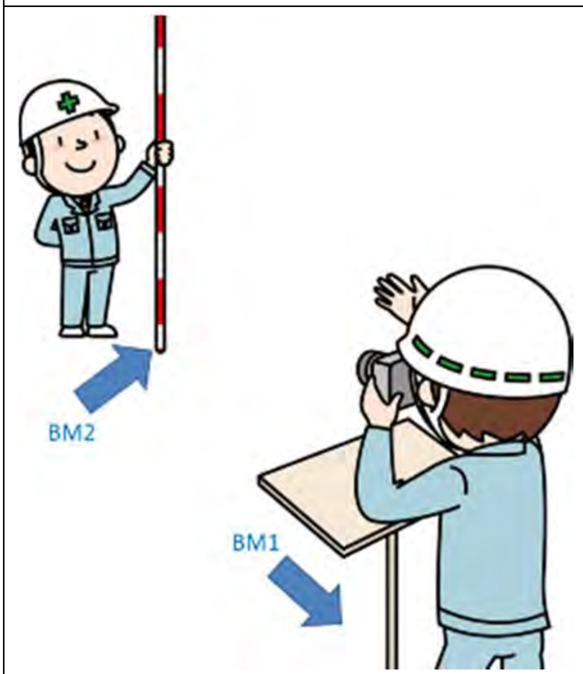
Confirm the situation of site and change the plan if it needed.

Table.2 The Check Point at the Site

The Check Point	Remarks
Tree Height	If the tree is higher then planned flight height, operator must change the plan
Visibility for taking photo	If the takeoff and landing point and Bench Mark point are covered by tree or something, operator must change the plan.
Visibility for Bench Mark	The Bench Mark is must be seen from another Bench Mark to survey coordination using Total Station or handy laser distance meter. When using GNSS Survey method, it don't have to.seen other Bench Marks

Example of Bench Mark Setting

GOOD	BAD
No Object Between Bench Marks	Some Object Between Bench Marks



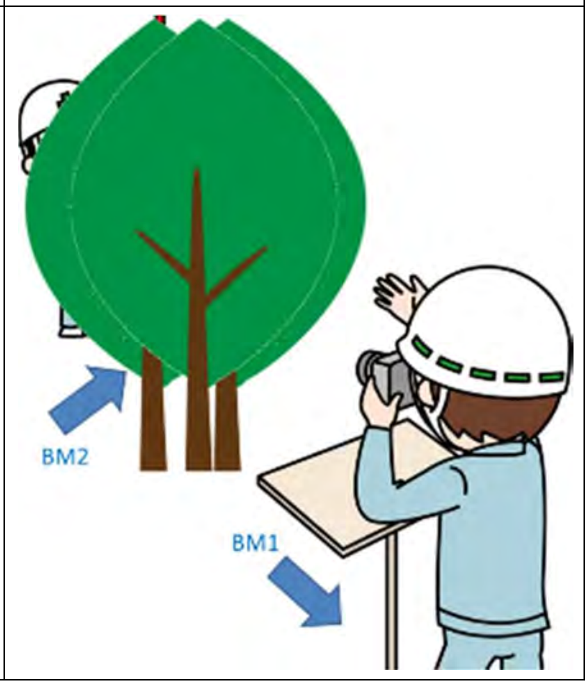


Figure.10 The Example of Bench Mark Setting

A-2.3 Site Survey

A-2.3.1. Outline

Taking Aerial Photo by UAV

Survey the Coordination of Bench Marks.
In this time, we use GNSS survey to know the coordination of bench marks.

A-2.3.2. Important Point

While flight UAV, operator have to check the condition of UAV. If some problem occur operator have to control and landing safety.
To takeoff higher place to flight lower place is the safest way. It can reduce risk of hit tree or higher place.

Table. 3 The Check Point until Flying

The Check Point	Remarks
Tree Height	Check the height of UAV and
Visibility for taking photo	If the takeoff and landing point and Bench Mark point are covered by tree or something, operator must change the plan.
Visibility for Bench Mark	The Bench Mark is must be seen from another Bench Mark to survey coordination using Total Station or handy laser distance meter. When using GNSS Survey method, it don't have need to see other Bench Marks
Condition of Communication Between UAV and Controller	If disconnect between UAV and Controller, operator can't operate. The risk of accident will increase..
Condition of Buttery	If the capacity going low, the risk of accident will increase. It is better that keep more than 20%.

Setting Bench Mark, the most important thing is able to see from aerial photo. If taking aerial photo higher place, it can't see small object. CDRS uses target (1m×1m), big stone, wall and etc. If the bench mark is small and not taken by photo that bench mark can't use for analyze.

Example of Safety Flight

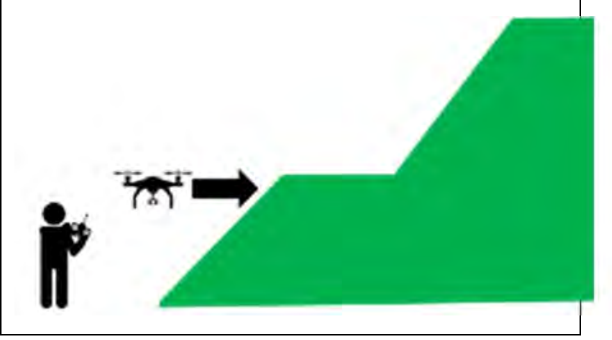
GOOD	BAD
Flight Higher Place to Lower Place	Flight Lower Place to Higher Place
	

Figure. 11 The Example of Safety Flight

A-2. 4. Analyze

A-2. 5. Output of This Survey

・Ortho Photo

Figure. 12 The Example of Output (Ortho Photo)

・Contour Map

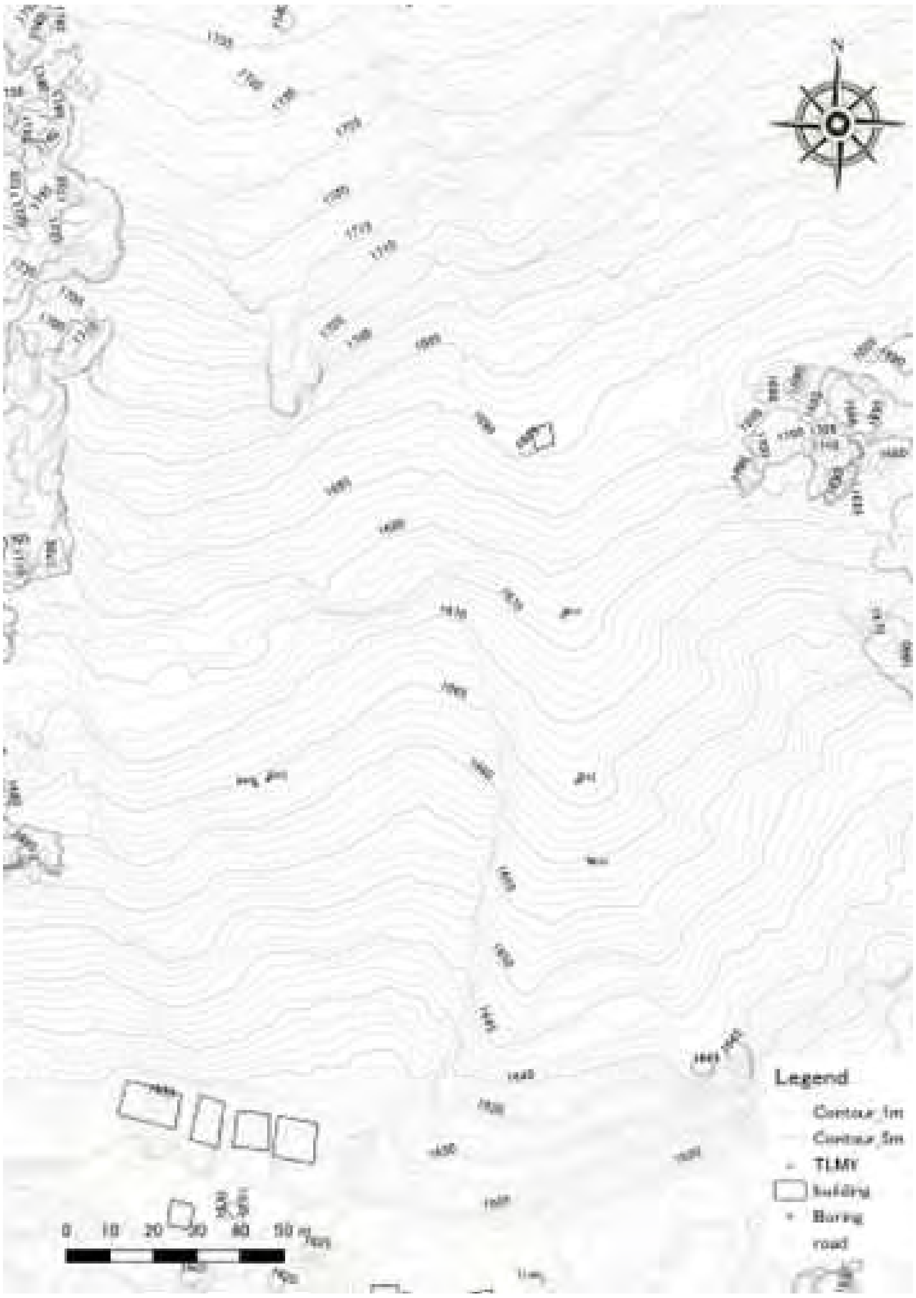


Figure.13 The Example of Output (Contour Map)

・3D Aerial View

Figure.14 The Example of Output (3D Aerial View)

・DEM

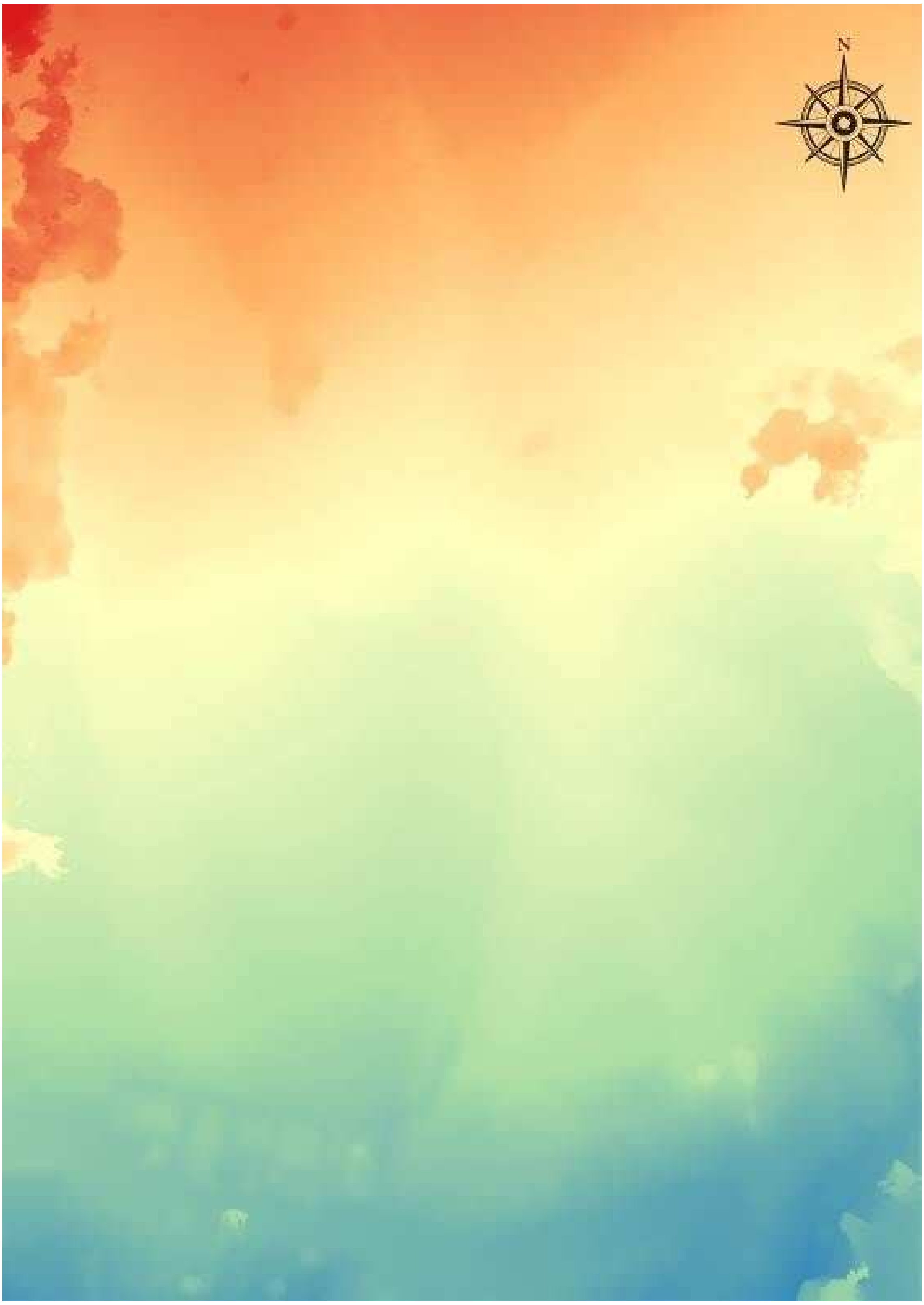


Figure.15 The Example of Output (DEM)

A-3. Equipment CDRS Use

A-3.1. UAV

Table.4 The Spec of UAV (CDRS Used)

Name	Solo
Made by	3D Robotics (made in USA)
Price	About $2,000 (Include Camera)
Size	450mm×450mm×250mm
Distance of Motor	450mm
Weight	2.1kg (Include Buttery)
Max Flight Time	16 minutes
Max Range	800m
Max Speed	89km/h
Max altitude	800m (must abide the low) For Aerial photo survey, max 200m
Payload	500g
Wi-Fi Connection	2.4GHz

Figure. 16 The Photo of UAV (CDRS Used)

Operation soft is free application for Android and ios. It can operate by smartphone and tablet

A-3.2. Analysis Software

Table.5 The Outline of Analysis Soft (CDRS Used)

Name	Photoscan Professional
Made by	Agisoft (Russia)
Price	About $5,000 (1 License)

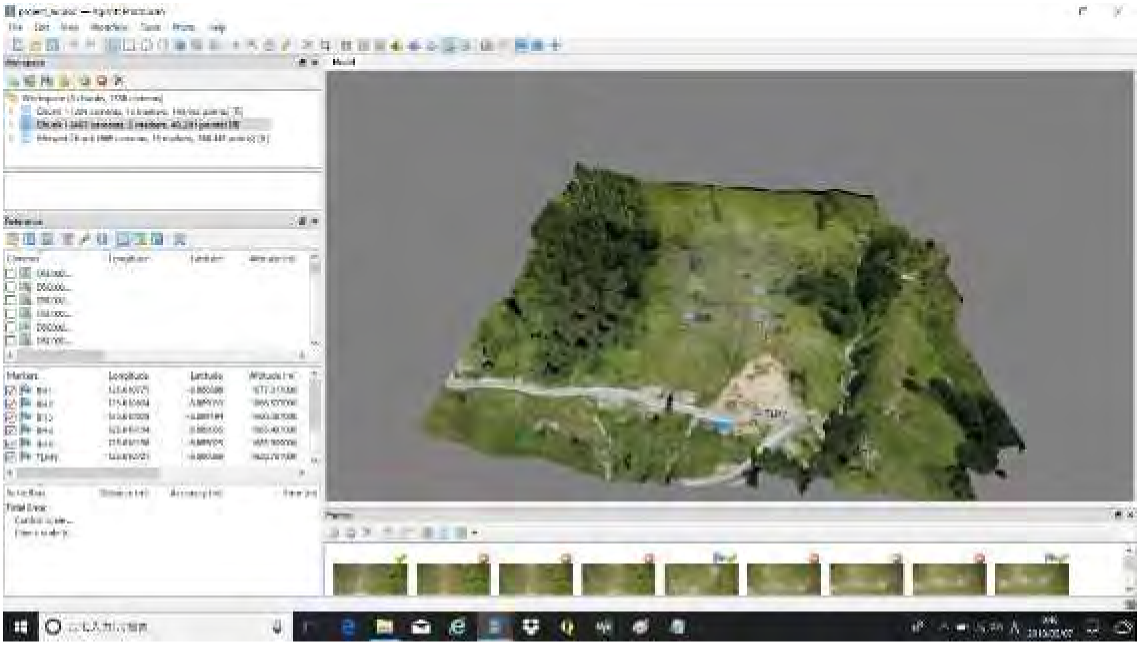


Figure.17 The Screen Shot of Analysis Soft (CDRS Used)

4. The points for Choice UAV (Drone) for Survey

・Must Equipped

-Auto Pilot Mode

When the UAV is far from operator, It is difficult to grasp the distance. It is a cause of flight different route from expect.

It is better to take photo fixed rate of overlap than manual operate.

-Fail-Safe System

Fail-Safe System is to operate safety side if problem happen. For example, UAV CDRS used equip some Fail-Safe System. Hear after, showing 2 examples. The first one, if the communication between controller and UAV lost, UAV try to go back to takeoff point automatically. On the way, if communication recovery, operator can control UAV again. The second one, if the buttery is low, UAV try to go back to takeoff point. And if it is difficult to go back takeoff point with the balance of buttery, UAV try to landing on the place automatically.

-Camera

The camera performance is very important for aerial photo survey. CDRS use 2 types of camera Gopro Hero 4 and Sony α6000 with 16mmF2.8 Lens.

For aerial photo survey, the camera face must directed just below. To survey slope like landslide, it is better to be able to change angle (10 degree - 30 degree).

The shutter of camera must be able to operate from controller or equip interval shooting system.

-The Power of Radio Wave

If UAV use for survey, UAV travel far from operator. Radio wave must go more than 500m. The UAV CDRS use can travel max 800m from operator.

・Better to Equipped

-Collision Avoidance System

Some UAV equip Collision Avoidance System. UAV detects obstructions by sensor. if UAV go near the obstruction, UAV stop and hovering at the place and can't move closer.

In Timor-Leste, some store sell UAV be able to use survey.
The name of drone is “Phantom4” made by “Da-Jiang Innovations Science and Technology Co., Ltd”]

Table.5 The Spec of UAV (Phantom4)

Weight (Battery & Propellers Included)	1380 g
Diagonal Size (Propellers Excluded)	350 mm
Max Ascent Speed	S-mode: 6 m/s
Max Descent Speed	S-mode: 4 m/s
Max Speed	S-mode: 20 m/s
Max Tilt Angle	S-mode: 42°
	A-mode: 35°
	P-mode: 15°
Max Angular Speed	S-mode: 200°/s
	A-mode: 150°/s
Max Service Ceiling Above Sea Level	19685 feet (6000 m)
Max Wind Speed Resistance	10 m/s
Max Flight Time	Approx. 28 minutes
Operating Temperature Range	32° to 104°F (0° to 40°C)
Satellite Positioning Systems	GPS/GLONASS
Hover Accuracy Range	Vertical:
	±0.1 m (with Vision Positioning)
	±0.5 m (with GPS Positioning)
	Horizontal:
	±0.3 m (with Vision Positioning)
	±1.5 m (with GPS Positioning)

Table.6 The Spec of Camera (Phantom4)

Sensor	1/2.3” CMOS
	Effective pixels:12.4 M
Lens	FOV 94° 20 mm (35 mm format equivalent) f/2.8 focus at ∞
ISO Range	100-3200 (video)
	100-1600 (photo)
Electronic Shutter Speed	8 - 1/8000 s
Image Size	4000×3000
Still Photography Modes	Single shot
	Burst shooting: 3/5/7 frames
	Auto Exposure Bracketing (AEB): 3/5 bracketed frames at 0.7 EV Bias
	Timelapse
	HDR
Video Recording Modes	UHD: 4096×2160 (4K) 24 / 25p
	3840×2160 (4K) 24 / 25 / 30p
	2704×1520 (2.7K) 24 / 25 / 30p
	FHD: 1920×1080 24 / 25 / 30 / 48 / 50 / 60 / 120p
	HD: 1280×720 24 / 25 / 30 / 48 / 50 / 60p
Max Video Bitrate	60 Mbps
Supported File Systems	FAT32 (≤32 GB); exFAT (>32 GB)
Photo	JPEG, DNG (RAW)
Video	MP4, MOV (MPEG-4 AVC/H.264)
Supported SD Cards	Micro SD
	Max capacity: 64 GB
	Class 10 or UHS-1 rating required
Operating Temperature Range	32° to 104°F (0° to 40°C)

Annex B
(informative)

TECHNICAL SPECIFICATION
FOR
GEOTECHNICAL INVESTIGATION ON AITUTO LANDSLIDE

B.1 Introduction

INGEROSEC/Earth System Science (hereinafter "JICA Expert Team") was awarded by the Japan International Cooperation Agency (hereinafter referred to as "JICA") for the conduct of the Capacity Development of Road Services in the Democratic Republic of Timor-Leste (hereinafter "CDRS")". Scope of work of the study requires undertaking of geotechnical investigation on Aituto Landslide that is located along the National Highway A05. The JICA Expert Team is to employ a local consultant company (hereafter referred to as "the Local Consultant") for the geotechnical investigation.

B.2 Objectives of the geotechnical investigation

The geotechnical investigation shall be carried out for the following items, and it is intended to obtain the geological and geotechnical information.
1) Borings to obtain the geological information.
2) Standard penetration test (SPT) in drilled holes
3) Measurements of Ground water level in drilled holes
4) Installation of grooved casings for inclinometer

B.3 Scope of works

Investigation items and quantities of the geotechnical investigation are shown in Table-1. There may be cases to change investigation items and quantities by instructions of the JICA Expert Team in consideration of the strata situation.
The Local Consultant shall obtain the written consent from the JICA Expert Team when the Local Consultant changes the investigation items due to the circumstances of local conditions.

Table-1 Items and quantities of geotechnical investigation

Items	Contents	Quantity	Unit	Remarks
1. Boring				
No.1	For inclinometer	30	m	A Block
No.2	For groundwater level monitoring	30	m	A Block
No.3	For inclinometer	30	m	A Block
No.4	For inclinometer	15	m	B Block
No.5	For groundwater level monitoring	15	m	B Block
2. Standard Penetration Test	5m×5 holes	25	times	All borings
3. Installation of grooved casings for inclinometer	30m×2 holes 20m×1 holes	75	m	No.1, No.3, No.4
4. Installation of PVC casings for groundwater level monitoring	30m×1 holes 20m×1 holes	45	m	No.2, No.5

B.4 Investigation method

a. General

The Local Consultant shall carry out the boring investigation at the points ordered in "Boring Location Map" provided by the JICA Expert Team in principle.

In the implementation of boring investigation, the Local Consultant shall obtain the consent of the JICA Expert Team.

Considering instability of the landslide, the Local Consultant shall use small and light weight equipment so that deformation of the land for installation and transport of the equipment will not cause moving of the earth blocks.

b. Drilling works

The borings shall be drilled with bits of larger than 86 mm in diameter. Core samples recovered from the borings shall be stored in core boxes. Boxing logs shall be prepared along with photographs of the core samples.

The boring logs shall include such information as: geologic and soil description: color: hardness: lithologic description; degree of weathering: alterations and fractures: strike and dip of bedding and joints; boring conditions: initial and stabilized groundwater levels: and rate of core recovery. Each borehole should penetrate slip surface, and drilled in stable bedrocks more than 5m in length.

Record of boring shall be submitted daily by the Local Consultant to the JICA Expert Team by e-mail or fax, which describes progress of drilling, result of geological observation, and groundwater-level of each borehole.

c. Standard penetration test

The Local Consultant should carry out the standard penetration test (SPT) according to ASTM D-1586, at intervals of 1 meter (depth) in the borehole.

The standard penetration test should be ended when the rock of N-value of 300 or more (SPT blow count 50 or more/5 cm) is confirmed.

d. Groundwater level observation

For the analysis of stability of the landslide, initial and stabilized groundwater levels should be measured during the drilling works. And in some of the important boreholes, periodic measurement of groundwater levels will be carried out in the future.

For the periodic measurement of groundwater levels, stiff PVC pipes of more than 40mm in diameter with slits or holes should be inserted into the borehole. The depth and length of slits or holes will be directed by the engineer of the JICA Expert Team.

Covering of slits or holes with geotextile sheets will be recommended.

e. Installation of grooved casings for inclinometer

To determine the slip surface for actively moving landslides, the monitoring with inclinometer will be carried out. By lowering a probe equipped with a tilt sensor, deformation in the casing can be detected and movement of a landslide can be determined.

A grooved casing should be inserted into the borehole extending into the bedrock formation. The stable bedrock shall be drilled more than 5m in length. And an adequate quantity of cement milk or sand should be placed into the borehole to assure an intimate contact with the borehole.

f. Protection of casings for inclinometer and groundwater level observation

Installed casings for inclinometer and groundwater measurement should be protected from traffic, vandalism, debris and so forth. For that purpose, the top of each casing should be covered with a steel protective pipe that is fixed to the base of cement. Each steel pipe should be capped and locked firmly.

In the case that top of a casing for inclinometer is deep inside a protective pipe, the pulley cannot be attached. So, the protective pipe should be installed so that the top of the pipe is only about 5cm above the top of the casing.

B.5 Report Contents

The Local Consultant shall submit the following:

1) Boring logs
2) Report on the geotechnical investigation results
3) Photographs of "boring-core samples (obtained by all-core drilling) and soil samples (obtained at the standard penetration test)"

The Local Consultant shall submit "five (5) hard copies and two (2) soft copies" of the above reports.
The Local Consultant should submit "boring-core samples, the JICA Study Team will instruct the way of submission after boring works.

B.6 Other Instructions

a. Close coordination with Local Government Units and other concerned agencies
The Local Consultant shall closely coordinate with the Local Government Units (LGUs). Prior to the start of the survey, the Local Consultant shall get permission to enter the area from the respective district authority.

b. Semi-monthly Reporting to the JICA Expert Team.
The Local Consultant shall nominate the coordinator who shall keep constant contact with the JICA Expert Team. The Local Consultant shall report semi-monthly progress of the work to the JICA Expert Team.

c. Insurance
All survey team members shall be insured by the Local Consultant at his own expenses during the execution of the field work, and the Local Consultant shall be solely responsible for any accidents, injuries, damage, etc.

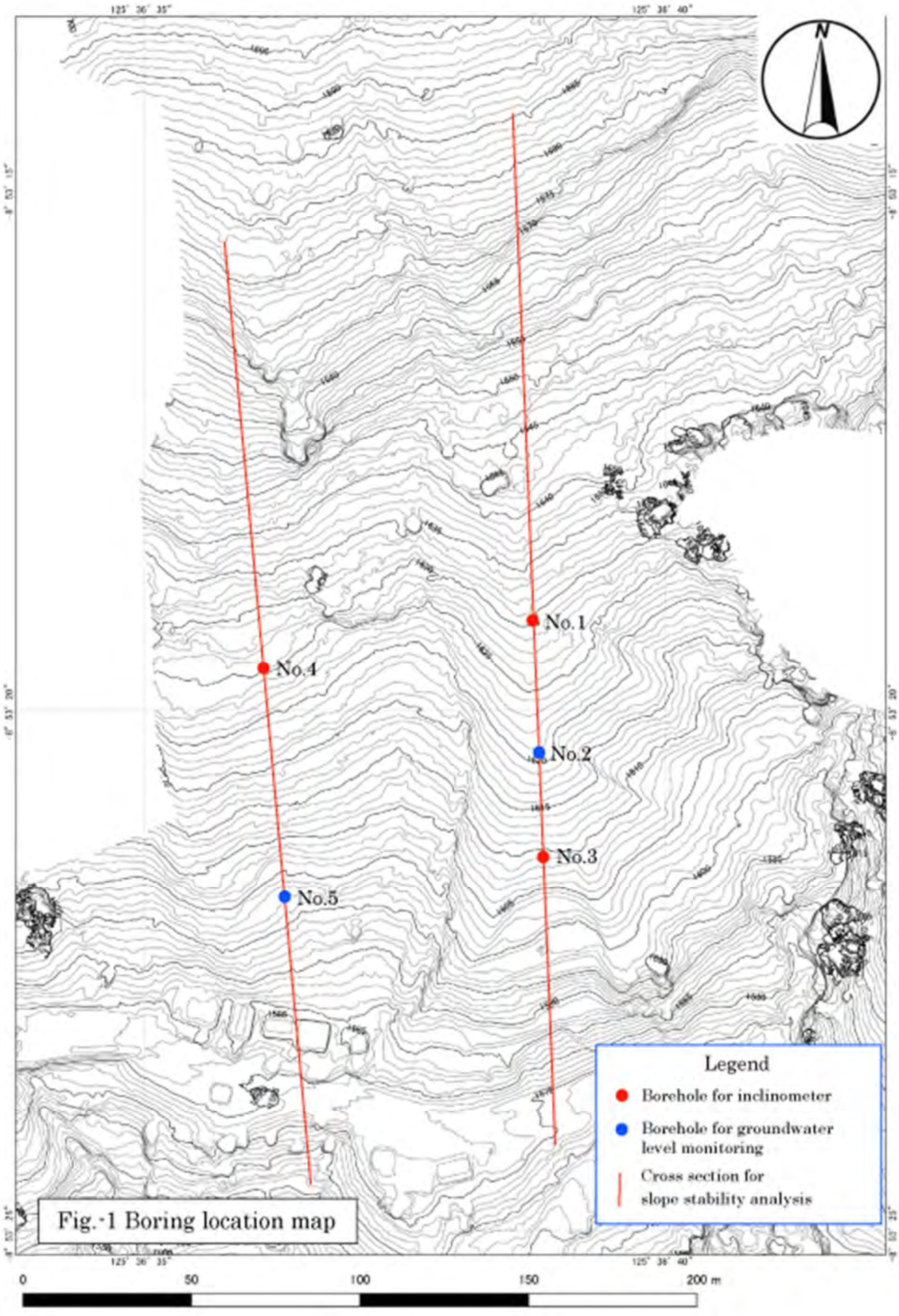


Fig.-1 Boring location map

ANNEX C
(informative)

Guideline for Installation of Inclinometer Casings

1 Installation of Inclinometer Casings into Monitoring Borehole

The method of installation of the inclinometer casings (hereinafter referred to as "casings") in monitoring borehole will be explained in following order,

1) Diameter of monitoring borehole,
2) Consideration of monitoring borehole,
3) Preparation for installation of casings,
4) Handling of casings,
5) Assembling of casings,
6) Grouting,
7) Curing of grout

1.1 Diameter of monitoring borehole

Diameter of the monitoring borehole shall be more than 86mm for the inclinometer casings of about 50 mm in diameter. Namely, the diameter of the monitoring borehole shall be 86 mm or more at the deepest portion.

In the following cases, it is necessary to consider increasing the borehole diameter at the deepest portion.

- Water level in the borehole is very low. (In such case, water is easy to leak from the borehole, and tend to cause cavities.)

- Remarkable collapse or swelling of borehole wall is observed during the drilling.

- Monitoring borehole is deeper than 50m. (In order to ensure installation of the casings and grouting.)

1.2 Consideration of monitoring borehole

Ground condition of a borehole should be carefully considered through the operation of drilling. The important items to be checked are described below.

1) Elevations or depths, at where the drilling fluid returns were lost, should be confirmed.

2) Any abrupt change and anomaly that occurs during drilling should be documented. For example, sudden drop of rods during drilling indicates existence of a cavity. Condition of cores should be also described, such as dip of strata, jointing, cavities, fissures, core loss, and any other observations, which is important information about the ground condition encountered during drilling.

3) Depth of leakage should be analyzed based on record of the water level in a borehole during the drilling operation.

4) Displacement of landslide mass should be checked. Collapse, choking or jamming of borehole during drilling may indicate displacement of landslide mass.

5) Effort to prevent bending of borehole during drilling should be taken. To prevent bending of borehole during drilling, steady operation and selection of proper tools are recommended.

1.3 Handling of casings

1) Casings should not be damaged during the transportation. Casings should be loaded on a truck so as not to cause bending, distortion, crushing, etc.

2) Casings should be suitably protected when they are temporarily placed on the site. Casings should be protected so as not to be stuck by soil particles or scratched on the surface.

3) In principle, cut-off pieces should not be used. In the case cut-off piece is in good condition, it can be used as uppermost section of casings.

1.4 Handling of casings

4) Casings should not be damaged during the transportation. Casings should be loaded on a truck so as not to cause bending, distortion, crushing, etc.

5) Casings should be suitably protected when they are temporarily placed on the site. Casings should be protected so as not to be stuck by soil particles or scratched on the surface.

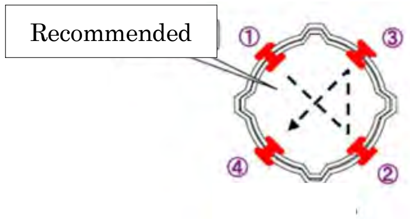
6) In principle, cut-off pieces should not be used. In the case cut-off piece is in good condition, it can be used as uppermost section of casings.

1.5 Assembling of casings

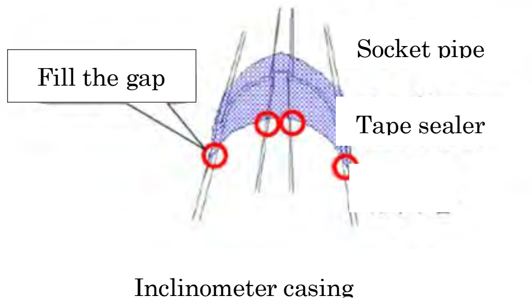
1) Prior to installation of the casings, bottom cap should be inserted at the bottom end of lowermost casing.

2) The socket pipe is fixed at one end of each inclinometer casing when it is shipped from the factory. So that the end of the fixed socket pipe functions as female end, and the other end of the inclinometer casing functions as male end.
To assemble inclinometer casings, the male end of inclinometer casing should be inserted into the female end of socket pipe, and rivet holes of the socket pipe should be adjusted to rivet holes of the inclinometer casing.

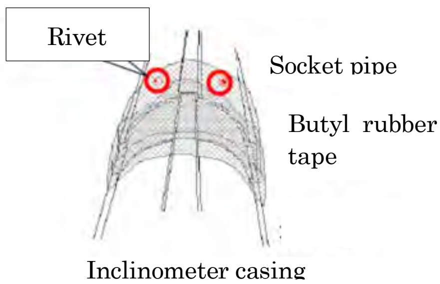
3) The inclinometer casing and the socket pipe should be fastened with blind rivets. It is recommended that the order of mounting of blind rivets is in the shape of cross as shown in the right figure.



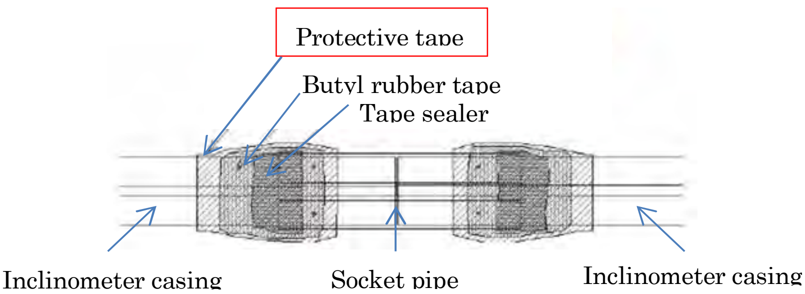
4) Coupling joint between inclinometer casing and socket pipe is to be wrapped with tape sealer. The gap at the coupling joint between a casing and a socket pipe, and bulging streak of groove should be filled firmly with tape sealer for water-proofing.



5) The tape sealer should be protected with butyl rubber tape. The tape sealer is to be overlaid with butyl rubber tape to prevent slippage or peeling. The butyl rubber tape also secures the water-proofing at rivet holes.



6) The tape sealer and butyl rubber tape should be protected with protective tape. The tape sealer and the butyl rubber tape should be overlaid with protective tape, to prevent diminution of waterproofing with peeling off of tape sealer caused by rubbing with the wall of the borehole.



1.6 Grouting

1) Mixing ratio of grout
It is desirable that modulus of static elasticity of grout which is back fill of the casings is

same as that of the ground, however, adjustable range of the strength of grout is limited. Also, when grout is injected with hand pump or pouring, viscosity of grout should be adjusted with admixture such as bentonite.
However, since products of admixtures have various specific gravities, it is desirable to stir them while confirming viscosity by adding them little by little.
Standard of mixing ratio for grout

①Target strength of grout

- The range of modulus of static elasticity of grout from E = 3,000MN/m² to 100MN/m², strength of grout is adjusted with the mixing ratio.
- For ground of which modulus of static elasticity is above E = 3,000 MN/m², mixing ratio with which grout may consolidate at the highest strength that can be injected by pump as following example;
  Example: water/cement ratio (by weight) 1: 1
- For ground of which modulus of static elasticity is less than E = 100 MN/m², mixing ratio with which grout may consolidate as following example;
  Example: water/cement ratio (by weight) 8: 1

②Viscosity of grout

The viscosity of grout is adjusted by the mixing ratio of water/solid content (cement + admixture + expanding agent).

- Slightly soft, limit that can be injected by grouting pump use or pouring (water reducing agent is not used)
  Example: water/solids ratio (by weight) 1: 1
- Stiff consistency, limit that can be injected by hand pump (water-reducing agent is not used)
  Example: water/solids ratio (by weight) 0.75: 1

2) Required equipment
A mixer, a grout pump, a pipe or hose for delivering the grout are required.

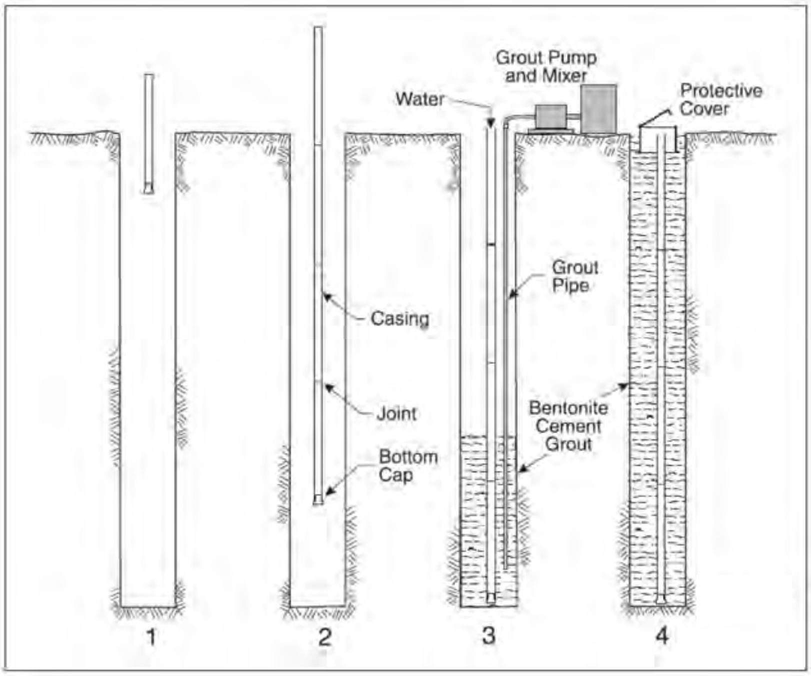
3) Using an External Grout Pipe (or Hose)
This method is used in boreholes that have room for a grout pipe (or hose) in the annulus between the casing and the borehole wall.

① Clear the borehole of debris. Check the borehole depth. Attach bottom cap. Attach grout pipe or hose.

② Install casing to the specified depth.

③ Lower the grout pipe to the bottom of the borehole and pump in grout. Then retrieve the grout pipe.

④ Top off the borehole with grout and install a protective cover.



Procedure of grout using external grout pipe

4) Important Notes on injecting grout

① Calculation of injection volume
The amount of injection is determined beforehand by calculating the content of borehole.

② Judgment to stop injection
Before stop the injecting, it should be confirmed that the grout comes up to the aperture of the borehole and the drilling fluid are completely replaced with grout.

③ Treatment after injection is stopped
After completion of the injection, the level of grout in the borehole may decrease due to infiltrating into the ground. In that case, grout material is to be poured from the aperture.

④ When grout descends faster after injection is stopped
If grout descends more quickly, it is suspected that the grout will leak into the ground. In the case of a shallow borehole, continue pouring from the aperture. If injection from grout hose is possible, reinfusion is done from grout hose.

1.7 Curing of grout

In the case that grout is composed of cementitious material, set a curing period of one week or more from the end of injection to observation of initial value.
If the observed initial value is not stable, measure the initial value again with the curing period up to about 2 weeks.

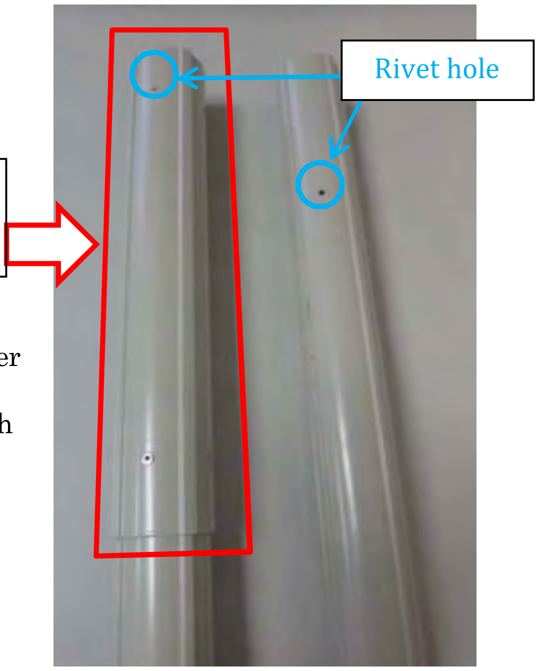
Annex D
(informative)

Supplementary Guide for Installation of Inclinometer Casings

A. How to set up Casing

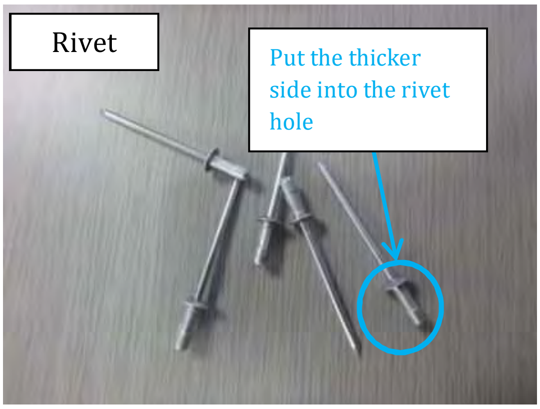
① Insert a casing to socket, and it should be confirmed that both end of casing touch to each other.

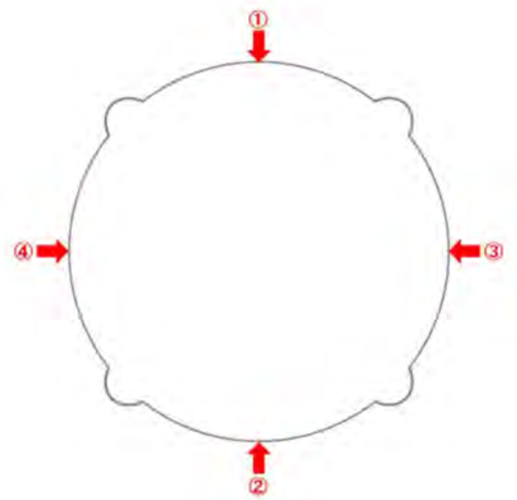
The socket pipe is fixed at one end of each inclinometer casing when it is shipped from the factory.



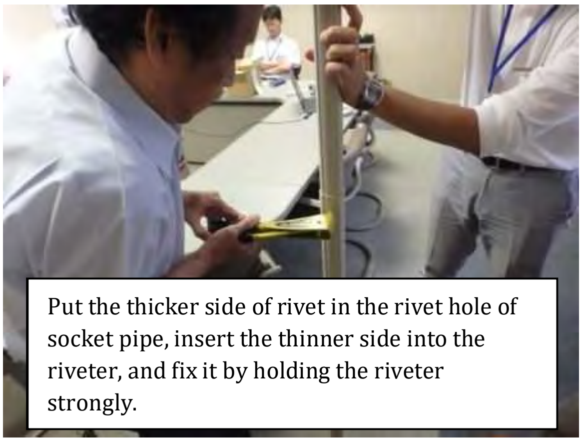
② Confirm that rivet holes of the socket pipe are adjusted to rivet holes of a inclinometer casing. In the case that holes of a socket pipes and a casing are not adjusted to each other, they may be modified using a drill.

③ The inclinometer casing and the socket pipe should be fastened with blind rivets. It is recommended that the order of mounting of rivets is in the shape of cross. Rivets of same quality of material as casing should be used. (When equipment relating to casings is delivered from the manufacturer, the included rivets are same quality of material as the casing. However, caution is required when separately procured.)



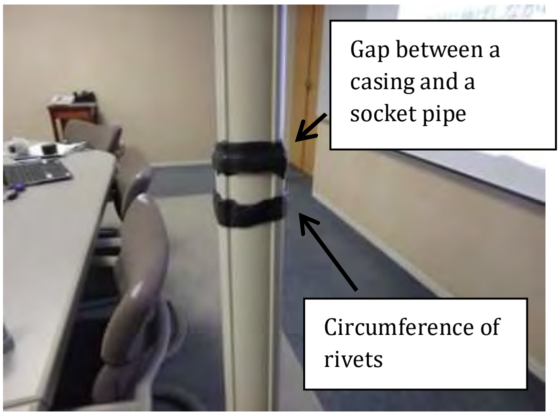


Example of the order for mounting of rivets in the shape of cross



④ The tape sealer shall be rolled around a gap between a casing and a socket pipe, and also rolled along a circumference where rivets are installed. The tape sealer should be rolled firmly so that unpreferable particles will not intrude into casings from a gap or rivet holes. After rolling, the tape sealer should be pressed firmly against casing to close the gap or rivet holes.

The tape sealer should be rolled with one turn (about 10 cm). If the tape sealer is rolled too thick, casings cannot be inserted into a borehole.



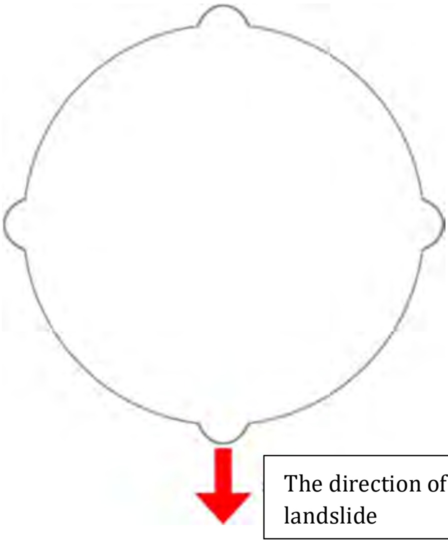
⑤ The butyl rubber tape should be rolled in triplicate. The butyl rubber stretches well, so roll it firmly while stretching. Same as the case of the tape sealer, the butyl rubber tape should be pressed firmly against tape sealer to adhere tightly to tape sealer. Since the butyl rubber tapes don't have stickiness, sometimes interstices occur between casings. However, there is no problem if the butyl rubber tapes adhere tightly to the tape sealer.


⑥ To prevent corrosion of the tape sealer and the butyl rubber tape, the anticorrosion tape should be rolled. The anticorrosion tape should be rolled twice.

Completed when three kinds of tapes are rolled firmly

⑦ Installation of casings into the borehole

Adjust a pair of grooves of the casing to the direction of displacement of the landslide.



The direction of displacement of the landslide

※Notes

- How to distinguish between three types of tape
  Tape sealer: Release paper is attached. There is little elasticity. It is thick and soft.
  Butyl rubber tape: There is no adhesion. It stretches about 3 times.
  Anticorrosion tape：There is no elasticity. It does not stretch even if it's pulled.

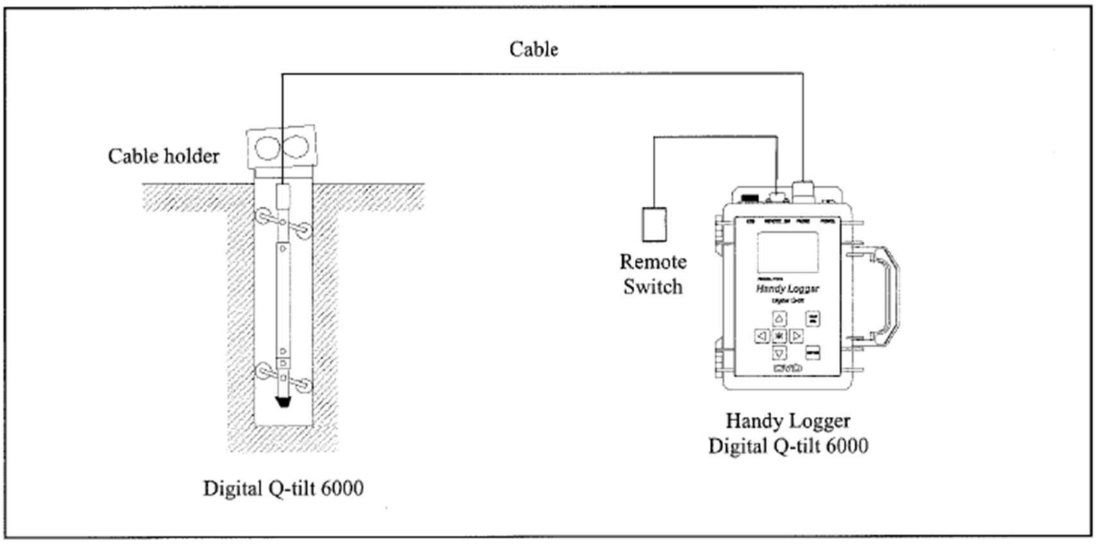
- Treatment of casing
  If they are deformed, accurate data cannot be obtained, so handling should be carefully done so as not to hit during transport.
  If the end of the casing is touched to the ground, casings may be deformed or unpreferable materials such as soil particles may stick, and it causes failure to connect properly.

- The lower end of casing
  At the bottom of casing, the casing bottom is attached. However, it is easy to drop, so it is recommended to drill holes, fix it to the casing with rivets and protect with 3 kinds of tapes.

Annex E
(informative)

How to use the Inclinometer

E.1 System configuration



Probe — The probe is a measuring instrument of borehole inclinometer. The probe and the data logger are connected with inclinometer cables, to measure the inclination angle at the depth where the probe is fixed.

Cable holder — The cable holder is used to adjust the probe to the specified depth to be measured.

Inclinometer cable — The inclinometer cable is used to connect the probe and the datalogger and to lower the probe into boreholes. On the surface of the cable, yellow, red, white tapes are rolled every 50 cm, 1 m, 10 m respectively to show the actual depth of the probe.

Logger — The logger is a handy-type datalogger for the borehole inclinometer. And using this logger, handling of files will be easier by supporting the multimedia card and SD card, and adopting CSV as data format.

Remote switch — The remote switch is used instead of the enter key of the logger.

E.2. Preparation before start to the site

2-1. Checking of the batteries

Check that the batteries of the logger are sufficiently charged. If the batteries are not sufficient, charge them with the battery charger.

2-2. Preparation of required equipment

Prepare for all necessary equipment, such as the probe, inclinometer cable, cable holder, the logger and remote switch.

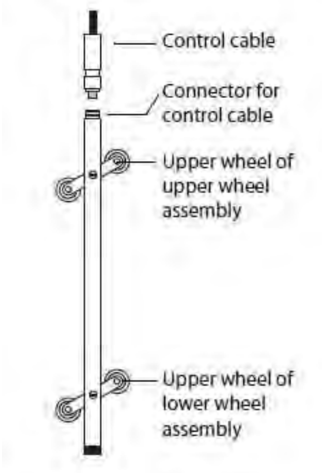
E.3. Preparation on the site

3-1. Open the cap of protecting steel tube

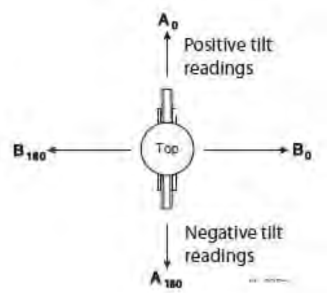
The head of the casings which has been installed to a borehole for monitoring of inclinometer is covered with protecting casing of square steel tube, and supported by base of concrete. At first, remove padlocks and open a cap. Then, remove the cap of the casing.

3-2. Set the cable holder on the head of the casing

The wheel assemblies consists of a yoke and two wheels. One of the wheels in each assembly is higher than the other. This wheel is called the "upper wheel" and has special significance, as explained below.



The inclinometer probe employs two force balanced servo-accelerometers to measure tilt. One accelerometer measures tilt in the plane of the inclinometer wheels. This is the "A" axis. The other accelerometer measures tilt in the plane that is perpendicular to the wheels. This is the "B" axis.



Inclinometer casing is installed so that one set of grooves is aligned with the expected direction of movement. One groove, typically the "downhill"
groove should be marked A0.

So the loading slot and cable stopper of the cable holder should be adjusted to the direction of displacement of the landslide.

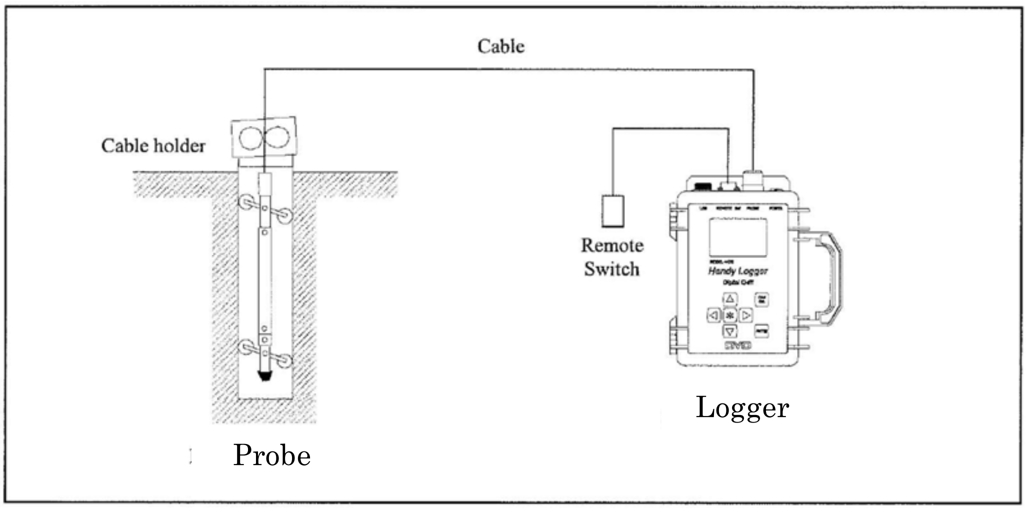
E.4 Straighten the inclinometer cable

Remove twists and kinks of the inclinometer cable before insert into a borehole. If enough space is available around the borehole, it may be recommended to stretch the cable on the ground.

.

E.5 Connection of equipment

Connect the equipment according to the following diagram. Before connecting, be sure to check that there is no dust or water on the connector, and no abrasion on the O-rings.



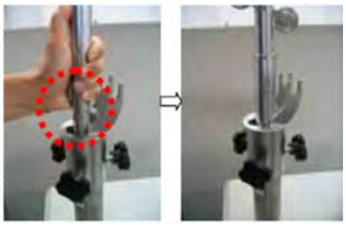
5-1 Connect the inclinometer cable to the probe.
At first, tighten firmly by hand. Then lightly tighten using accompanying crescent wrench. (O-rings will be damaged if they are tightened too tight.)

5-2 Connect the inclinometer cable to the logger. And connect the remote switch to the logger.

E.6 Inserting the probe into the borehole

6-1 Remove the stopper of the attached cable holder, and insert the probe in to the casings in accordance with a direction of measurement.

Cup the wheels with your hands to compress the springs for a smooth insertion.



6-2 Gently lower the probe until it reaches to the bottom of borehole.
When lowering the probe to the bottom of borehole, please lower it gently about 1.5m to 2.0m each descent using a cable holder, and set the probe at a starting depth of the recording.

6-3 After the probe is set at a starting depth of the borehole, leave it for about 15 minutes, and do not turn on the power of the logger.

Note: Leaving the sensor in the probe for about 15 minutes would make the sensor to be stable in terms of temperature.

6-4 Turn on the power switch of the logger, and wait for about 1 minute to have the sensor in the probe warming up. Then start the recording of the data.

6-5 When recording of the data at the starting depth is completed, raise the probe 50 cm.
On the inclinometer cable, marks of colored tape to identify the depth of the probe are rolled at every 50 cm. And the mark should be fixed at the same position as previous measurement.

6-6 To avoid damages to the tape which are rolled on the cable, upper edges of marks of colored tape should be fixed at the same level as the top of wheels of the cable stopper.

6-7 Repeat this operation every 50cm until the probe reaches to the head of the borehole.

E.7 Rotation of the probe

When the recording is completed to the head of the borehole, remove a cable stopper, pull out the probe and rotate it 180 degrees around.
Then put it back in the casing again, and lower it to the bottom of borehole. Then, wait for 1 minute warming up, and raise the probe and record the data for every 50cm.

E.8 Cleaning after use

When measurement is completed, turn off the power switch of the logger. And clean each device promptly.

Wash off the mud, sand etc. which stuck to the probe. Especially wash the rotating parts of the wheel carefully.
Then wipe out the probe with soft cloth, and put it into the case.

E.9 Setting of the protecting casing

Put the cap on the head of inclinometer casing, and then lock the protecting casing and its cap with a padlock.

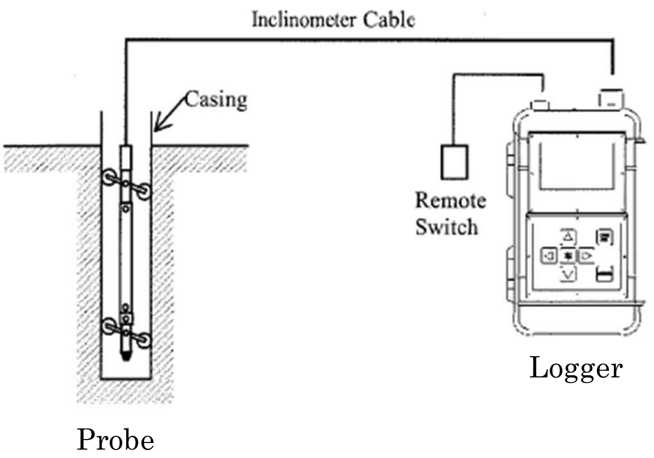
Annex F
(informative)

How to use the Logger for Inclinometer

1. Appearance of the logger and name of each section

① Power switch	⑤ LCD
② Probe connector	⑥ Keyboard
③ Remote switch connector	⑦ Battery holder
④ USB connector	⑧ Memory card slot

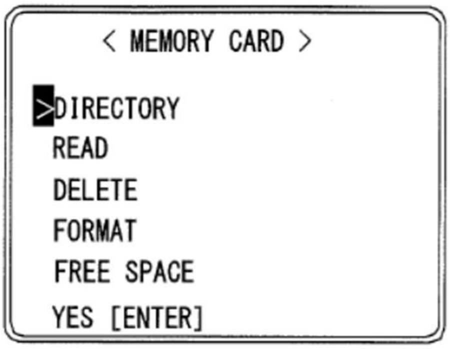
2. System configuration



3. Start the logger.

Turn ON the power switch.

3-1. Checking the free space in the memory card

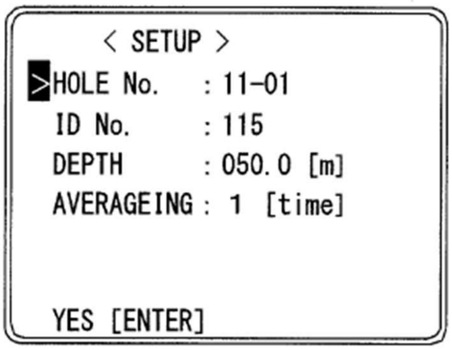


Select “Memory Card” of Main Menu.

Check the free space in the memory card before starting measurement.

Format the memory card with the logger if it is not yet formatted. (The attached memory card is already formatted and ready to use).

3-2. Specifying measurement conditions.



Select “Setup” of Main Menu, and specify each setting in the Input Measurement Condition menu.

1) Input the hole number of the borehole to be measured.

2) Input the ID No. of the inclination data to be measured. If an inappropriate ID No. is input, an error message is displayed. In such case, input another ID No.

3) Input the measurement depth. If an inappropriate depth is input, an error message is displayed. In such a case, input another depth.

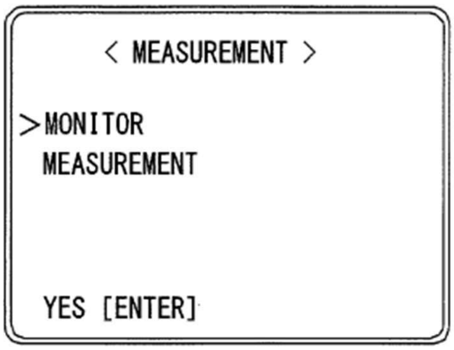
4) Specify how many times data is averaged at acquisition. The more times data is averaged, the more stable the measurement value is. However, this results in a longer measurement time. Therefore, usually select the smallest number. The options are 1, 6 or 12.

Hole No. and ID No. to be imputed in the logger

Borehole	Hole No.	ID No.		Hole condition	
		Initial measurement	Following measurement	Casing length (m)	Measurement range (m)
No.1	17-01	100	101, 102, 103, …	30.82	－30 ~ －0.5
No.3	17-03	300	301. 302, 303, …	30.45	－30 ~ －0.5
No.4	17-04	400	401, 402, 403 …		

After completing these settings, press Enter. Setting is completed when the “Setting Completed" message is displayed.

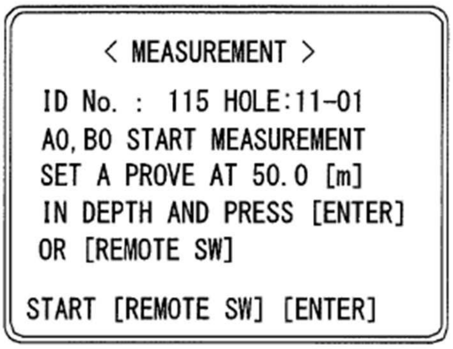
4. Starting measurement



Select "Measure" of Main Menu, and select Measurement in the Measurement menu.

(Notice) If the specified ID No. is already in use, an error message is displayed. In such a case, input another ID No.

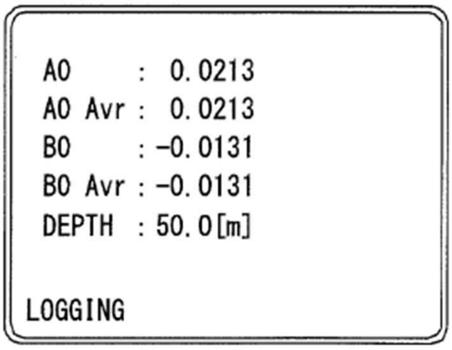
4-1 Measurement in the 0° direction



1) Insert the probe into the borehole until the specified depth.

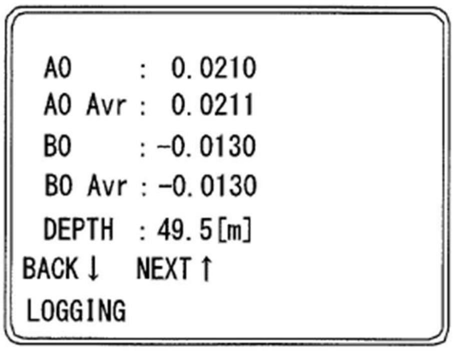
(Remarks)To acquire more stable data, it is recommended to leave the probe for about 15 minutes after inserting it into the borehole at the measurement depth.

2) Press the remote switch or Enter. Communication between the logger and the probe starts and the measurement value is displayed on the logger.



3) Make sure that "A0" and "A0 Avr" as well as "B0" and "B0 Avr" values are similar.

4) If the value is unstable, wait for a while. If the value is stable, press the remote switch or Enter. Data is acquired and the next measurement depth is displayed.



5) Move the probe to the next measurement depth and repeat Steps 2) through 4).

*(Notice) If Enter or the remote switch is pressed before **A0 Avr** and **B0 Avr** are displayed, correct values may not be acquired. Wait for a while until they are displayed.*

6) To redo measurement from a previous depth, press ↑ or ↓ to display the depth where you want to start re-measurement. When the desired depth is displayed, press the remote switch or Enter.

```
A0      :
A0 Avr :  0.0000
B0      :
B0 Avr :  0.0000
DEPTH  : 50.0[m]
BACK ↓   NEXT ↑
                START[ENTER]
```

```
A0      :  0.0210
A0 Avr :  0.0211
B0      : -0.0130
B0 Avr : -0.0130
DEPTH  : 50.0[m]
BACK ↓   NEXT ↑
LOGGING
```

(Notice) When you go back to a previous depth and redo measurement, the data for shallower depths becomes invalid. Therefore, it is necessary to perform re-measurement from the shallowest depth

```
    < MEASUREMENT >
A180, B180 START MEASUREMENT
SET A PROBE AT    50.0 [m]
IN DEPTH AND PRESS [ENTER]
OR  [REMOTE SW]

START [REMOTE SW] [ENTER]
```

7) When measurement until the depth of 0.5 m is finished, measurement in the 0° direction is completed.

8) Invert the probe following the message and prepare for measurement in the 180° direction.

4-2 Measurement in the 180° direction

```
A180       :  0.0213
A180 Avr :  0.0213
B180       : -0.0131
B180 Avr : -0.0131
DEPTH      : 50.0[m]

LOGGING
```

Invert the probe by 180°, put it into the borehole again, and insert it until the deepest depth specified at first.

Press the remote switch or Enter. Communication between the logger and the probe starts and the measurement value is displayed on the handy logger.

Perform measurement in the same way as the A0° direction.

```
    < MEASUREMENT >
A180,B180 END OF MEASUREMENT
DATA STORED IN FILE NAMEBELOW

HOLE     : 00-00
ID No.   : 000
DEPH     : 050.0[m]
           CONFIRM [CANCEL]
```

When measurement until the depth of 0.5 m is finished, the message indicating the completion of measurement in the 180° direction is displayed. Press Cancel following the message.

(Remarks) If a battery runs out during measurement, the resume function operates to temporarily save the status.

Turn OFF the power switch.

Annex G
(informative)

Design of Countermeasure for Mass movement phenomenon

F.1 What is Disaster along the Road and Design of Countermeasure?

(1)Purpose of Countermeasure

Disaster of Mass movement along the road is phenomenon that disturbs traffic on the road since soil and rock are moved by gravity. It often caused by surface and subsurface water by rainfall. When disaster occurs, countermeasure for keeping safety traffic is necessary therefore its design and execution will be implemented.

(2)What is Design of Countermeasure?

Based on the design of countermeasure, it is important to grasp disaster phenomenon as scientific evaluation and to estimate the appropriate controllable countermeasure. If countermeasure is not enough against phenomenon, it cannot control the phenomenon and cannot achieve the object keeping safety traffic. Otherwise, if countermeasure is too surplus estimation, it gives excess cost and tax is lost wastefully. Therefore, the evaluation of design of countermeasure is important task.

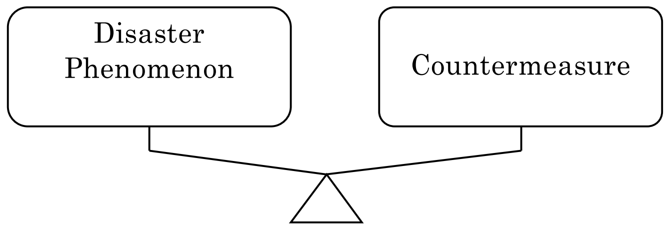


Fig.1.1 Countermeasure balances out disaster phenomenon just enough

(3)Scientific Grasp of Disaster Phenomenon

Regarding to above (2), Scientific grasp of disaster phenomenon is essential to appropriate countermeasure design. because the phenomenon caused by what soil and rock moves downward by gravity force under influence of water, the necessity information to grasp it scientifically are topography information, geology information and groundwater information.

(4)Necessity of Comparative Study on Countermeasure

It spends the huge budget to execution of countermeasure. Therefore, the most important thing in a round of design work is to select optimum countermeasure to control the disaster phenomenon. In order to do above this, comparison among multiple plans (generally 3 plans) is necessary. Comparative plans should be made from each different principle methods these are control work, prevention work and protection work which is described in section 3. This process can give certification of validity to third persons opinion.

(5)Necessity of Design Process Record

It shall need to be recorded the design process of countermeasure. For the purpose of this report is to describes information for grasping phenomenon, explanation of phenomenon, and process of countermeasure selection and detail design. Additionally, the information must be stored as referenced document. The report fulfills the function as below.

- It's the document to explains why the countermeasure is selected to third persons.
- If it is successful case, it can be good example for similar cases.
- If disaster phenomenon reoccurs, it can be a foothold to find out failure reason and to remake surely countermeasure.

Photo.1.1 Failure example of mass movement countermeasure

F.2 Necessary Information to Grasp Disaster Phenomenon

It is essential to grasp the scientific disaster phenomenon to appropriate for countermeasure design. because the mass movement is phenomenon what soil and rock moves downward by gravity force under influence of water, the necessity information to grasp it are topographic, geological information and groundwater information.

F.3 Principle Classification of Slope Disaster Countermeasure

All of slope disaster countermeasure can be classified into 3 works (control work, prevention work and protection work) and avoidance. The design engineer confirms that the countermeasure plan is adapted into the principle through deep understanding of the principle. When comparative plans are made from each different principle works, the engineer can select countermeasure from wide viewpoint.

Table 3.1 Principle classification of slope disaster countermeasure

Classification	Principle
Control work	Control work makes the ground itself be stable. This is basic means of countermeasure. Represented by adoption of adequate slope gradient, subsurface drainage and so on.
Prevention work	Structure prevents soil mass movement by equilibrium of force. This work is broadly classified two. One counteracts moving force by structure's own weight as retaining wall. Another counteracts by structure's tension or stiffness as anchor or pile.
Avoidance plan	When size of disaster phenomenon is too large to treat from technical point or cost, road avoids disaster point by route change, bridge, tunnel etc. Avoidance plan must be reasonable than countermeasure works.

F.4 Countermeasure against Mass Movement

(1) Basic Classification of Countermeasure

Generally mass movements are large-scale phenomena, whose land mass in motion can reach tens to hundreds of thousands of cubic meters. Also, in many cases, it spends huge scale and cost of countermeasure works. It is therefore extremely important to make sufficient studies and observations to understand the phenomenon accurately and make the design based on this knowledge.

The basic classification of countermeasure against mass movements is shown in Table 4.1. Being large-scale phenomena, we will analyze the applicable control works to decide the priority. In many mass movements, rising groundwater level is a strong contributory factor. Drainage works are essential in control works because it prevents the water supply to the sliding block and quickly eliminate the water outside the block. Within the drainage, drainage of groundwater is of particular importance. The essence for the underground drainage is in the technology to drill lateral angles bore holing. The earth removal works, and the counter weight embankment are control works through the modification of topography, where the first reduction of the sliding force to remove the weight of the head and secondary, increases the slip resistance by adding weight to the foot.

The prevention works is to resist sliding force of mass movement by structural force. They are represented by pile works and anchor works. The pile works in Japan are installed steel pipe piles after making a large caliber hole by heavy equipment. It is applicable only for the limited conditions such as the sliding is stopped, the load acting once all the piles, the piles should be installed in the compressed block, and so on. The anchor works are installed when the applicable control works is difficult to install or when these effects do not work enough. Additionally, the capability conditions are limited in comparison to the pile works. the anchor works also need the lateral boring technology to drill deep correctly and anchoring systems with sufficient corrosion features (a set of steel elements, shirt, parts assembly, slurry system) are needed.

Basically, the protection works for the gigantic force of mass movements are not existence. <u>Namely, if mass movement is too large to solve within realistic control works or prevention works, avoidance plans such as tunnels or bridges as alternative route shall be considered.</u>

Table 4.1 Basic classification of countermeasure against mass movement

Classification	Countermeasure	Point of view
Control work	Surface water drainage: channel, infiltration prevention works Shallow groundwater drainage: drainage conduit, open drainage conduit, lateral boring Deep groundwater drainage: lateral boring, drainage well, drainage tunnel Earth removal works Counterweight embankment works	Drainage works try to lower the water table, which is a strong contributory factor. The earth removal work lightens the slope's head to reduce the sliding force. The counterweight embankment work is embankment on the foot to increase the weight of slip resistance.
Prevention work	Pile works Anchor works	Pile works contain mass movement installing piles that go through the surface of mass movement, in rows perpendicular to the direction of movement. Anchor works fix steel materials with high strength to the stationary ground and installs structures to catch pressure in head of tensile member, to contain the mass movement with stress of tensile member.
Protection work	-	Basically, they are not established due to gigantic force of mass movement

(2)Planned Safety Factor

In the design of mass movement countermeasure works, the actual safety factor is increased (used during mentioned inverse calculation) to reach the planned safety factor. The planned safety factor is basically “$F_{SP}=1.20$”

In case that it is possible to implement additional measures during mass movement observation (ex. Groundwater drainage work), a planned safety factor “$F_{SP}=1.05$ a 1.10” can be used.

(3) Surface Water Drainage Works

Surface water drainage works mitigate or stop the sliding movement, containing the up rise of water level by reducing direct infiltration of rain water and re-infiltration from swamps, etc. the specific works are channel and infiltration prevention. Although the analysis of stability is not assessed quantitatively the effects of the drainage of surface water, is a measure to be considered at first, since the elimination of water produces positive effects insurance.

1) Channel works

Channel works are formed by collection channels located in branched shape in concave terrains inside the sliding slope, added to channels of drainage that drain the water collected by the first one. Also, perimeter drainage channels are installed according to the topographical conditions to prevent entry of external water to the sliding area.

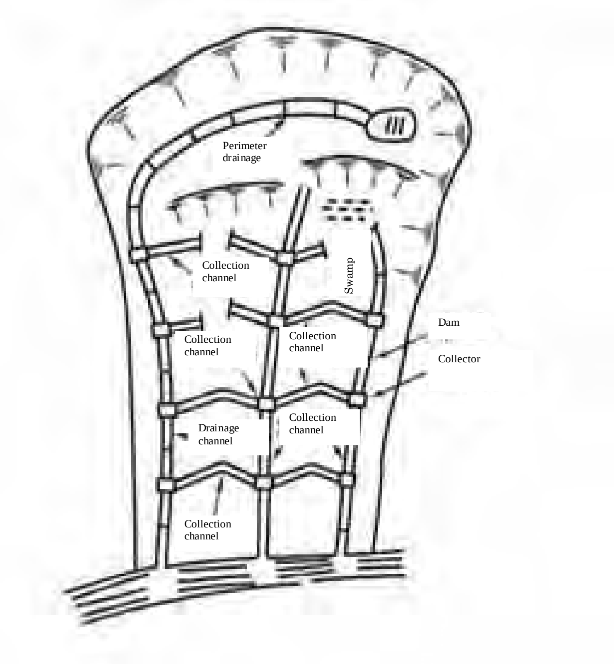


Fig. 4.1 Surface drainage network

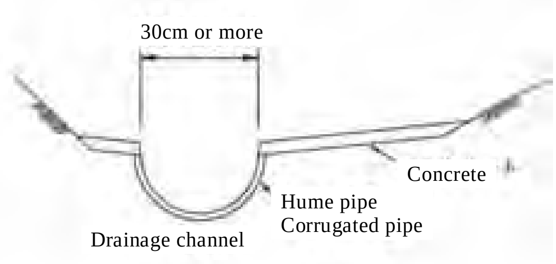


Fig. 4.2 Surface drainage channel

In aspects of taking into account during the design of channel works are the following:

i. Channels have to be trench type as in **Fig. 4.1**, to collect surface water. Must be selected to reduce as possible the excavations and this way can be avoided excessive earth work that could destabilize the mass movement.

ii. For maintenance and management issues, the minimum width of the channels must be 30cm or more, if possible giving a wide, shallow way. The edges of the channel must be covered with concrete or asphalt.

iii. Should prevent re-infiltration from channels, using existing channels lined on the bottom or implementing protection and lining works to the bottom of channels.

iv. If it is anticipated sliding motion caused by the installation points of channels, channel structures are discussed that may follow this movement to some degree.

v. Main drainage channels should have a cross section of channel capacity to ensure the runoff based on the collection flow obtained with the rational formula. Chance of precipitation will be 1/50 (it uses the value of 100mm/h while preparing the formula of intensity of precipitation). As margin for the deposit of debris, it is expected an additional 20% in the flow cross section.

vi. Collectors are installed at points of confluence, bending and change of slope. If falls are planned on the collectors, the size of the collectors is obtained using the following formula:

$$L = k(h_1 + t)$$

L: Internal length of collector

k: Coefficient (2.5 a 3.0)

t: Depth of the flow upstream

h_1: Fall between bottom of upper and lower channels

h_2: Depth of collector from level of water (0.2 a 0.5m)

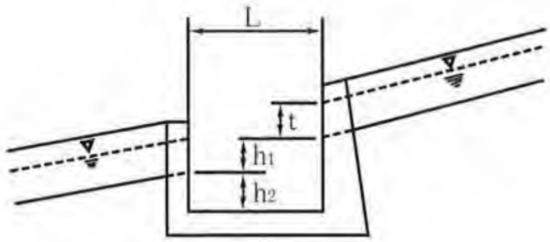


Fig. 4.3 Profile of collector

2) Infiltration prevention work

Infiltration prevention works are to prevent infiltration of surface water through cracks, etc.

i. Filling: Fill the cracks with clay or concrete.

ii. Coating with vinyl cover: covers the cracks with vinyl covers and is suitable as an emergency measure.

iii. Filtrations prevention: If it is a swamp and there are leaks, the bottom is lined with impermeable material such as asphalt.

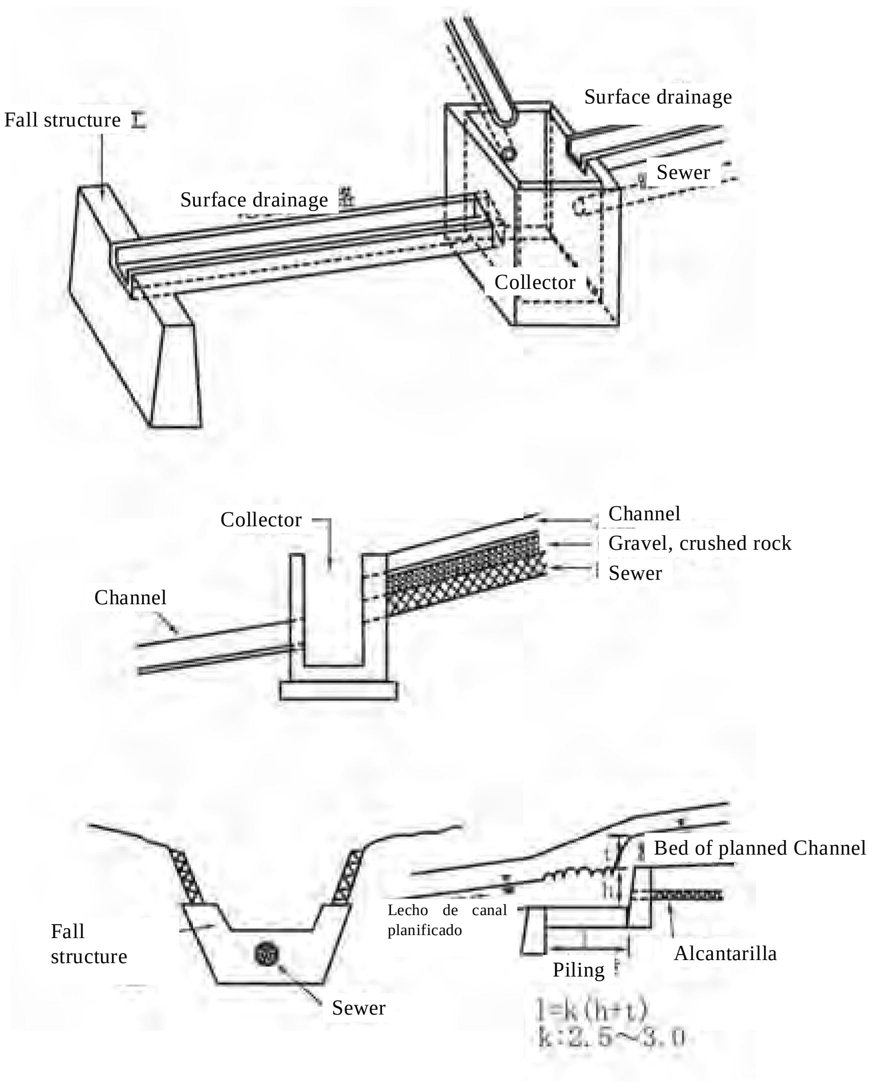


Fig. 4.4 Fall structure and collector

(4) Groundwater Drainage Works

The drainage of groundwater, mitigate or stop the sliding motion, eliminating the groundwater within the slide area to reduce the pore pressure (water table) within the moving mass. The groundwater drainage is divided into shallow groundwater drainage and deep groundwater drainage. Shallow groundwater drainage is aimed near the surface, and deep groundwater drainage is intended to groundwater near the sliding surface.

The planed lowering height of water table will refer to these values. These are the maximum that can be expected to successfully deploy facilities to reduce the water table. It is necessary to continue monitoring of the water table after executing the works and not obtained the expected results, should be strengthened by reviewing the types of drainage and distribution.

Lateral boring	3m
Drainage well	5m
Drainage tunnel	8m

1) Shallow groundwater drainage work

a) Drainage conduit

Aspects to consider in drainage conduit design are the following:

i. Drainage conduit distribution must be defined based on the status of the geology and shallow groundwaters distribution.

ii. The maximum length of each drainage conduit unit will be of approx. 20m in straight line and Hill drain to surface drainages through connection to collectors.

iii. The depth of drainage conduits will be of approx. 2m and will have impermeable covers in the bottom to avoid leaking. Also, material will be installed to prevent aspiration of debris around the drain. The perimeter is filled with filter material to search for water collection.

iv. If surface water will be collected, filter material to the surface will be used.

v. If movements of mass movement are foreseen in points with installed channels, the channel structures that follow the movement at a certain degree are to be analyzed.

vi. If the longitudinal gradient is higher than 30º, the drainage conduit works are se fixed with piles.

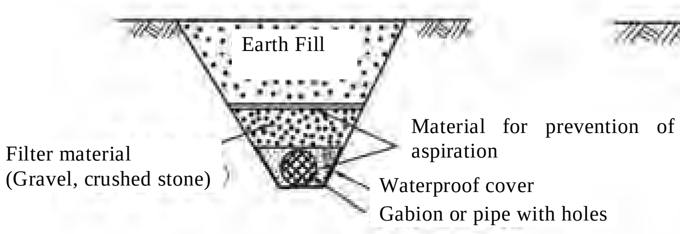


Fig. 4.5 Drainage conduit

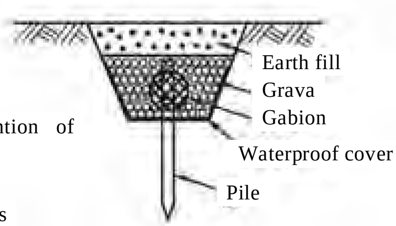


Fig. 4.6 Gabion drainage conduit

b) Open drainage conduit

Open drainage conduit is adopted in cases where the water table in the route of installation of surface drainage is high. Aspects to consider are the same as in drainage conduit works.

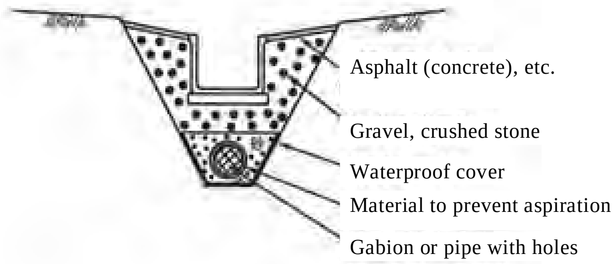


Fig. 4.7 Open drainage conduit

c) Lateral boring drainage works

Lateral boring, eliminating shallow groundwater that can't be eliminated by conduits (due to its depth), and are distributed in concentrated way in points with many groundwater. Depending on the results of hydro geological surveys, is more effective to define positions after knowing layers with flow of ground water.

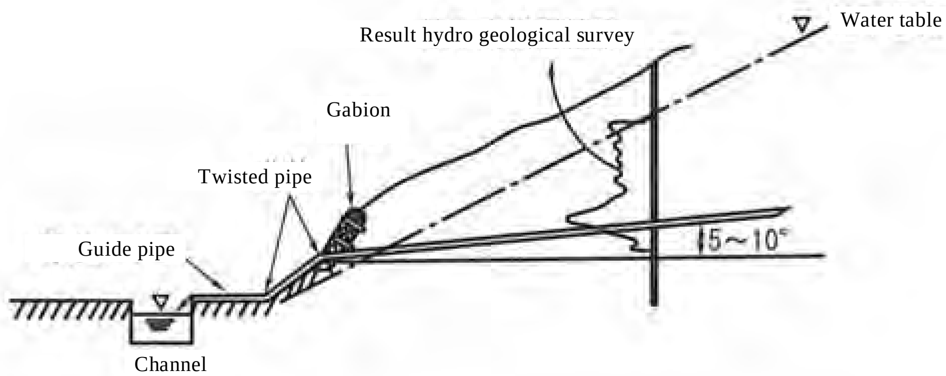


Fig. 4.8 Lateral boring

Aspects to consider in the design of lateral borings are the following:

i. Lateral borings are distributed in radial or parallel shape, so that space between ends is of 5 to 10m

ii. Collected groundwater is guided to collectors or drainage channels to be drained out of the zone.

iii. The borehole mouths are installed in stable soils. Protection works are implemented for borehole mouths, with the objective to prevent collapse of borehole mouths due to drained water.

iv. Borings are made with slopes of 5º to 10º and up, to drain by natural flow. The boring diameter must be 66mm or more.

v. Pipes to be used as collectors must be those with more than 40mm of internal diameter. In groundwater zones the pipe is used to work as collector with filter.

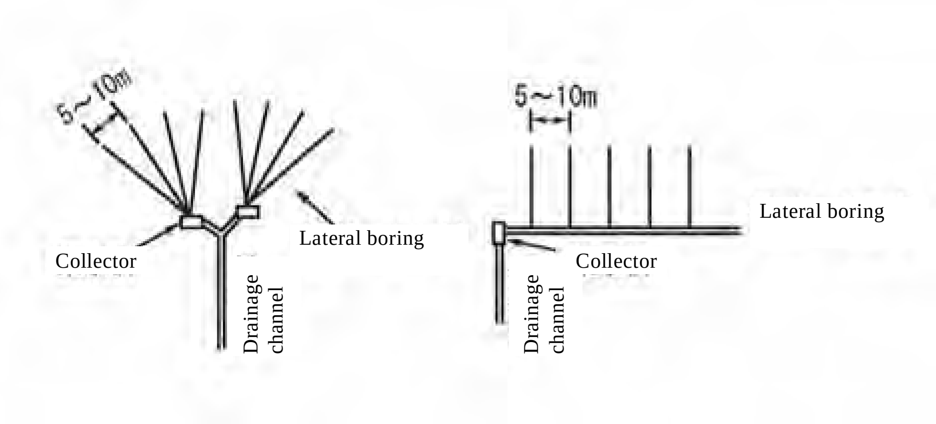


Fig. 4.9 Distribution of lateral borings

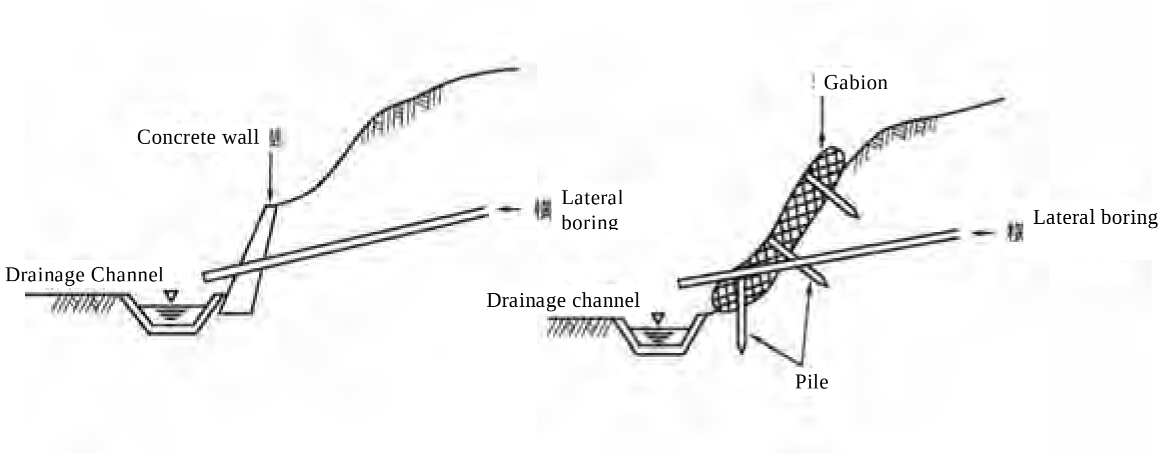


Fig. 4.10 Protection work of lateral boring mouth

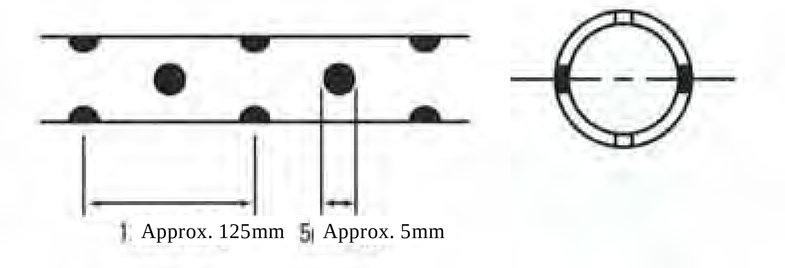


Fig. 4.11 Example of pourer of collection pipe

2) Deep groundwater drainage

a) Lateral boring

Lateral boring implemented as great depth groundwater drainage work has the objective of eliminating distributed groundwater in surroundings of sliding surface. Because of object boring is made from 5 to 10m or deeper than estimated sliding surface. Boring length must have as maximum 50m approx., having boring diameter in the head of 66mm or more. Other aspects to consider in design that are common to lateral borings for shallow groundwater drainage.

b) Drainage well

Lateral boring has approx. 50m as limit of length and if the mass movement block is big, the boring does not reach the surroundings of the sliding surface. In these cases they are installed in workable positions drainage wells which installation eliminates efficiently the groundwater from surroundings of sliding surface. Later lateral boring is implemented from the interior of wells (called collection boring). Drainage borings are installed from drainage wells towards the surface of the slope. The design of drainage wells will be described in a separate paragraph.

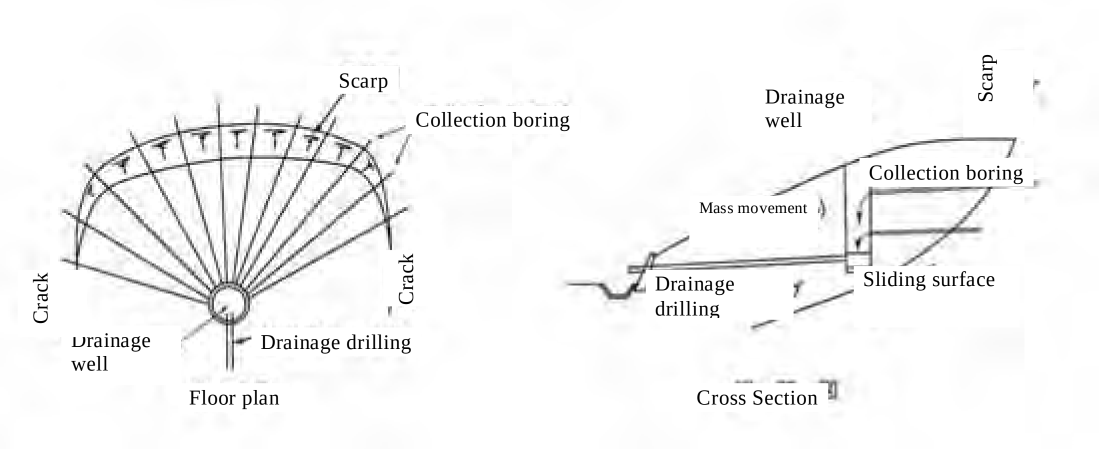


Fig. 4.12 Drainage well

c) Drainage tunnel

If mass movement scale is extraordinarily big, then attention through drainage wells gets complicated, due to requirement of greater depth and quantity of these. Also, in mass movements with high movement speeds, there are cases where the installation of drainage wells within the moving layer is difficult. The drainage tunnel is a type of work that eliminates water from surroundings to sliding surface through a drilled tunnel in unmoving ground. This type of work must be implemented based on an special case-study that will not be object of actual Guide.

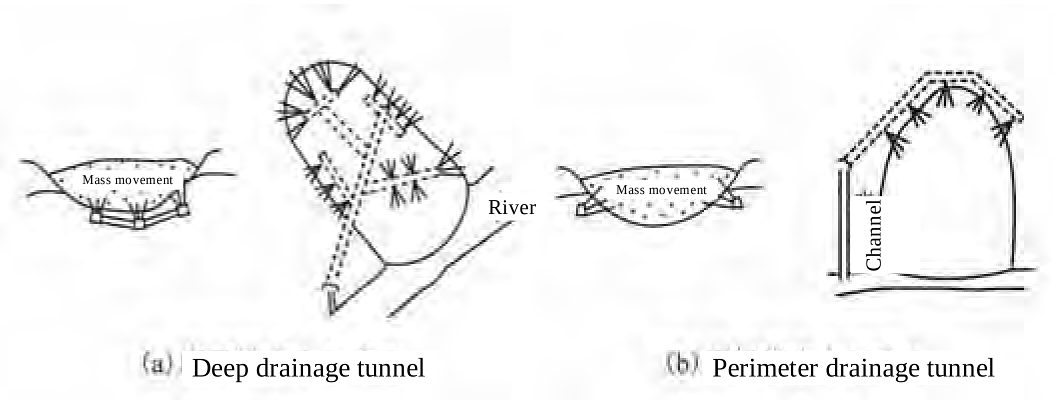


Fig. 4.13 Drainage tunnel

(5) Drainage Well

1) Depth of drainage well

Depth of drainage well is appropriate depth according to collection borings and drainage borings distribution. However, it should be 2m or more above the sliding surface for security purposes.

2) Design of drainage well with steel structure

Standard in drainage wells is steel structure (liner plates). Internal diameter of well has 3.5m as standard, that is a diameter that makes possible lateral boring. 50cm of concrete are poured in the bottom with the objective to prevent leaks underneath. Drainage well is designed in such way that can maintain its internal space under earth pressure.

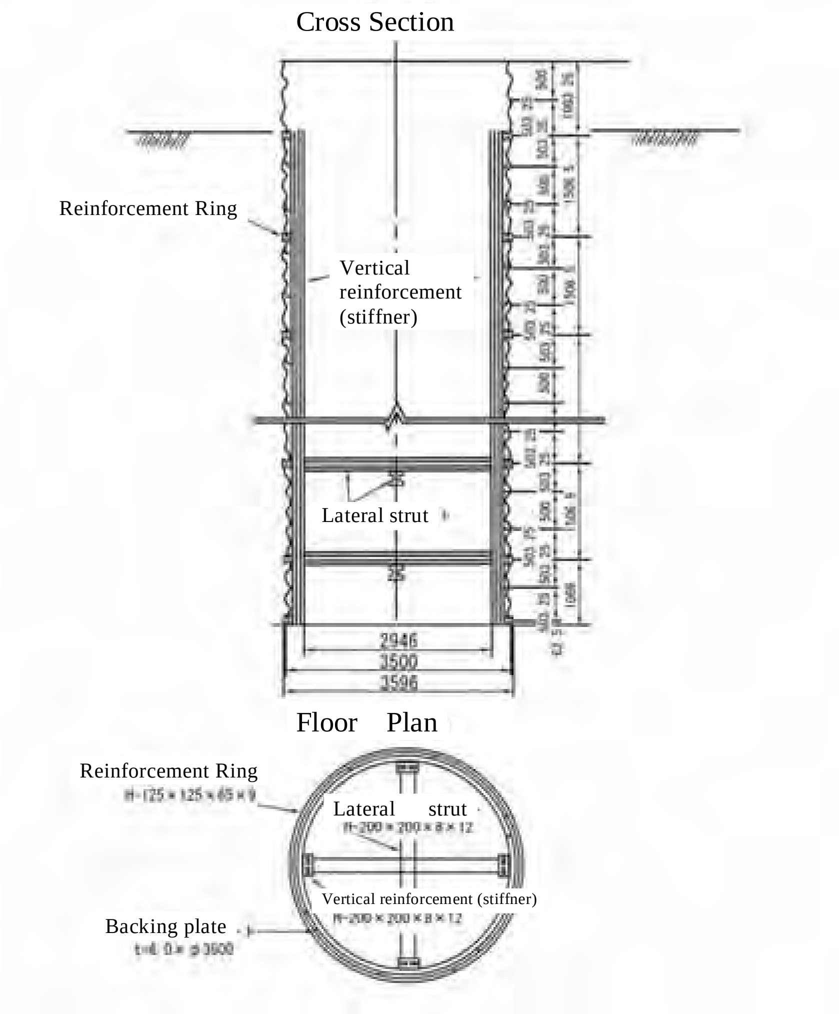


Fig. 4.14 Example of Drainage well

3) Drainage boring

Drainage boring drains water of drainage wells collected from surroundings of sliding surface by collection borings. Aspects to consider in design are the following:

① Drainage boring is made with 5º to 10º of descending slope, to drain by natural flow.

② The maximum length of drainage boring will be 80m. If exceeding this length, intermediate wells are installed.

③ Standard of drainage pipes is 80 to 100mm of internal diameter. If great drainage flow is expected, multiple pipes are planned.

④ The end of drainage boring is installed in stable ground inside the mass movement block. Protection works are installed in boring mouth with the objective to avoid collapse of boring mouth (Reference in lateral boring)

4) Collection boring

Collection boring is executed radially from interior of drainage wells. Aspects to consider in design are the same as lateral boring.

(6) Earth Removal Works

Earth removal work is a work that mitigates or stops mass movement when cutting and reducing mass movement head, to reduce sliding force. The design of earth removal is defined after searching shapes of cutting that will raise the safety factor efficiently, introducing for this cut shapes in the stability analysis. If effective shapes of removal are not found, it is considered that adequacy of the work of removal is low and other countermeasure works are analyzed. Aspects to consider in design are the following.

1) Stability of cut slope

Earth cuts in the head many times generate cut slopes with relatively big extensions. It’s necessary to design a cut slope that maintains stability for long periods of time.

2) Mass movement in upper part of slope

If removal of head is made in mid lope, there is a risk to destroy balance of upper slope and induce mass movements this way. If you care about upper slope mass movement is necessary to assess the risk through adequate geological studies. If mass movement is induced upper slope will require new measures for these slides, thus generating additional costs and efforts. In this and other cases where mass movements are large scale, it creates a situation where the only alternative is avoidance.

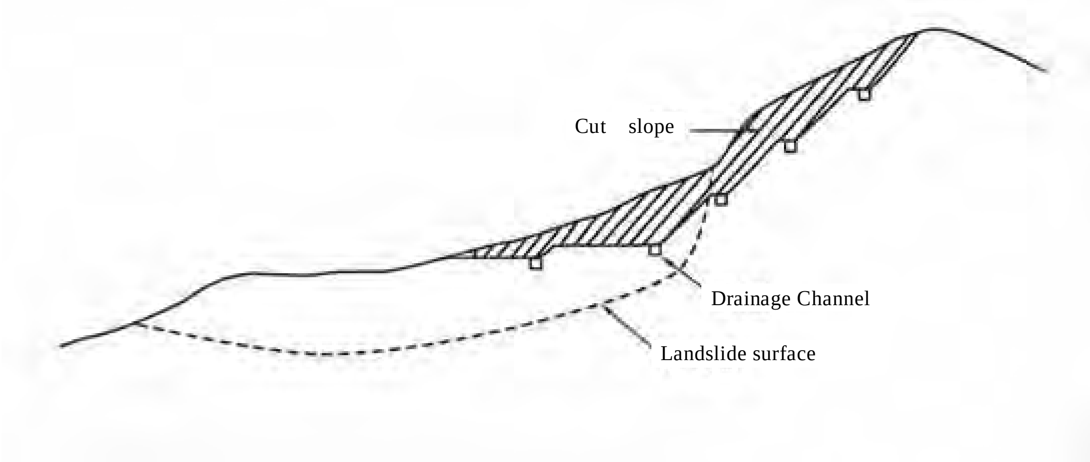


Fig. 4.15 Removal of head and cut slope

Counterweight Embankment

The counterweight embankment stops mass movement by embankment on the toe of the mass movement to increase resistance force. It is the pair of earth removal that reduces sliding force. The design of the counterweight embankment is defined by introducing the shape of embankment stability analysis to find shapes so as to increase the safety factor effectively. Failure to find effective shapes it is considered that the suitability of embankment is low and discusses other measures. The aspects to be considered in the design are:

3) Stability of embankment slope

It is necessary to design the slope of embankment, so that it can preserve its stability for long periods of time. You must select a slope protection work that may follow, to some degree, the displacements caused by the mass movement.

4) Groundwater treatment

There is a possibility that toe of mass movement is an aquifer of shallow groundwater. In this case the embankment plugs up groundwater and makes mass movement block and embankment itself unstable. To avoid this the treatment of groundwater shall be implemented.

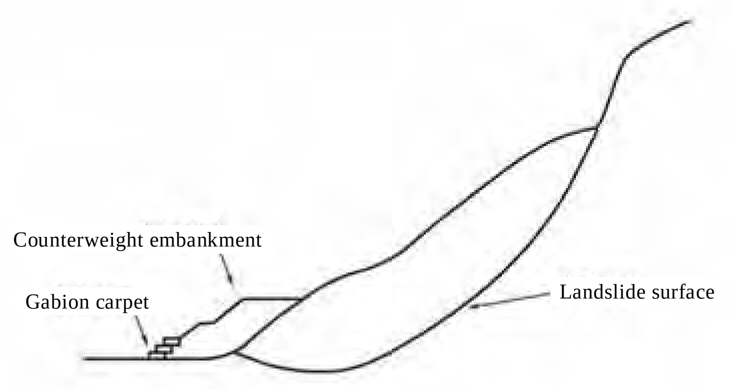


Fig. 4.16 Counterweight embankment

(7) Pile Works

In the pile works piles resist mass movement, setting piles in line at right angle with moving direction, striking through sliding surface into the unmoving ground.

1)Piles Material and execution methodology

In Japan almost 100% of the materials used in the pile works are steel pipes. The diameter of the piles is 300 to 1000mm and thickness from 6 to 60mm. The execution procedure is to drill large diameter hole, steel pipe installation, grouting (among drilled wall, pipe and inner pipe). The following machinery and materials are needed:

- Machinery for drilling large diameter hole (Rock drill, “Down the Hole Hammer”, etc.)
- Heavy crane
- Transportation to the site mentioned machinery, temporary scaffolding
- Steel pipe supply
- Quality hand welding for pipe connections
- Fill grout (grout plant)

Photo. 4.2 Execution of pile work of steel pipe for mass movement prevention in Japan

Currently, it is difficult to collect and count the elements identified with them, is a future challenge. At present, works are executed reinforced concrete piles with drilling manuals for bridge structures below, and this method could be considered to be applied as a prevention of mass movements.

2) Conditions for the application of pile work

The following outlines are the conditions for the application of pile works. The work can be taken when driving the following conditions are met:

i. The moving layer thickness does not exceed approximately 20m and the total length of the pile should not exceed 30m. This is because if you exceed these dimensions, the construction becomes difficult.

ii. The moving layer is not soft soil and divided into small masses. This is because there is a risk that the mass is moving out through the pile line.

iii. The unmoving layer is not soft soils. This is due to the need to hold steady the piles.

iv. The mass movement activity is stopped (no more than 1mm/day). This is because in the pile work, you must build the entire line simultaneously. If slip is active, the load is concentrated in the first installed piles, destroying them.

3) Position of pile installation

The ideal conditions for pile installation points include:

i. Compression zone below the central places of moving block, where the gradient of the sliding surface is relatively mild.

ii. Zone where the moving layer is relatively thick and does not occur passive layer destruction in motion by the reaction of the piles.

(8)Anchor Works

The anchor work is a prevention work that faces the sliding force of the moving mass through the tension of the stretched material, fixing steel material of high strength as the material stretched on solid ground, and installing pressure receiving structures in the head of the stretch material.

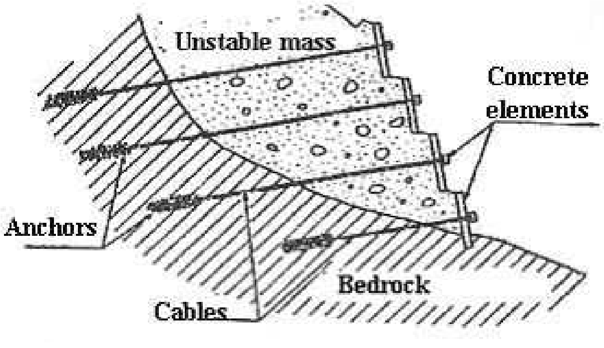


Fig. 4.17 Structure of Anchor

1) Anchor effect

The anchor effect is evaluated by dividing the tension of the anchor in the vertical component and tangential component respect to the sliding surface. The effect of the vertical component is called tight effect and the effect of tangential component is called retention effect.

a) Tight effect

The effect of tight is something that increases the frictional resistance due to the vertical component of anchor force over the sliding surface. The tension of the anchor would be transmitted from the structure of the anchor receiving pressure to the sliding surface, if the moving mass was rigid. However, actual moving mass is generated decay caused by compression and consolidation. Therefore, in cases where the mass is moving clay colluvium or weathered rock with many cracks, often cannot be expected effects of tight. Likewise, no effects can be expected if the moving mass is thick and sliding surface is deep.

b) Retention effect

The retention effect is one that retains the sliding of the moving mass through the tangential component of the anchoring strength on the sliding surface. The effect of retention can be expected regardless of the geology of the moving mass. In many measures in mass movements, anchors are executed near the top, waiting retention effects.

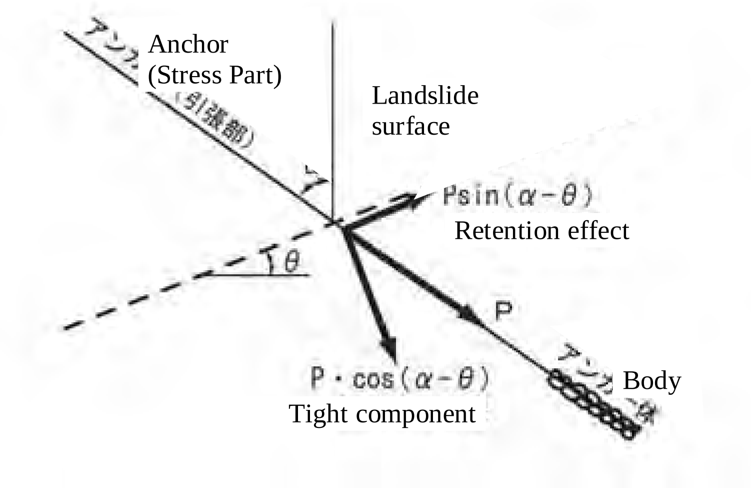


Fig. 4.18 Anchor functions

2) Anchor distribution

Anchor distribution is defined considering the following aspects:

i. Basically, the anchor is distributed near the toe of the mass movement.

ii. As anchor tilt angle the range of ±5° regarding the horizontal is avoided.

iii. If possible the direction of the anchor is matched with the direction of mass movement.

iv. In many cases spaces between anchors take 2 to 4m.

República Democrática de Timor-Leste

Ministério das Obras Públicas

Direcção Geral das Obras Públicas

Direcção Nacional de Estradas, Pontes e Controlo de Cheias

Matadalan Estrada — Protesaun Rai Halis — Investigasaun Rai Halai

Road Guidelines — Slope Protection — Landslide Investigation

Faze EFM

Atensaun

Documentos ida ne'e laos Padraun Nacional Timor Leste. Dokumentus ne'e sei fahe hodi halo revisaun no fo komentario. Materia ida ne bele halo mudansa no sein fo hatene no la refere hanesan padraun nacional.

Benefisiariu ba esbosu hetan convida atu submite, sira nia komentario, notifikasaun kona ba sira nia direitu ba patent nebe relevante no sira hatene no fornese apoio ba dokumentasaun.

Tipu Dokumentu: Spesifikasaun Teknikaocument
Subtipu Dokumentu:
Faze Dokumentu: (EFM) Esbosu Final Matadalan
Dokumentus ho lingua: TDT

Ministério das Obras Públicas
Direcção Geral das Obras Públicas
Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
Enderesu: Avenida da Restauração, Rai Kotuk, Comoro, Dili, Timor-Leste
Nu. Kontaktu: +670 3311408

Konteudu

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REPÚBLICA DEMOCRÁTICA DE TIMOR-LESTE
MINISTÉRIO DAS OBRAS PÚBLICAS
GABINETE DO VICE-MINISTRO
Av. Nicolau Lobato, Mandarin, Dili, Timor-Leste

Prefasiu

Iha interese ba harii ho qualidade as no ekonomikamente viabiliza infrastrutura hodi servi nasaun, matadalan ida ne'e atu dezennu investigasaun rai halai nebe prepara ona husi JICA Projeito Desenvolvimento Kapasidade ba Servisu Estrada iha República Democrática de Timor-Leste (CDRS) nebe iha kolaborasaun ho Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC), Ministério das Obras Públicas. Ami hakarak hato'o agradese ba JICA ba kontinua suporta.

Setembru, 2019

Eng. Nicolau Lino Freitas Belo
Vice-Ministro das Obras Públicas
Ministério das Obras Públicas

Prefasiu husi JICA

Japan International Cooperation Agency (JICA) halao ona projetu kooperasaun téknika ida ba desenvolvimento kapasidade kona ba servisu estrada, nebe'e hanaran CDRS, nune atu fasilita DNEPCC jere no halo manutensaun ba infra-estrutura estrada bazea ba actividade soscial no ekonomiku. Ba ida-ne'e nia rohan, JICA despasa ona ekipa espesialista sira husi fulan-Marsu tinan 2016 to'o fulan Dezembru tinan 2019. Hanesan rezultadu servisu kolaborasaun hamutuk ho DNEPCC, matadalan ida ne'e ba dezennu investigasaun rai halai ne'ebe finaliza tiha ona. Ha'u espera katak matadalan ida-ne'e sei kontribui ba dezenvolvimentu infra-estrutura no manutensaun, no valorizasaun relasaun belun di'ak entre nasaun rua.

Ikus liu, ha'u hakarak hato'o ha'u-nia apresiasaun sinceriamente ba funcionariu governu República Democrática de Timor-Leste nia ho equipa peritu.

Setembru, 2019

Masafumi NAGAISHI
Representante Chefe Gabinete JICA iha Timor-Leste
Japan International Cooperation Agency

Agradesimentu

Projetu ba Desenvolvimentu Kapasidade Servisu Estrada iha República Democrática de Timor-Leste (CDRS) hakarak atu fó-agradese ba parte hotu-hotu ne'ebé envolve an hodi prepara matadalan.

Apoia projetu ne'e, ofisial husi (eis) Ministério de Desenvolvimento e de Reforma Institucional: M. R. M. Cruz, J. L. C. C. P. Mestre and J. Santos; no ofisial husi Ministerio Obras Publiku: C. M. Henrique no especialmente ba R. H. F. Guterres; hodi rekonese.

Durante halo preparasaun ba dokumentus ida ne'e hetan kontribuisaun husi ofisial DNEPCC: M. R. C. Monteiro, J. P Amaral, J. M. G. Sousa, J. G. Carlvalho, I. M. L. Gutteres, N. Lobato, L. Luis, M. Soares, J. L. Kehy; no Organizasaun Internasional Trabalho ou International Labour Organization's (ILO) nudar ekipa asistente teknika ba apoiu programa Desenvolvimento Estrada (R4D-SP): A. O. Asare, K. H. Myaing, S. Done, U. Yat, L. Thakuri; hodi rekonese.

Komentariu:

Sei apresia tebes ba komentariu nebe positivu ba posibilidade inkorporasaun ba edisaun tuir mai. Favor fo komentario no sugestaun ba iha enderusu tuir mai ne'e.

Direcção Nacional de Estradas, Pontes e Controlo de Cheias (DNEPCC)
Enderesu: Avenida da Restauração, Rai Kotu, Comoro, Dili, Timor-Leste
Nu. Kontaktu: +670 3311408

Introdusaun

Timor-Leste hanesan nasaun ne'ebe montanhoso,nune'e estrada prinsipal barak liu mak kontruidu korta/koa foho ninin. Maibe, tamba kondisaun topografiku, susar tebes atu konstroe corta taludes ho gradiente ne'ebe satabel, no taludes falla, no taludes falla akontese iha fatin barak. Aleinde ne'e, rai halai, ne'ebe bo'ot liu fali taludes falla mos bele estraga estrada iha Timor-Leste.

Rai halai mak fenomena movimentu rai ho skala bo'ot, no ninia movimentasaun neneik, nune'e mak halo defisil atu rekonnese sira nia ekzistensia iha faze inisiu kona ba aktividade. Aleinde ne'e, bainhira sira komesa bo'ok an, defisil tebes atu prevene sira nia movimentasaun. Tanba ne'e, metodu ne'ebe diferente husi protesaun taludes jeral mak presija tebes ba investigasaun no kontramedida kona ba rai halai.

Iha kapitulu ida ne'e, rezultadu husi investihasaun iha rai halai Aituto iha Munisipiu Ainaro ne'ebe, halo husi Projetu CDRS, ne'ebe mak introdus ezemplu ida ba investigasaun rai halai.

Matadalan Estrada — Protesaun Rai Halis — Investigasaun Rai Halai

1 Saida mak rai halai?

1.1 Defenisaun kona ba termus “rai halai”

Iha nasaun barak iha mundu, termus “rai halai” mos uza iha dezastre ba taludes oioin. Iha matadalan, termus “rai halai” jeralmente refere ba fenomena movimentasaun masa atu kontinua forma bloku no nia muda ho neneik los (0.01 ~ 10 mm/day). Aleinde ne'e, karakteristika ida kona ba movimentasaun masa mak inklinasaun husi anglu taludes ne'ebe mak relativamente ninia anglu kiik oan (entre 5 - 20 graus) kompara ho taludes falla sira seluk. Aleinde ne'e, iha situasaun balun, movimentasaun ninia velosidade sae no dezelvolve ba iha kollapsu ne'ebe bo'ot liu tan. Karakteristika rekursu balun jeralmente hatudu hanesan Figura 2.

1.2 Mekanismu

Mekanismu movimentasaun massa mak konsidera hanesan tuir mai ne'e.

1) Wainhira be'e subternea nia mosu,balansu entre forsa deslizamento no forsa resistensia rahun balance between sliding force and resistance force breaks since pore water pressure rises and effective stress drops.

2) Estrada terraplenagem hanesan corte iha bloku ne'ebe halo movimentasaun iha ain hun ka aterru iha bloku ne'ebe halo movimentasaun iha leten ne'ebe rahun ninia balansu entre forsa deslizamentu no forsa resistensia.

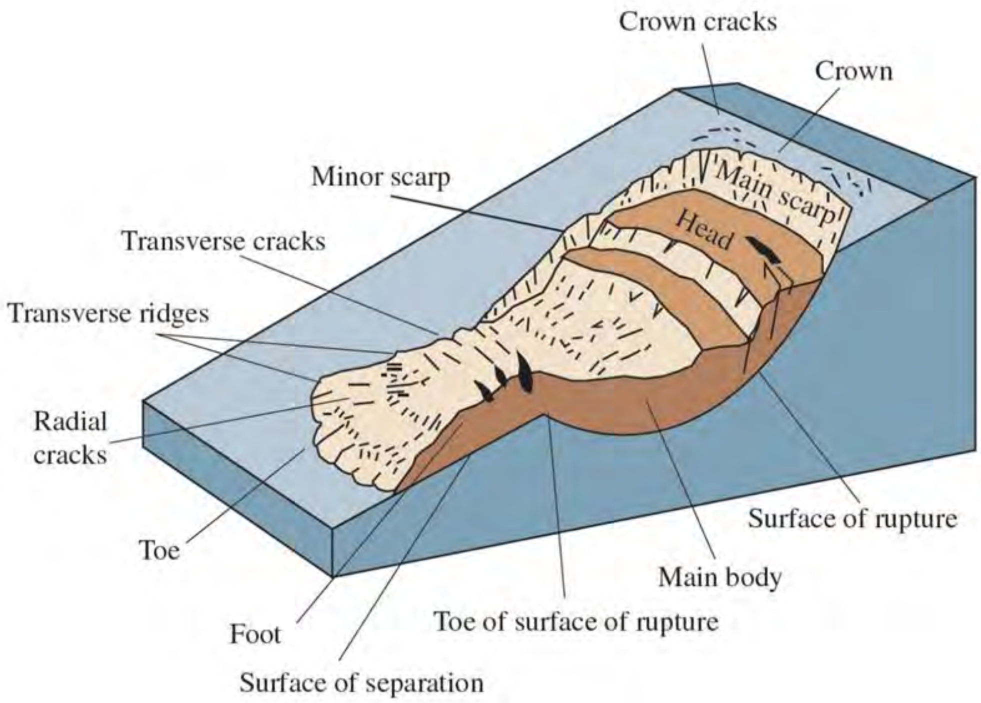

Figura 1 — Rai halai rotasional ne'ebe idealizado hatudu nomenclautura ne'ebe jeralmente ba markasaun parte rai halai.

2 Saida mak sinal avizu kona ba rai halai?

Hosi perspetiva kona-ba papél inspetór estrada, DNEPCC ne'ebé hanoin ne'ebé sinál atensaun tanba rai-halai hanesan fenomena ida ne'ebe bele hare. Tipiku fenomena mak hanesan apresenta tuir mai ne'e:

2.1 Nakfera

Jeralmente, Nakfera sira ne'e mak jeneraliza liu husi forsa trasaun ne'ebe besik liu ba iha koroa. Defisil tebes atu detekta nakfera nakfera iha area florestal, maibe se quando nakfera sira ne'e mak jeneraliza iha estrada nia superficie ka uma, inspector sira bele suspeita sedu fenomena rai halai.

Figura 2 — Nakfera iha estrada nia superficie no kabas (rai halai iha Sri Lanka)

A2-672

Figura 3 — Uma nakfera besik area rai halai (rai halai iha Sri Lanka)

2.2 Flexão Ai hun

Wainhira movimentasaun taludes liu husi rai halai mak akontese,ai hun sira sei sai dobradu relasiona recoperasaun ho diresaun loromatan. Iha kazu inklinasaun ai hun ne'ebe mak sae, bele asume katak movimentasaun dalaruma ativu hela.

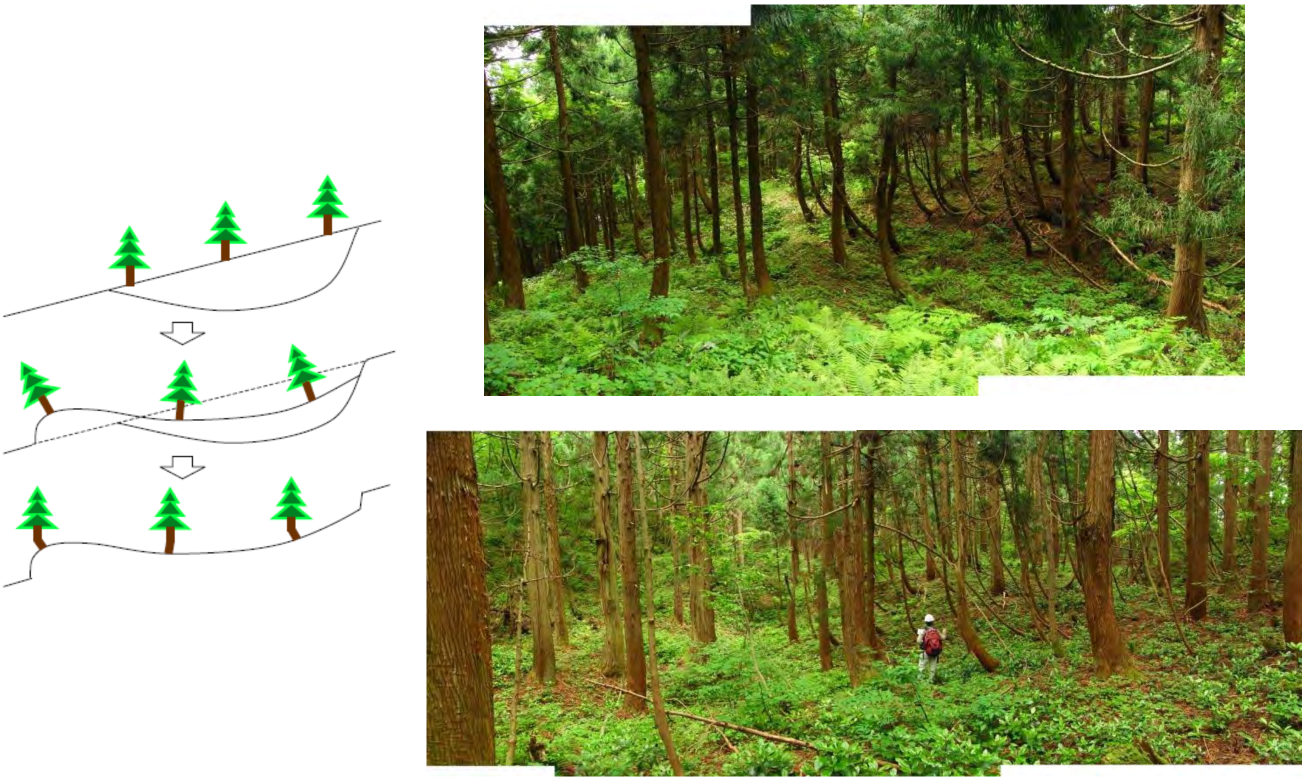

Figura 4 — Ai ne'ebe kleuk iha rai halai (rai halai iha Japaun)

2.2.1 Foka liu ba iha rai halai iha Aituto

2.2.1.1 Lokalizasaun rai halai iha Aituto

Rai halai iha Aituto lokaliza iha fronteira entre munisipio 3 mak hanesan Ainaro, Manufahi, Aileu, no Suco Aituto iha Administrativio Munisipio Ainaro nia okos. Aituto iha parte central husi foho íngreme ne'ebe ho ninia as bele to'o 2,000 m altitude.

Rai halai akontese iha altitude entre 1,700 m husi taludes sul ridgeline ne'ebe kontinua ba diresaun leste-oeste.

Figura 5 — Lokalizasaun Rai halai iha Aituto

2.2.1.2 Oinsa bele rekonnese rai halai iha Aituto

Durante halo obra ampliação ba estrada A05, akontese kolapsu iha corte de taludes, no eksistensia rai halai ho skala bo'ot ne'ebe identifika iha taludes nia kotuk. Relasiona ho fenomena hirak iha leten, obra ampliação suspende tiha.

Husi razaun hirak iha leten, levantamento geolojiku ho obra perfurasaun lansa. Perfurasaun hahu iha Novembro no completa iha inisiu Dezembro. Kaisa ba monitorizasaun ho inclinometer intala ona iha koak perfurasaun balun.

Figura 6 — Kolapsu relasiona ho corte de taludes

3 Grafiku investigasaun rai halai

Se fenomena rai halai ne'e hetan rekonesementu, importante tebes atu halo investigasaun ba kondisaun geologikal, skala rai halai no nia aktividade. Rezultadu investigasaun, kontra medida ne'ebe mak propoin.

Grafiku ida ne'e hatudu oinsa halao investigasaun rai halai iha Aituto. Ba investigasaun rai halai sira seluk, sei efektivu liu wainhira operasaun sira halo tuir procedimentu hirk ne'e.

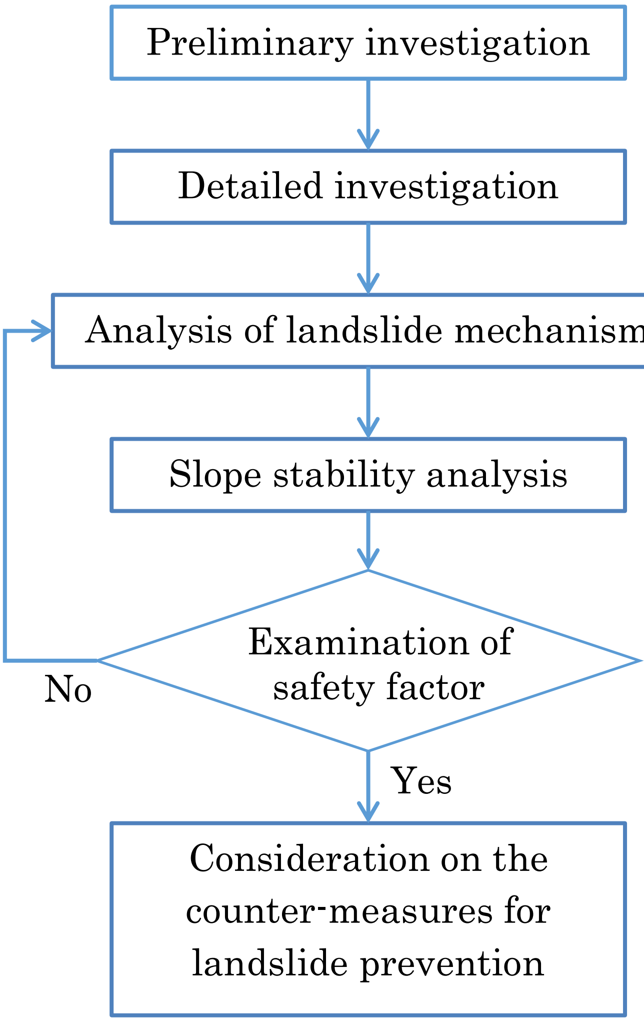

Figura 7— Grafiku investigasaun rai halai

4 Investigasaun preliminár

Metodu investigasaun hirak ne'e la hanesan depende ba skala bo'o rai halai ne'ebe deskreve iha leten. hanesan rai halai rotasional, rai halai translasional, bloku ne'ebe muda a'an, no rai halai seluk tan.

Investigasaun topográfiku ne'e nia objetivu mak atu komprende assuntu tuir mai ne.

1) Karakteristika topografiku en jeral kona ba lokal taludes

2) Hatene karkteristika topografiku kona ba lokal taludes

3) Halo estimasaun kona ba estrutura geolojiku rejional iha terennu

Grafiku mak hanesan hatudu tuir mai ne'e.

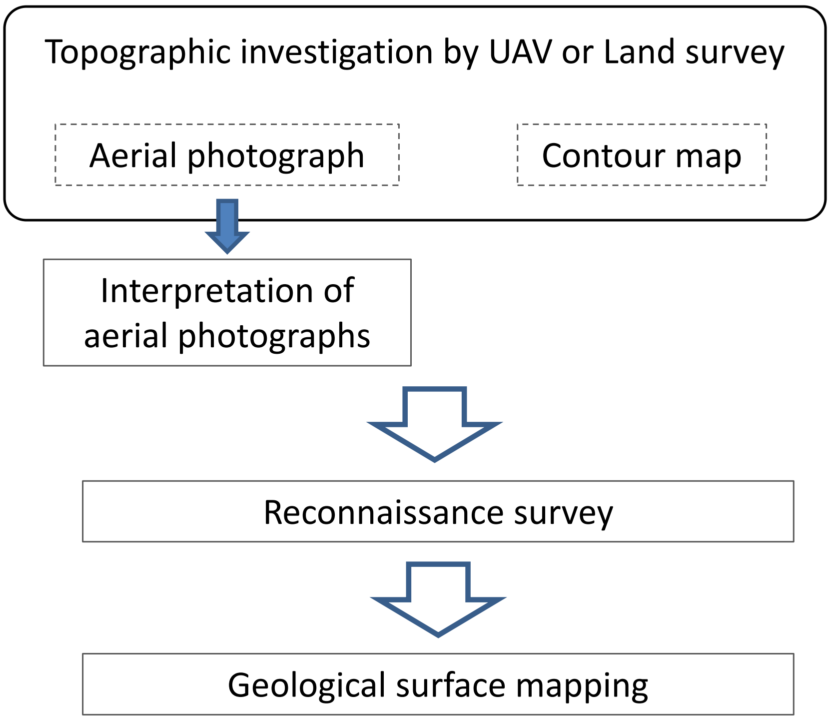

Figura 8 — Grafiku investigasaun preliminár

4.1 Investigasaun topografiku

Objectivu husi investigasaun topografiku ida ne'e mak atu hetan informasaun topografiku. Produtu principal mak mapa kontur no fotografiku aerea. Linna kontur ne'ebe forma liu husi pontu ne'ebe gropu ne'ebe ninia as hanesan. Kontur map mak dezennu ne'ebe reprezenta topografiku husi rejiaun balun liu husi linna kontur kona ba intervallu ne'ebe fikxu ona.

Figura 9 — UAV (drone)

Eziste tipu 2 kona ba metodu investigasaun; Peskiza UAV (drone), peskiza rai. Peskiza rai ne'e mak metodu maun de obra utiliza total station no medisaun GNSS. Peskiza UAV mak utiliza mediasaun UAV, no teknolojia foun atu hetan informasaun topografiku. Vantajem husi metodu UAV mak efisiensia halibur presizaun no dadus iha area oin-oin. Iha parte seluk, susar tebes atu foti dadus iha sirkuntansia area florestal ne'ebe impede superficie topografiku. Padraun spesifikasaun no metodu operasaun kona ba UAV iha Aneksu A.

4.1.1 Foka liu ba iha rai halai iha Aituto

4.1.1.1 Fotografia aerea

Ezemplu fotografia aerea ne'ebe foti husi UAV mak hanesan hatudu iha Figura 14. Resolusaum imajem husi satelite ortho mak 3.85 cm/pixel no, modelu elevasaun digital orijinal (DEM) atu bele jeneralida kontur map mak 15.4 cm.

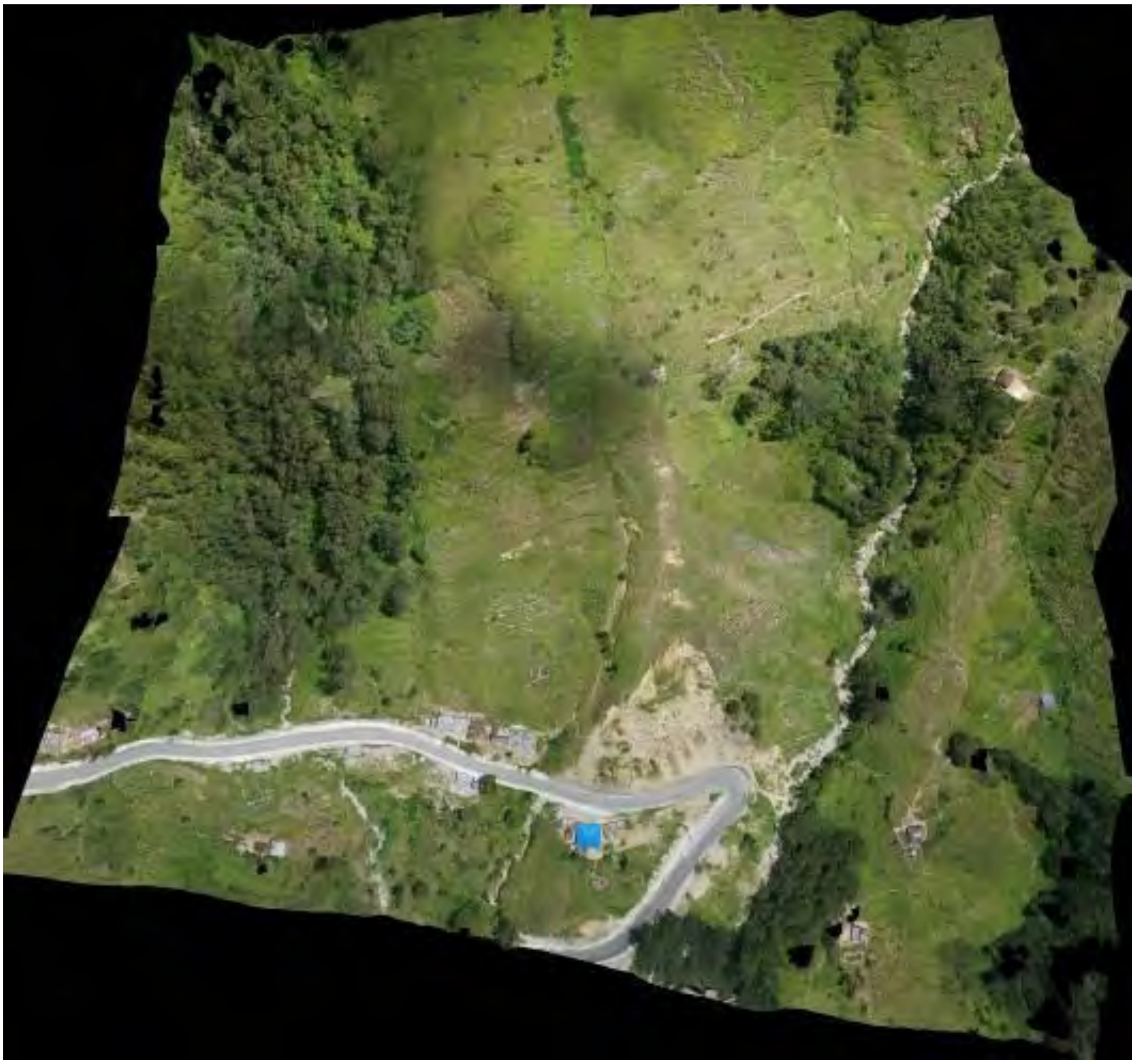

Figura 10 — Fotografia aerea foti husi UAV (Drone)

4.1.1.2 Kontur map

Bazeia ba rezultadu investigasaun topografiku, kontur map bele halo ona.

Linna contour mak linna ne'ebe forma husi pontus groupu ne'ebe mak ninia as hanesan. No mapa kontur mak representa topografiku husi rejiaun balun liu husi linna kontur husi interval ne'ebe fiksu ona. Mapa kontur mos utiliza hodi dezenna seksaun transversal ba geolojiku ninia perfil no seksaun topografiku ba analiza stabilidade taludes nian.

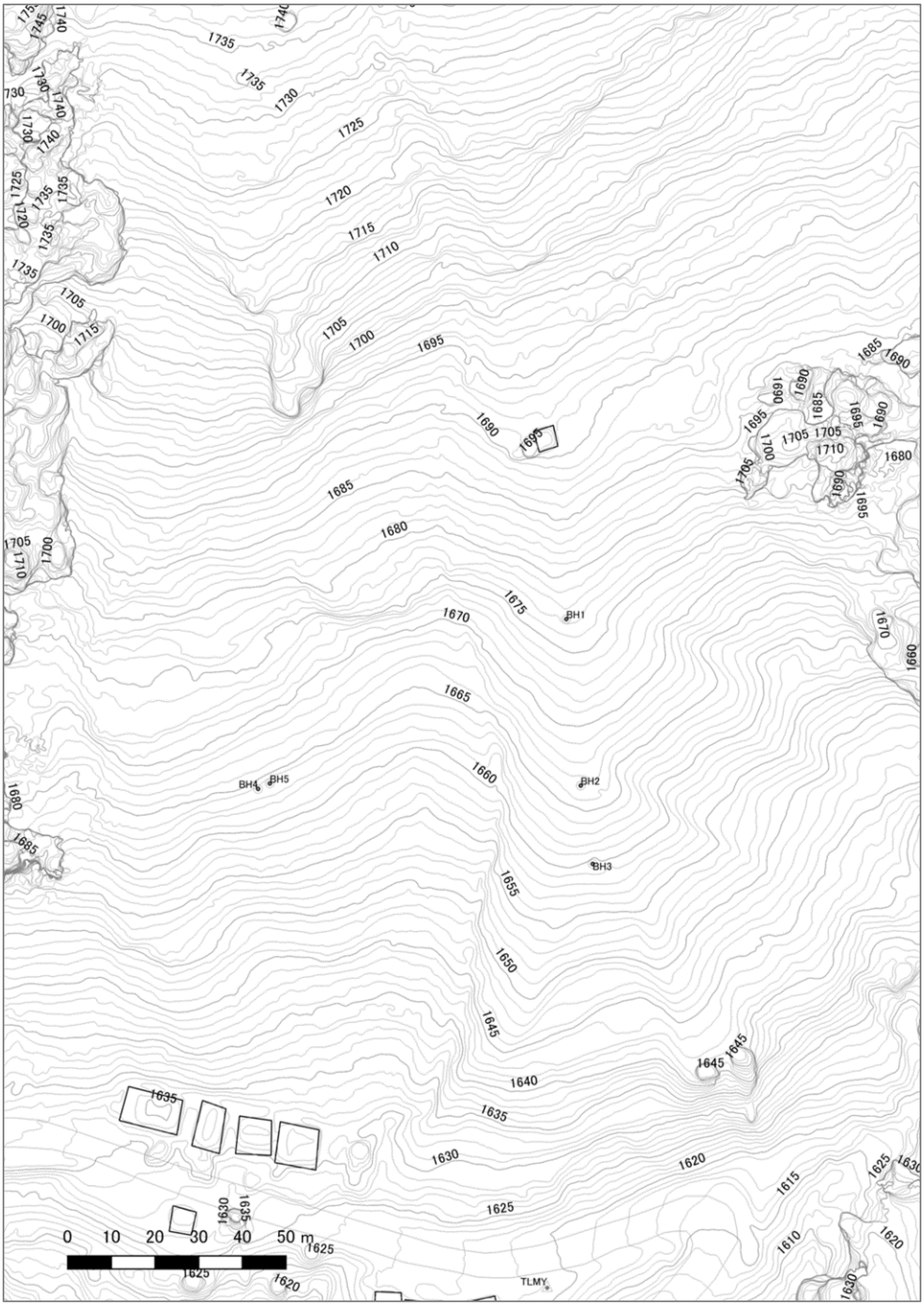

Figura 11 — Mapa kontur ne'e kria utiliza fotografia aerial ne'ebe foti ho UAV

4.2 Intepretasaun fotografia aerea

Bloku rai halai ninia forma bele identifika liu husi vizualizasaun stereoscopically ne'ebe monta ona fotografia aerea ne'ebe foti husi pontus ne'ebe besik. Formas husi bloku rai halai ne'ebe identifika ona tenki marka/ trasa iha mapa kontur no utiliza atu konsidera ba planu investigasaun geolojiku.

Figura 12 — Visualizasaun stereoscopic husi par ida husi fotografia aerea

4.2.1 Foka liu ba iha rai halai iha Aituto

Bazeia ba intepretasaun stereoscopic husi fotogrfia aerea, traço esbosu rai halai preparadu ona. Bazeia ba mapa traçado, plano ba invesigasaun geolojikal sei hahu.

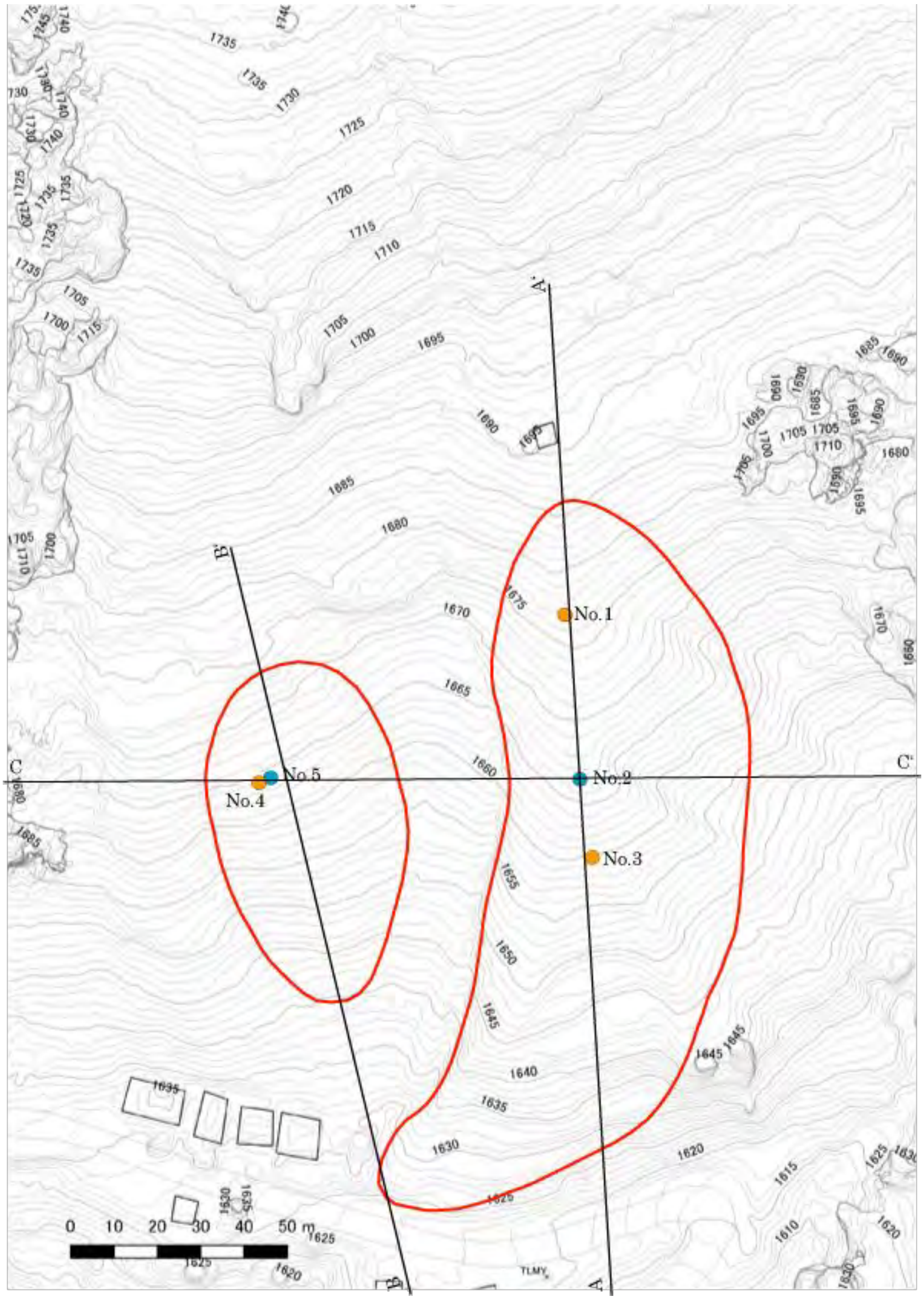

Figura 13 — Traço outline bloku rai halai nian ne'e intepreta tiha ona ho fotografia aerea

4.3 Peskiza kona ba rekonnesementu

Peskiza kona ba rekonnesementu halao kedas iha etapa inisiu investigasaun. Objektivu husi peskiza kona ba rekonnesementu mak atu

1) Komprende ekstensaun aerea no diresaun jeral movimentasaun rai halai

2) Halo avaliasaun kona ba jeolojia no estrutura geolojiku

3) Estima kauza deslizamentu

4) Prever movimentasaun iha futuru

4.4 Mapeamentu superficie geolojika

Mapeamentu superficie jeolójiku hala'o ona utiliza mapa contour atu komprende kona-ba geologia no estrutura jeolójika. Scarps, nakfera no karakteristika sira seluk inclui iha rai halai ne'e rejistu hotu ona iha mapa laran.

4.4.1 Foka liu ba iha rai halai iha Aituto

4.4.1.1 Kondisaun geolojiku iha Terrenu

4.4.1.1.1 Depósitos de tálus

Supeficie iha terrenu ne'e cobre ho talus depositos. Depositos sira ne'e kompstu husi gravel limestone ho medida oioin, no rai mamar castanho ne'ebe prense iha gravel nia laran.

Figura 14 — Afloramento dos depósitos do tálus

4.4.1.1.2 Baze fatuk

Bazeia ba observasaun afloramento, kondisaun geolojiku Rai halai ne'ebe analiza tiha ona. Baze fatuk iha terrenu kompostu husi alterasaun limestone ninia dalas no mudstone ninia dalas. At the outcrop, strata of mud stone are often sheared into fragile layers. Dalas mamar hirak ne'e tenke kompostu husi superficie arrebatmento.

Figura 15 — Afloramento fundamento fatuk

4.4.1.1.3 Zona de cisalhamento

Iha kantu sudoeste Bloku A, mudstone mamar afloramento iha dalan. Strata hirak ne'e konsidera fratura liu husi failansu.

Figura 16 — Afloramento da zona cortada

4.4.1.1.4 Rezultadu husi mapeamentu superficie geolojika halo resumo tiha ona hanesan mapa rota.

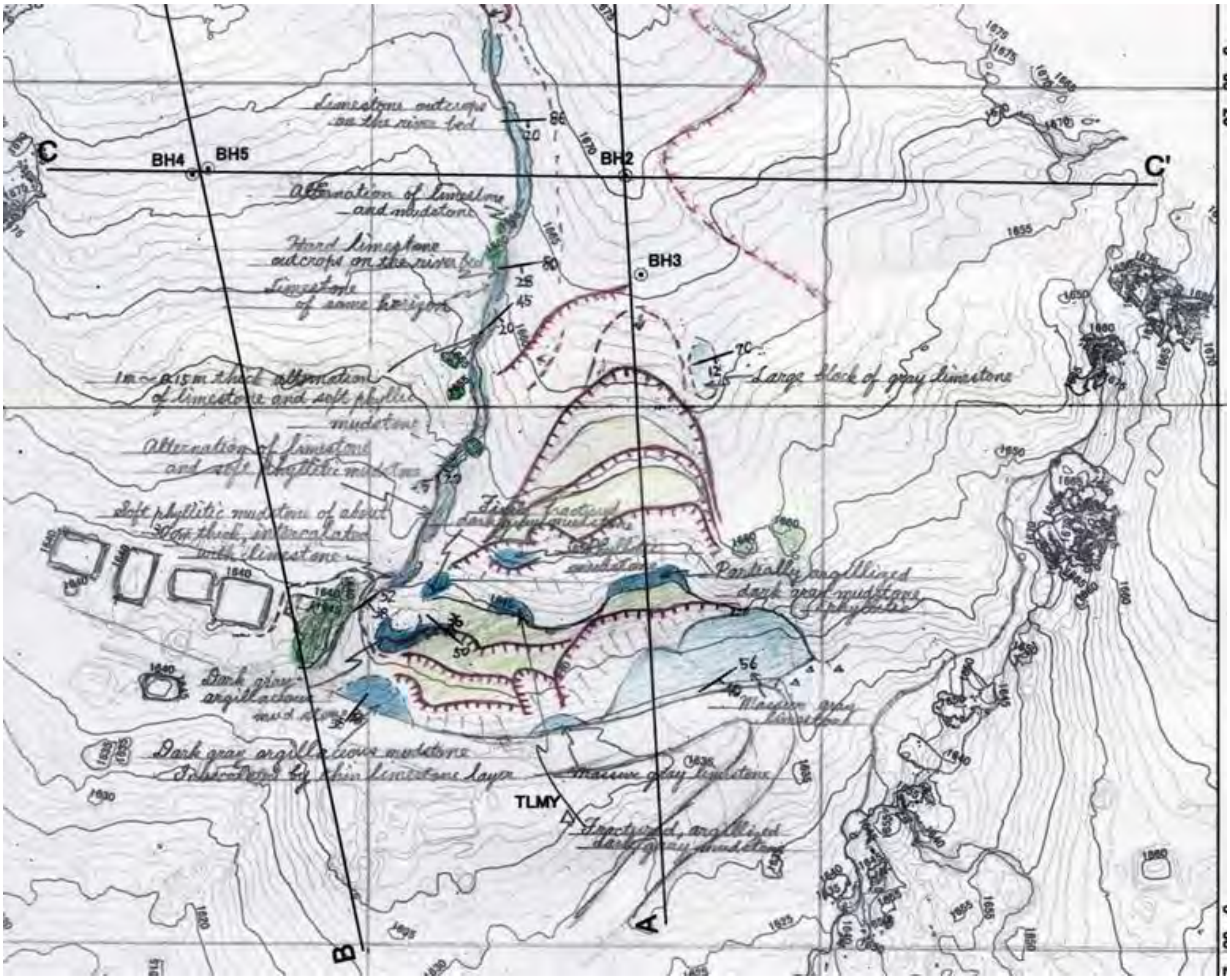

Figura 17 — Rota mapa rai halai iha Aituto

5 Investigasaun detalladu

Bazeia ba rezultadu invetigasaun preliminar, planu ba investigasaun detalladu elabora ona. Investigasaun detalladu tenki halao liu husi selesiona metodu investigasaun no instrumentu ne'ebe apropriado.

5.1 Metodu simples hodi sukat movimentu

Iha kazu kontese tensaun nakfera ruma ne'ebe mak observa iha terrenu, metodu tuir mai sei efektivu liu atu bele hatene rai nia movimentasaun.

Diriji estaka tensaun nakfera tuir orientasaun movimentasaun. Then attach horizontal board to the stakes, and saw through the board. Any movement across the tension crack can be determined by measuring the space between the sawed portions of the board.

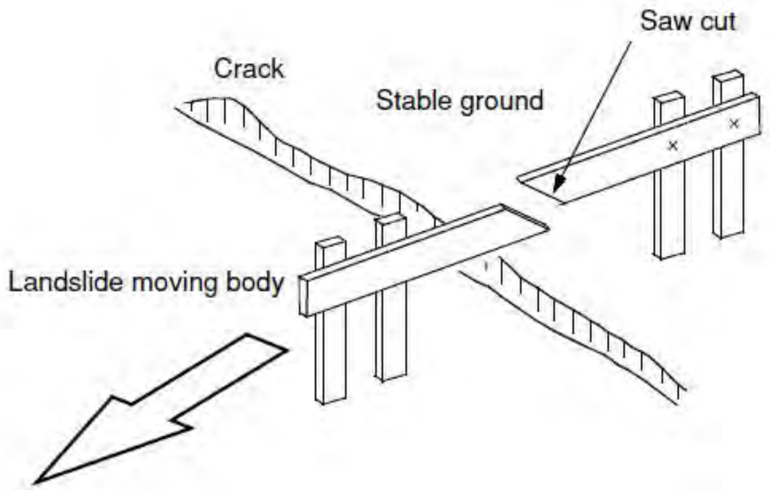

Figura 18 — Metodu simples atu sukat movimentasaun

5.2 Obra perfurasaun

Perfurasaun obra sira hala'o ona atu hetan informasaun jeolójika kona-ba subterráneu. Profundidade kona ba superficie raptura nia mak hanesan asume tiha ona bazea ba observasaun amostrajem prinsipal ne'ebe recupera tiha ona. Espesifikasaun tekniku mak hanesan aneksa tiha ona hanesan Aneksu 2.

Informasaun tuir mai mak hanesan rejistu tuir ligs perfurasaun:

- Geolojiku no deskrisaun rai
- Kor, dureza no litologia
- Grau intemperismo nia
- Alterasaun no fratura
- Strike and dip of bedding and joints
- Nivel inisiu be rai okos ne'ebe estabele
- Taxa ba rekuperasaun prinsipál.

Figura 19 — Amostrajem prisipal la pertubada simples iha movimentasaun massa

5.3 Komfirmasaun kona ba superficie raptura liu husi medida utiliza inclinometer

Atu detekta deslokamentu kona ba massa seslizamentu, monitoriza ho inclinometer mak hanesan instrumentu ne'ebe util. Measurement the inclination of casings with the inclinometer should be performed periodically, and the cumulative displacement of the casing should be analysed to detect the depth of the surface of rupture.

Matadalan ba instalasaun inclinometer nia kobertura mak inerente nu'udar Aneksu 3 no Aneksu 4.

Manual ba iclinometer no logger mak inerente nu'udar Aneksu 3 no 4 Aneksu.

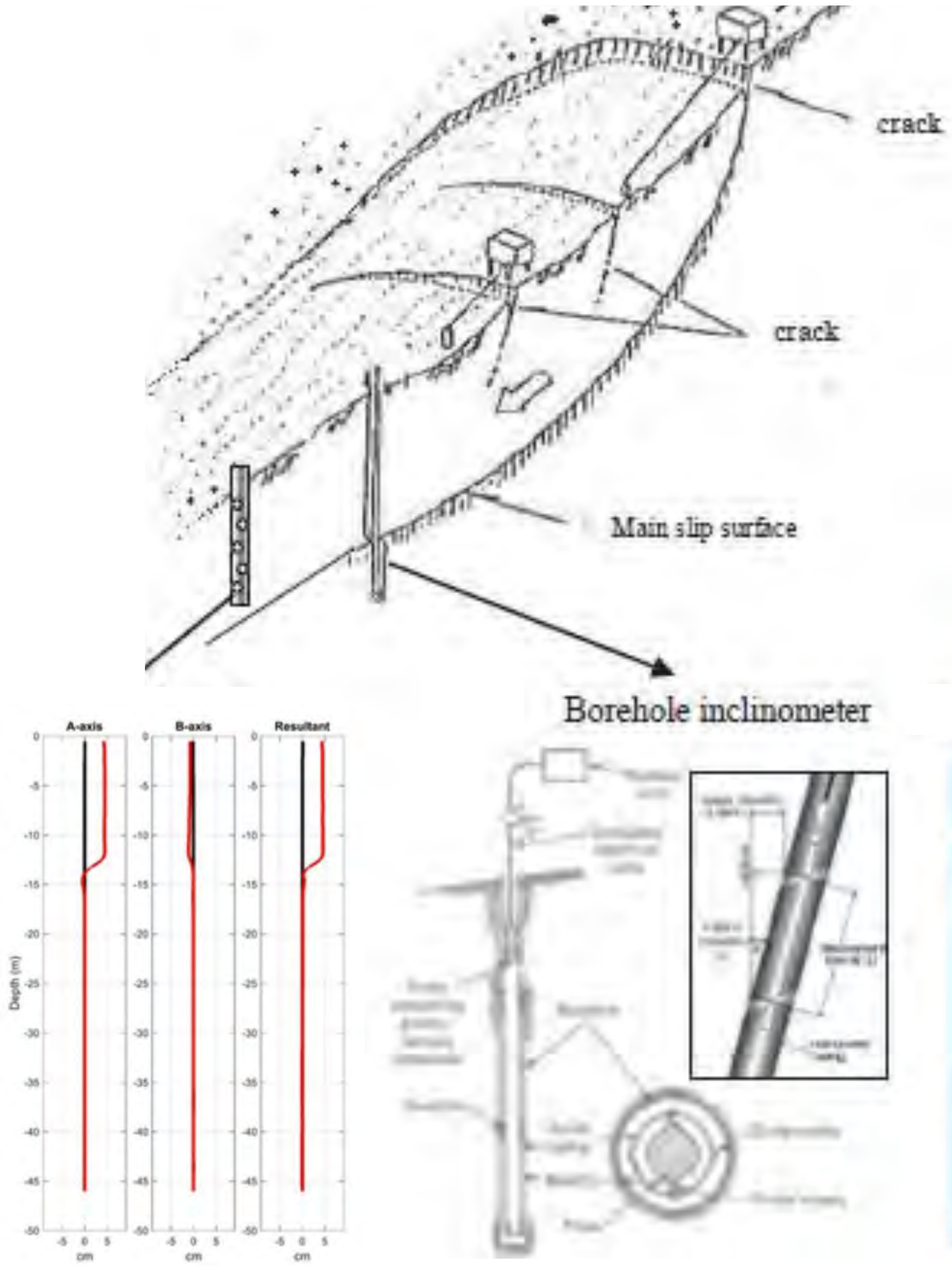

Figura 20 — Imajem jeral ba inclinometer

5.3.1 Foka liu ba iha rai halai iha Aituto

5.3.1.1 Registro kona ba inclinometer

Inclinometer bele halao iha perfurasaun Nu.1, Nu.3 no Nu.4. Nivel be iha rai okos mos bele observa iha perfurasaun Nu.2 no Nu.5.

Figura 21 — Inserção da sonda do inclinômetro nas carcaças

Figura 22 — Lee kona ba valor husi inklinasaun husi sonda ho logger

Dadus perfurasaun inclinometer Nu.1, Nu.3 no Nu.4, ne'ebe mak hatudu iha Figura 26, 27 no 28.

Iha perfurasaun Nu. 1, iha neba oha sinal deslokamentu iha profundidade tolu (hare iha Figura 26). No caso ida husi sinais hirak ne'e sei rekonnese claramente, ruptura ninia superficie husi seksaun transversal tenki halo revizaun.

Iha perfurasaun Nu. 3, iha ne'eba mak sinal deslokamentu iha profundidade 4.0 m (hare iha Figura 26). Tamba ne'e, atensaun ho kuidadu sei presiza liu iha futuru. Atualmente, la iha sinal deslokamentu ne'ebe bele hare iha perfurasaun Nu. 3 (refere Figura 28).

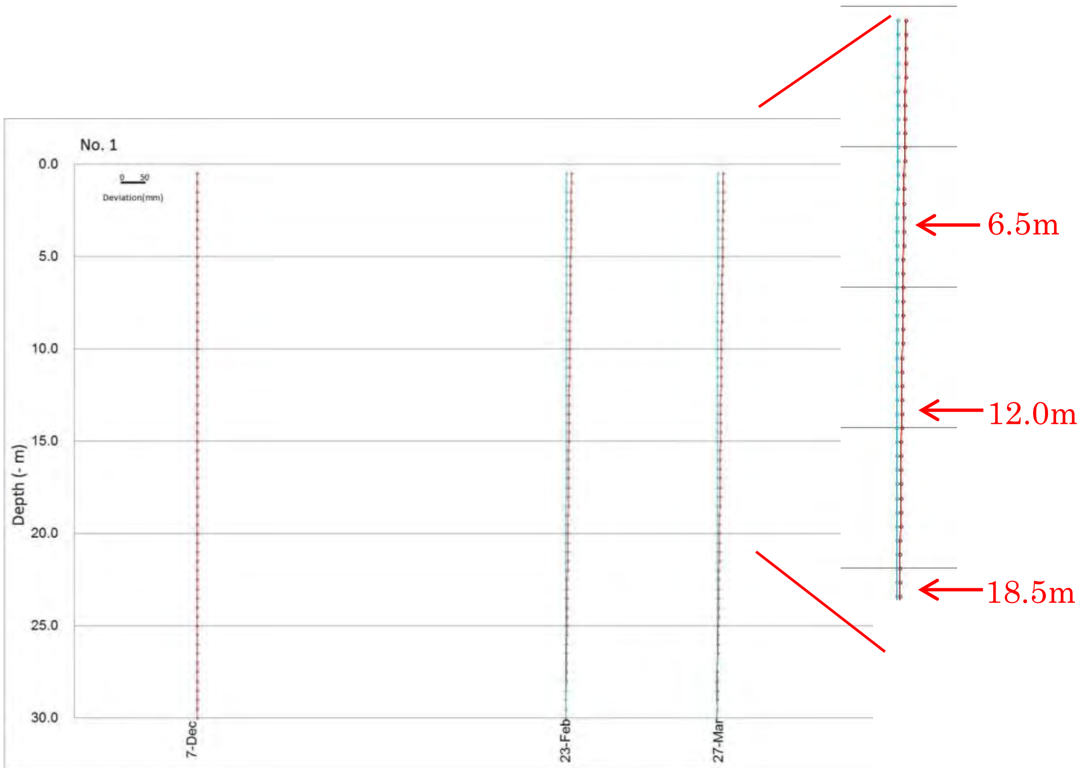

Figura 23 — Registro kona ba inclinometer ba perfurasaun Nu. 1

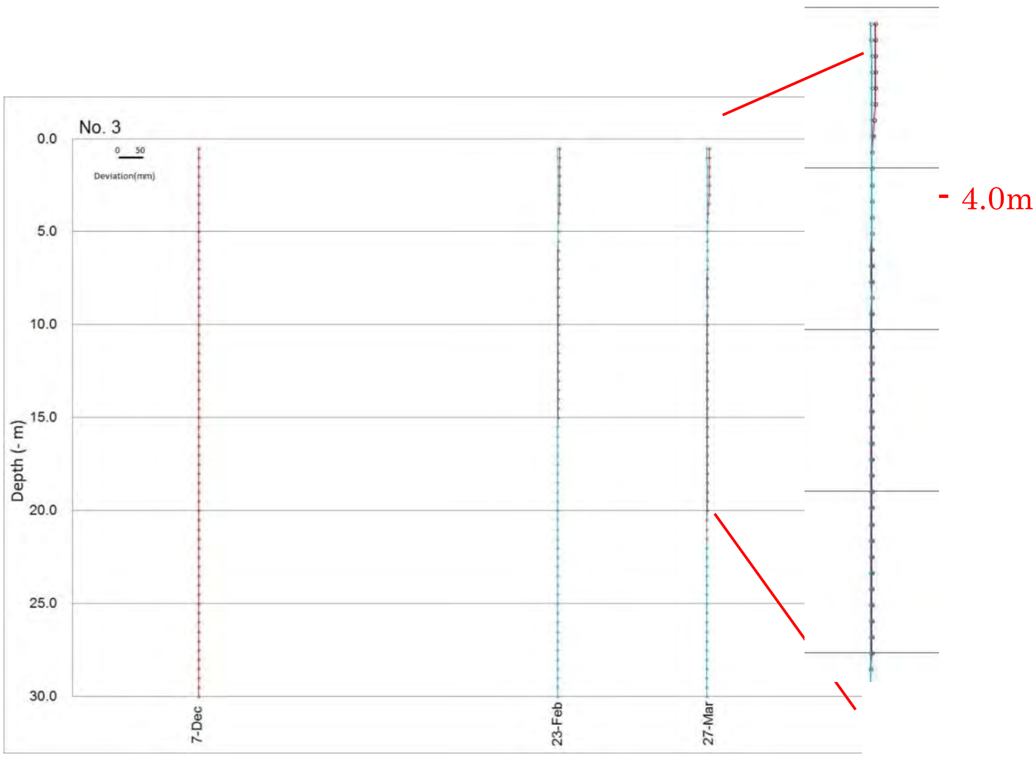

Figura 24 — Registro kona ba inclinometer ba perfurasaun Nu. 3

6 Analiza mekanismu kona ba rai halai

Bazea ba rezultadu investigasaun, kondisaun geolojiku rai halai sira nia sumariu eksekutivu, no mos ninia mekanismu husi deslizamentu ne'ebe analiza tiha ona.

6.1 Dezenvolvimetu perfil Jeolojiku

Bazea ba mapa kontur, seksaun transversal ba perfil jeolojiku no seksaun topografiku ba estabilidade taludes analiza tiha ona.

6.1.1 Foka liu ba iha rai halai iha Aituto

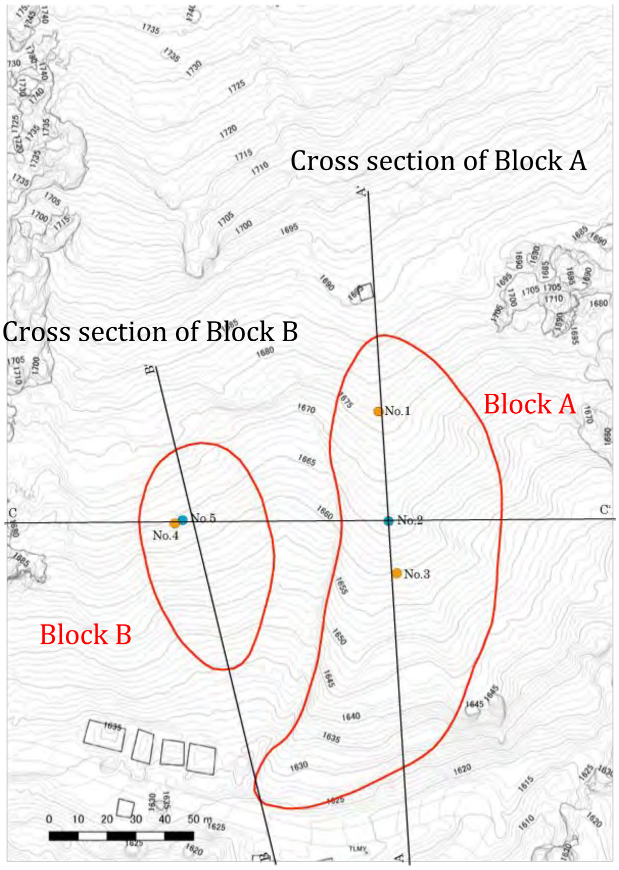

Figura 25 — Linna seksaun transversal kona ba figura tetuk

6.1.1.1 Seksaun transversal geolojika Bloku A

Iha besik rai halai Aituto fundamentu fatuk nian konsiste hui alterasaun dalas limestone no dalas mudstone. Ao longo superficie fundamentu fatuk nian, fatuk sira alterada husi intemperismo, nune parte hirak ne'e defini hanesan zona intemperizada. Iha zona intemperizada ida ne'e, strata kon ba mudstone mak cisholamento dalas ne'ebe frágil, no nakfera aberta dezenvolve iha dala limestone.

Superficie ruptura nian asume besik ba iha zona intemperizada. Circulasaun ruptura sira seluk mos asumi iha borda inferior bloku nian.

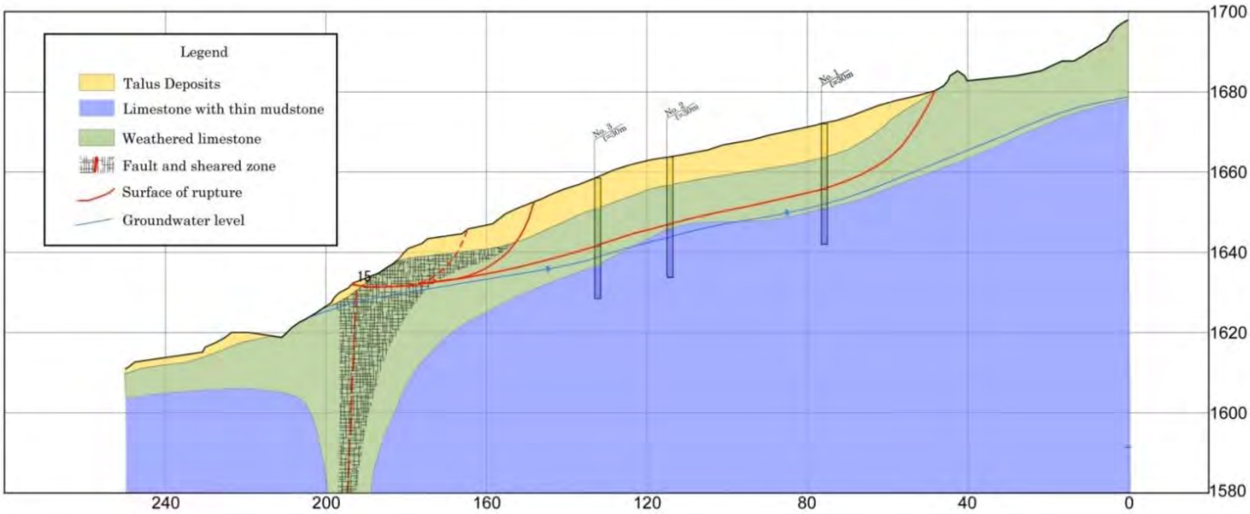

Figura 26 — Seksaun transversal jeolojika Bloku A

6.1.1.2 Seksaun transversal jeolojika Bloku B

Iha Bloku B, massa rai halai razu mak asume tiha ona iha dalas depozitu talus.

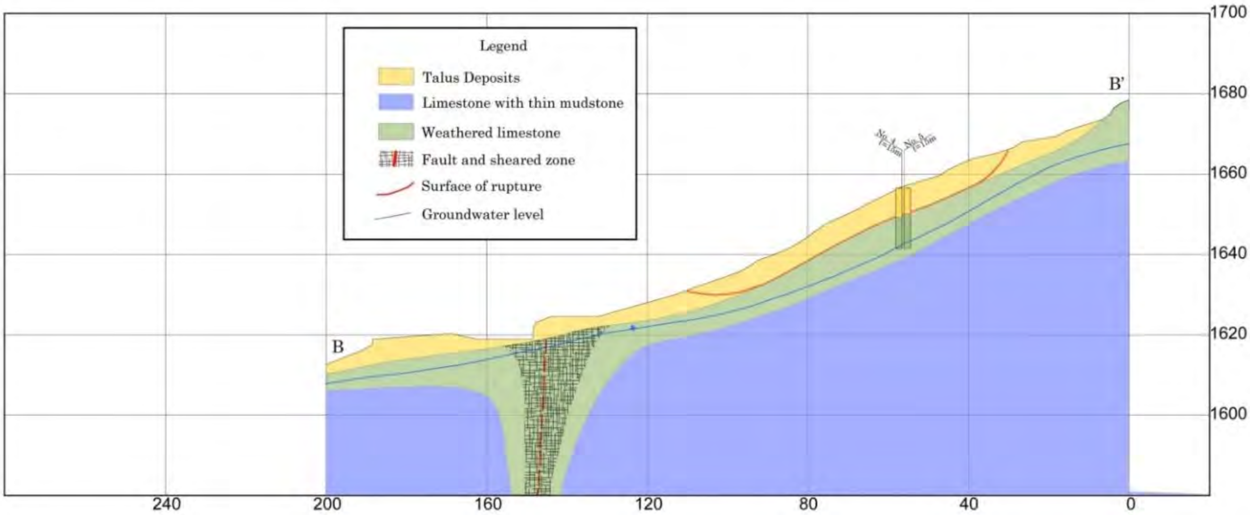

Figura 27 — Seksaun transversal geolojikal kona ba Bloku B

6.2 Analiza stabilidade Taludes

Estabilidade rai halai nian kalkula bazeia ba seksaun transversal. Konstanta ne'ebe uza hodi halo kalkulasaun hodi determina emperikalmente iha Japaun.

6.2.1 Equasaun ba kalkulasaun kona ba fator seguransa

Metodu Fellenius (1927) ne'ebe mak aplika ba kalkulasaun kona ba fatores seguransa.

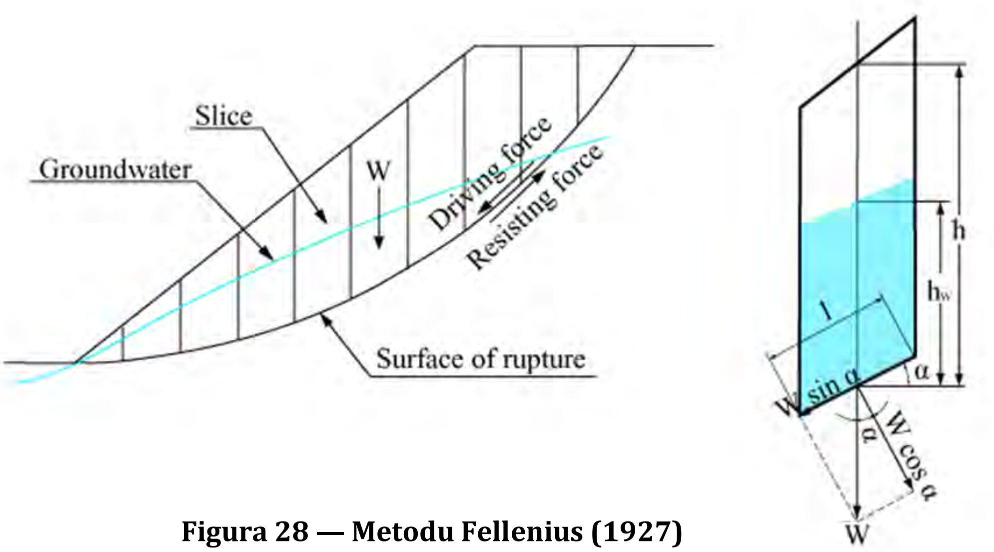

Figura 28 — Metodu Fellenius (1927)

Rai halai fahe ba varios fatia, no forsa resistensia no forsa motriz mak kalkula ba kada fatia.

$$Fs = \frac{Resistance\ force}{Driving\ force}$$

$$Driving\ force = W \sin\alpha$$

$$Resistance\ force = cl + (W\cos\alpha - ul)\tan\emptyset$$

Depois kalkulla proporsaun husi total forsa resistensia no forsa motriz ne'ebe mak hanesan fator seguransa (Fs).

$$Fs = \frac{\sum\{cl + (W\cos\alpha - ul)\tan\emptyset\}}{\sum W\sin\alpha}$$

c : $Cohesion\ of\ surface\ of\ rupture\ (kN/m^2)$

$\emptyset$: $Angle\ of\ Internal\ Friction\ of Surface\ of\ rupture\ (°)$

u : $Average\ pore\ water\ pressure\ of\ slice\ (kN/m^2)$

$u = h_w \cdot \gamma_w$

h_w : $Height\ of\ groundwater\ from\ surface\ of\ rupture (m)$

γ_w : $Unit\ weight\ of\ water\ (kN/m^3)$

l : $Length\ of\ surface\ of\ rupture\ of\ slice\ (m)$

W : $Unit\ weight\ of\ slice\ (kN/m)$

α : $Gradient\ of surface\ of\ rupture\ of slice\ (°)$

6.2.2 Foka liu ba iha rai halai iha Aituto

Prepara file excele ba analiza stabilidade taludes. File excel sira prepara ba analiza stabilidade taludes.

6.2.2.1 Seksaun transversal husi massa deslizamento ba analiza estabilidade taludes

Seksaun transversal husi Bloku A no Bloku B mak hanesan hatudu iha Figura 30 no 31.

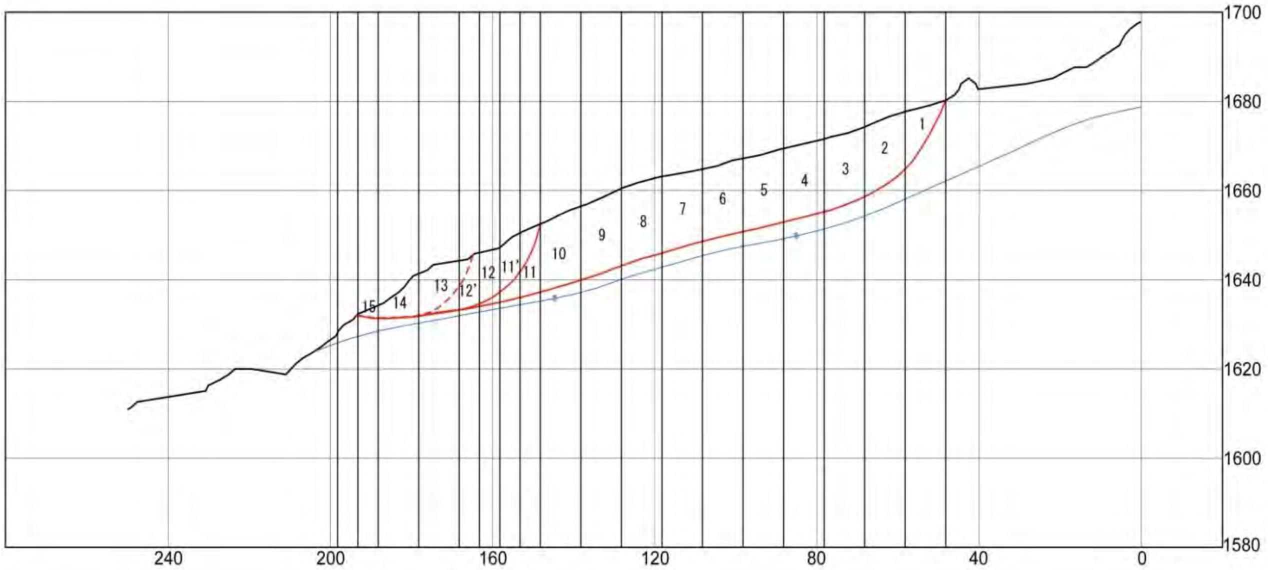

Figura 29 — Seksaun tranversal Bloku A ba analiza estabilidade taludes

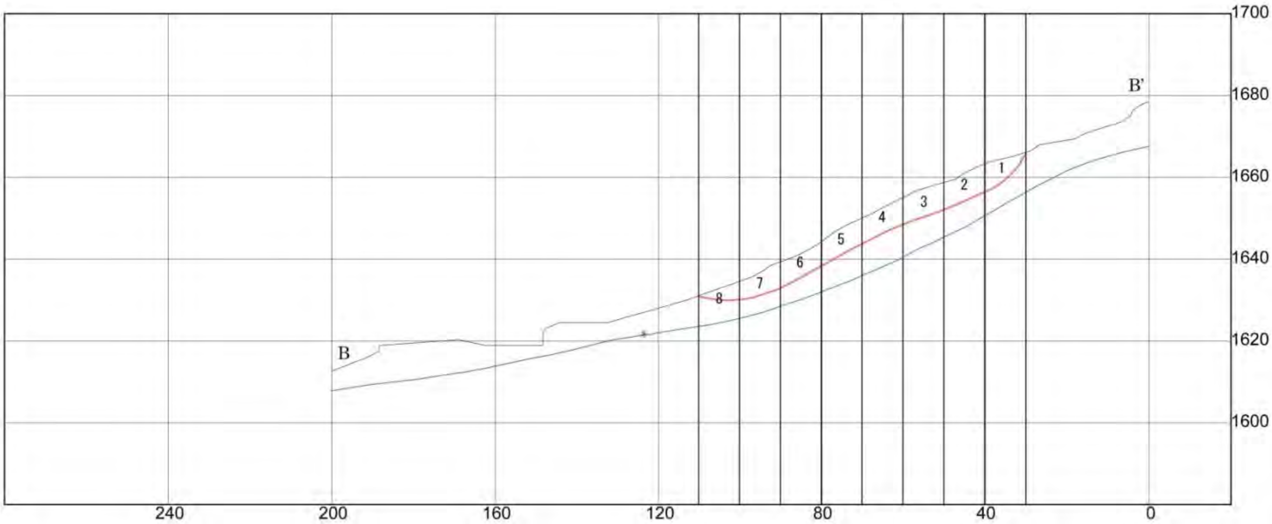

Figura 30 — Seksaun tranversal Bloku B ba analiza estabilidade taludes

Seksaun transversal ne'ebe uza ba analiza estabilidade taludes, superficie arebatamento ne'ebe asumi tiha ona bazeia ba observasaun husi perfurasaun nucleos. Iha kazu ba qualquee deformasaun sei detekta ho inclinometer, seksaun transversal idane'e tenki modifika.

Landslide	Section	Unit weight of earth γ(kN/m³)	Cohesion of surface of rupture (kN/m²)	Angle of Internal Friction of surface rupture (°)		Unit Weight of water(kN/m³)
Aituto	A-A'	γ= 20.00	c= 17.00	Φ= 12.50	Φ(radian)= 0.21817	$γ_w$= 10.00

Slice No.	cumulative distance (m)	Elevation (m) ground surface	Elevation (m) surface of rupture	Elevation (m) Ground-water	Width of slice b(m)	Average elevation (m) ground surface	Average elevation (m) surface of rupture	Average elevation (m) Ground-water	Area of slice A(m²)	Unit weight of earth γ(kN/m³)	Weight of earth W(kN/m)	Gradient of surface of rupture of slice α (radian)	Gradient of surface of rupture of slice α (°)	cosα	sinα	Wcosα	Wsinα
	0.0	1680.2	1680.2	1662.0													
1					10.0	1678.95	1672.50	1659.98	64.53	20.00	1290.50	0.99	56.96	0.5452279	0.8382879	703.617	1081.810
	10.0	1677.7	1664.8	1658.0													
2					10.0	1676.01	1661.74	1656.16	142.73	20.00	2854.60	0.55	31.57	0.8519946	0.5235507	2432.104	1494.528
	20.0	1674.3	1658.7	1654.3													
3					10.0	1672.96	1656.91	1652.91	160.52	20.00	3210.40	0.34	19.43	0.9430617	0.3326179	3027.605	1067.836
	30.0	1671.6	1655.1	1651.5													
4					10.0	1670.61	1654.08	1650.26	165.22	20.00	3304.40	0.21	11.95	0.9783177	0.2071099	3232.753	684.374
	40.0	1669.6	1653.0	1649.0													
5					10.0	1668.39	1651.81	1648.28	165.81	20.00	3316.20	0.24	13.71	0.9714985	0.2370456	3221.683	786.091
	50.0	1667.2	1650.6	1647.5													
6					10.0	1665.93	1649.59	1646.41	163.45	20.00	3269.10	0.20	11.30	0.9805995	0.1960218	3205.678	640.815
	60.0	1664.7	1648.6	1645.3													
7					10.0	1663.98	1647.28	1644.04	166.98	20.00	3339.60	0.26	14.66	0.9674444	0.2530835	3230.877	845.198
	70.0	1663.3	1646.0	1642.8													
8					10.0	1661.90	1644.50	1641.44	174.03	20.00	3480.70	0.29	16.38	0.959396	0.2820624	3339.370	981.775
	80.0	1660.6	1643.0	1640.1													
9					10.0	1658.51	1641.34	1638.58	171.68	20.00	3433.70	0.33	18.68	0.9473199	0.3202889	3252.812	1099.776
	90.0	1656.5	1639.6	1637.1													
10					10.0	1654.45	1638.46	1636.11	159.93	20.00	3198.50	0.23	13.39	0.9728052	0.2316249	3111.517	740.852
	100.0	1652.4	1637.3	1635.2													
11					5.0	1651.57	1636.69	1634.81	74.38	20.00	1487.55	0.23	12.92	0.9746828	0.2235922	1449.889	332.605
	105.0	1650.7	1636.1	1634.5													
11'					5.0	1648.88	1635.53	1634.00	66.74	20.00	1334.70	0.23	13.24	0.9734376	0.2289525	1299.247	305.583
	110.0	1647.1	1634.9	1633.5													
12					5.0	1646.70	1634.34	1633.24	61.81	20.00	1236.20	0.24	13.55	0.9721663	0.2342921	1201.792	289.632
	115.0	1646.4	1633.7	1632.9													
12'					5.0	1645.35	1633.52	1632.48	59.17	20.00	1183.30	0.09	5.02	0.9961677	0.0874635	1178.765	103.496
	120.0	1644.4	1633.3	1632.0													
13					10.0	1642.83	1632.59	1631.08	102.31	20.00	2046.10	0.14	8.04	0.9901642	0.1399102	2025.975	286.270
	130.0	1641.3	1631.9	1630.1													
14					10.0	1637.92	1631.54	1629.31	63.81	20.00	1276.10	0.07	4.04	0.9975171	0.0704247	1272.932	89.869
	140.0	1634.5	1631.2	1628.5													
15					5.0	1633.45	1631.77	1628.01	8.39	20.00	167.70	0.23	13.22	0.973481	0.228768	163.253	38.364
	145.0	1632.4	1632.4	1627.5													
																37349.870	10868.873

Figura 31 — Dadus excel ba analiza stabilidade taludes

Elevasaun husi superficie rai, superficie ruptura no nivel be rai okos ne'ebe mak ita le husi seksaun trasversal, no hatama. Pezu unitaria rai, kohesaun superficie ruptura nian, pezu unitaria ba be ne'ebe mak hatama tiha ona hanesan konstanta. Iha Japaun, valor husi kohesaun nia mak asume bazea ba mahar husi massa deslizamento (refere ba Tabela 1).

Tabela 1 — Valor asumptivo husi kohesaun

Espressura rai halai (m)	Kohesaun C (kN/m²)
5	5.0
10	10.0
15	15.0
20	20.0
25	25.0

$$F_s = \frac{\Sigma\{c\cdot l + (W\cos\alpha - u\cdot l)\tan\Phi\}}{\Sigma w\sin\alpha} = 1.0100232$$

Average pore pressure of slice u(kN/m²)	Length of surface of rupture of slice l(m)	Height of groundwater from surface of rupture h_w (m)	Unit pore pressure of water $u=h_w\cdot\gamma_w$ (kN/m2)	u·l (kN/m)	Wcosα-u·l	tanΦ	(Wcosα-u·l)tanΦ	c (kN/m²)	c·l (kN/m)
0.00	18.34	0.00	0.00	0.000	703.617	0.221694663	155.988	17.00	311.796
0.00	11.74	0.00	0.00	0.000	2432.104	0.221694663	539.184	17.00	199.532
0.00	10.60	0.00	0.00	0.000	3027.605	0.221694663	671.204	17.00	180.264
0.00	10.22	0.00	0.00	0.000	3232.753	0.221694663	716.684	17.00	173.768
0.00	10.29	0.00	0.00	0.000	3221.683	0.221694663	714.230	17.00	174.987
0.00	10.20	0.00	0.00	0.000	3205.678	0.221694663	710.682	17.00	173.363
0.00	10.34	0.00	0.00	0.000	3230.877	0.221694663	716.268	17.00	175.721
0.00	10.42	0.00	0.00	0.000	3339.370	0.221694663	740.320	17.00	177.195
0.00	10.56	0.00	0.00	0.000	3252.812	0.221694663	721.131	17.00	179.454
0.00	10.28	0.00	0.00	0.000	3111.517	0.221694663	689.807	17.00	174.752
0.00	5.13	0.00	0.00	0.000	1449.889	0.221694663	321.433	17.00	87.208
0.00	5.14	0.00	0.00	0.000	1299.247	0.221694663	288.036	17.00	87.319
0.00	5.14	0.00	0.00	0.000	1201.792	0.221694663	266.431	17.00	87.434
0.00	5.02	0.00	0.00	0.000	1178.765	0.221694663	261.326	17.00	85.327
0.00	10.10	0.00	0.00	0.000	2025.975	0.221694663	449.148	17.00	171.689
0.00	10.02	0.00	0.00	0.000	1272.932	0.221694663	282.202	17.00	170.423
0.00	5.14	0.00	0.00	0.000	163.253	0.221694663	36.192	17.00	87.316
							8280.267		2697.547

Figura 32 — Dadus excel ba analiza stabilidade taludes

6.2.2.2 Rezultadu analiza stabilidade taludes

Depois valor oin-oin kona ba angulo atrito ba superficie rupptura mak hanesan imputadu tiha ona hanesan parametru atu halo Fs besik liu ba iha 1.0. Tenki tau iha hanoin katak fator seguransa ne'e valor relativo laos valor ne'ebe absoluta.

Rezultadu husi analiza stabilidade taludes mak hanesan sumario iha Tabela 2.

Tabela 2 — Rezultadu analiza stabilidade taludes

Variante ne'ebé uza iha kálkulu	Bloku A	Bloku B
Peso unitário ba rai, γ (kN/m³)	20.0	18.0
Kohesaun superficie ruptura (kN/m²)	17.0	7.0
Ângulo ba atrito interno ba superficie ruptura (°)	12.5	20.2
Peso unitário ba be (kN/m³)	10.0	10.0
Fatores seguransa	1.01	1.004

6.2.2.3 Ezaminasaun fatores seguransa

Wainhira kondisaun topografiku ka nivel be rai okos sei muda an, fatores seguransa ba be rai okos iha bloku rai halai sei muda an.

6.2.2.3.1 Ezaminasaun fatores seguransa ba Bloku A

Tamba baze iha declive bloku A mak frájil relasiona ho cishalamento liu husi falla ne'ebe bele halo kolapsu iha futuru. Se kolapsu ne'e akontese iha parte okos liu taludes nian, fator seguransa husi Bloku A tun husi 1.01 ba 0.91, iha ne'ebe extremamente instavel (refere ba Figura 34).

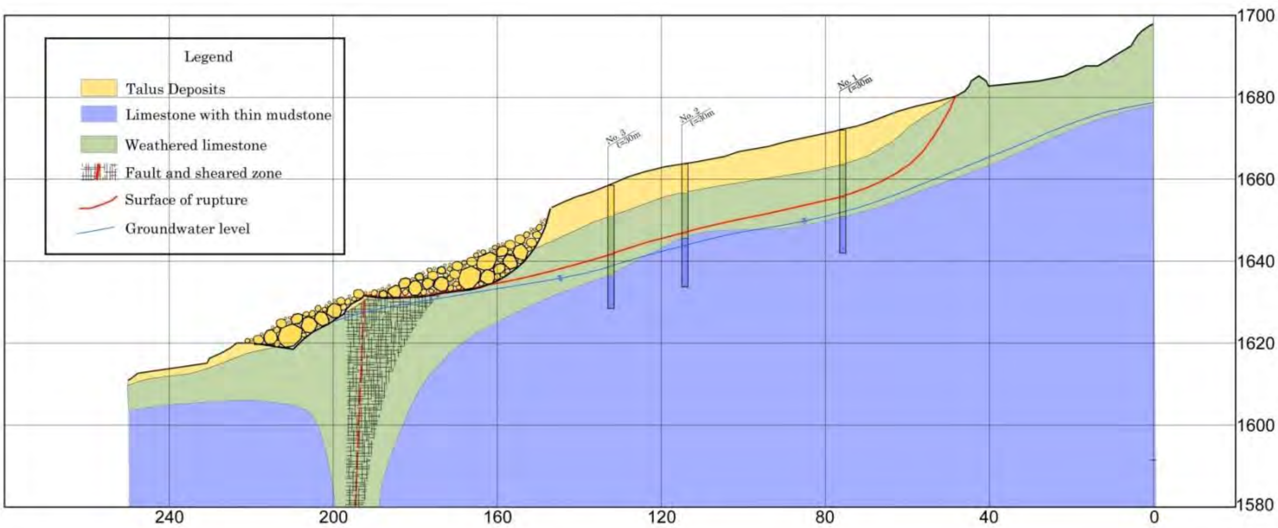

Figura 33 — Seksaun transversal jeolojiku presumida husi Bloku A hafoin kolapsu/monu.

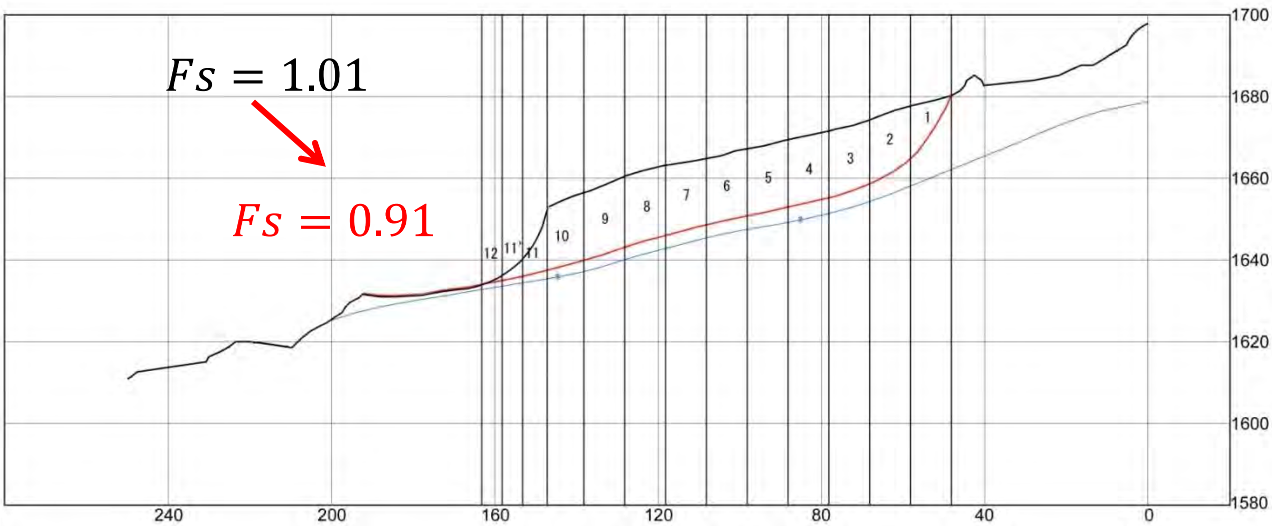

Figura 34 — Seksaun transversal kona ba Bloku A nia kalkulasaun Fs depois asumi kolapsu

Katak nivel be ubteranea iha Bloku A sae to'o 7 m, fator seguransa sei tun husi 1.01 to'o 0.91, nune'e Bloku A sei iha posibilidade hahu cisholamento (regere ba Figura 35).

Ataulmente, La provavel wainhira presipitasaun diaria liu husi 100 mm no sei kontinua mesmu iha Aituto. Maske nune, mudansa klimatika relasiona ho aquesimento global hanesan mundo nia prekupasaun. Se nivel be subteranea mak sae iha rai halai Aituto iha futuru oin mai, drenajem ho prefurasaun horizontal mak sei sai efektivu liu ona.

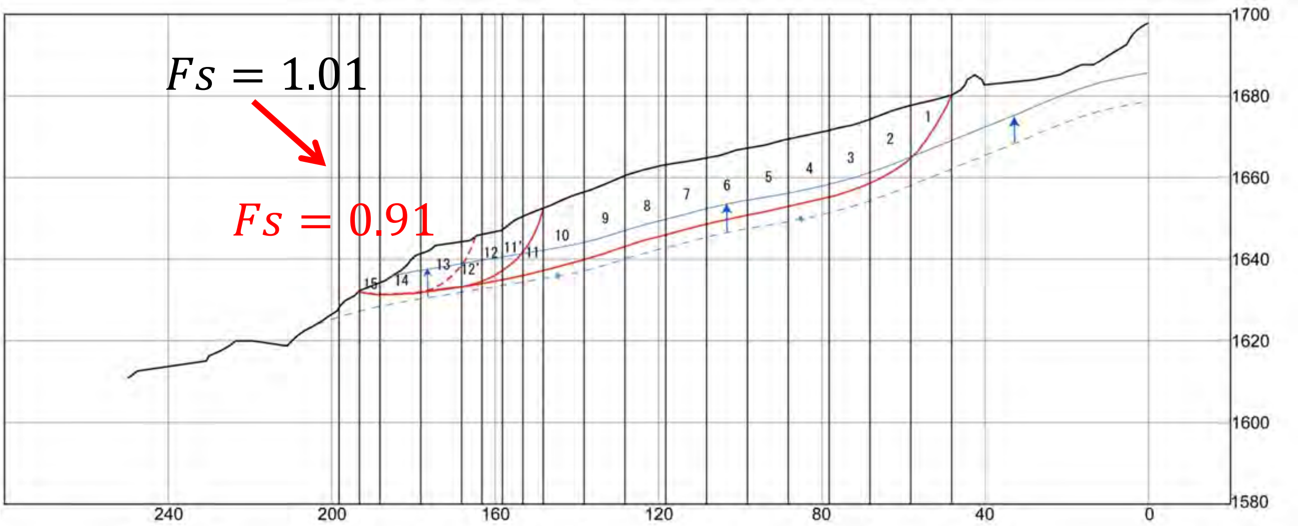

Figura 35 — Seksaun transversal kona ba Bloku A ba kalkulasaun fator seguransa depois nivel suteranea sae liu 7 m.

7 Konsiderasaun kona ba kontra medida sira ba prevensaun raihalai

En jeral, movimentasaun massa mak fenomena ho sakala ne'ebe bo'ot skala hirak ne'e bele sae to'o iha atus ba rihun ho metru kubiku. Bazea ba skala, iha kazu barak, ida ne'e han kustu barak atu gasta ba kontramedida. Nune, investigasaun no analizasaun ne'ebe suficiente ne'e importante tebes ba dezennu ne'ebe mak akurat bazea ba konnesementu hirak ne'e.

Movimentasaun massa no medida mak klasifika hanesan obra kontrollu no preventiva. Obra kontrollu mak obra ne'ebe liu husi mudansa kondisaun forma geotekniku ka nivel suberanea be nian. Reprezentante husi obra kontrollu mak obra drenajem no remosaun rai ba movimentasaun massa iha leten. Obra preventiva nian mak forsa resistensia cisolhamento ba movimentasaun massa liu husi forsa strutural. Reprezentante obra strutura nia mak obra ilar no obra anchor. Obra kontramedida ne'ebe detallu liu no dezennu strutura mak introsu ona ih Aneksu G hanesan dokumentus referensia.

Tabela 3 — Klasifikasaun kona ba Kontra medida

Klasifikasaun	Kontra medida	Pontu vizualizasaun
Kontrollu servisu	Superficie drenajem be: Kanal,infiltrasaun servisu prevensaun Drenajem be superficial: kanal drenajem,kanal drenajem nakloke,perfurasaun lateral. Drenajem profunda be subterrâneas: perfurasaun lateral,drenajem posu,drenajem tunel. Obra remosaun rai Obra aterru kontrapezu	Obras drenajen koko atu hatun tabela bee nian, ne'ebé hanesan fatór kontributivu ida ne ' ebé forte. Obra remosaun rai halo kmaan taludes nian leten atu redus forsa cisolhamento. The counterweight embankment work is embankment on the foot to increase the weight of slip resistance.
Obra preventiva	Pile works Anchor works	Pile works contain mass movement installing piles that go through the surface of mass movement, in rows perpendicular to the direction of movement. Anchor works fix steel materials with high strength to the stationary ground and installs structures to catch pressure in head of tensile member, to contain the mass movement with stress of tensile member.
Obra protesaun	-	Obra protesaun nian-bazikamente, la estabelese relasiona ho forsa gigante ba movimentasaun massa.

Se movimetasaun massa ne'e bo'ot liu atu rezolve liu husi obra kontrollu ne'ebe realistik ka obra preventiva planu prevensaun hanesan tunnel ka ponte tenki konsidera.

7.1 Foka liu ba iha rai halai iha Aituto

Bazeia ba rezultadu analiza stabilidade taludes, kontra medida ba rai halai iha Aituto propoin. Kontra medida ne'ebe selesionado mak moru retensaun no aterrru ne'ebe teknikamente limita no disponivel iha Timor-Leste. Jeralmente, kontra medida ne'ebe efektivu liu ba movimentu massamak atu mantein deterosaun nivel be rai okos, no be rai okos ne'ebe rasas no profunda be rai okos nia drenajem ne'ebe mak nudar kontra medida representativu ne'eba mak rekere teknolojia perfurasaun lateral iha area gradiente taludes. Kontra medida hirak ne'e mak sei intalla hanesan kontra medida ne'ebe mak efektivu liu iha rai halai Aituto.

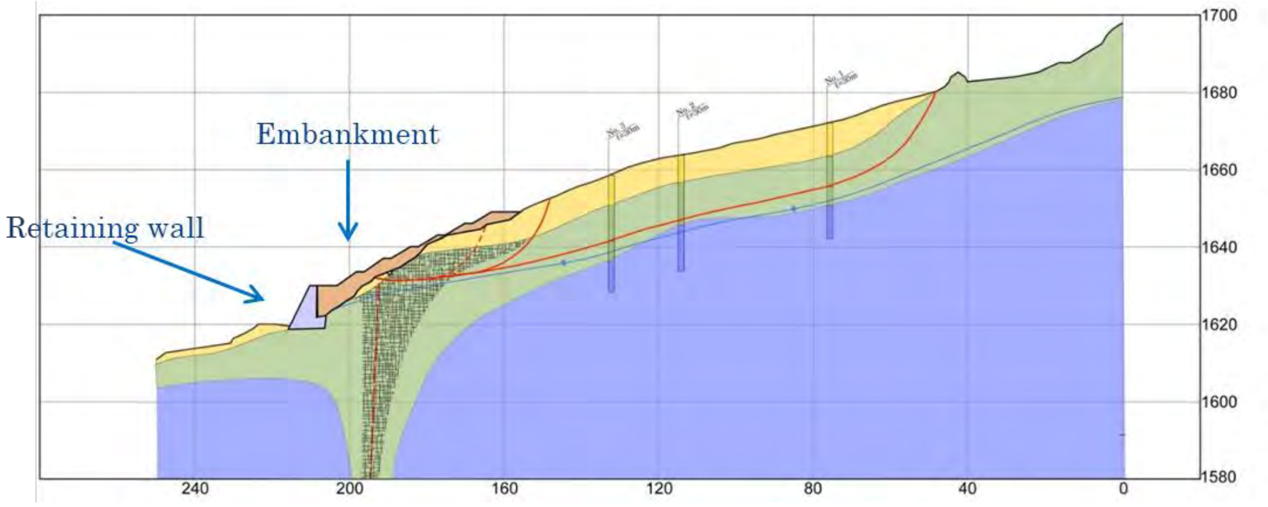

Figura 36 — Seksaun transversal husi Bloku A ba kalkulasaun Fs depois nivel be rai okos nia sae ba 7 m iha koak.

8 Konkluzaun

Iha relaoriu ida ne'e, investigasaun ne'ebe halao tiha ona iha Rai halai aituto ne'ebe esplina tiha ona tuir prosedimento ne'ebe iha. Iah Timor leste maioria rai sira ne'e okupa ho foho, nune'e rai halai barak ne'ebe bele eziste.

Maske nue'e investigasaun, observasaun ka dezennu kotramedida ba rai halai, sei dauk halao. Tuir investigasaun ne'ebe halao husi projetu CDRS ne'ebe sei sai hanesan ezemplu ba studu rai halai sira seluk. Sei sai ksolok ida mai ami wainhira pesoal husi DNEPCC no organizasaun ne'ebe mak interese sei refere ba relatoriu ida ne'e.

Iha bloku A, ezaminasaun ba fator seguransa hatudu kolapsu nebe akontese iha parte okos taludes, fator seguransa ba bloku A tun husi 1.01 - 0.91, se bloku sira ne'e sei sai instavel tebes. Tamba ne'e mak importante teb-tebes ba DNEPCC atu kontinua monitoriza ho inclinometer no mantein tau matan ba deslokasaun ba bloku sira.