APPENDIX 5 STABILITY ANALYSIS

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APPENDIX V

STABILITY ANALYSIS

5.1 STANDARD

Each Countermeasure conformed to the following standards.

(1) Sta.17+400

Table 5.1.1 Each Countermeasure conformed to the following standards

Plan1	
Countermeasure work	Standard
Shotcrete	Manual for slope protection,Japan Road Association
Rock bolt works	Manual for slope protection,Japan Road Association
Gabion wall	Mamual for river works in japan ,River Bureau,Ministry of Land,infrastraucture,Transport and Tourism
Vegetation works	Manual for slope protection,Japan Road Association
Gravity-type retaining wall	Manual for Retaining wall,Japan Road Association
Plan2	
Countermeasure work	Standard
Leaning wall	Manual for Retaining wall,Japan Road Association
Gabion wall	Mamual for river works in japan ,River Bureau,Ministry of Land,infrastraucture,Transport and Tourism
Vegetation works	Manual for slope protection,Japan Road Association
Gravity-type retaining wall	Manual for Retaining wall,Japan Road Association
Plan3	
Countermeasure work	Standard
Leaning wall	Manual for Retaining wall,Japan Road Association
Gabion wall	Mamual for river works in japan,River Bureau,Ministry of construction
Vegetation works	Manual for slope protection,Japan Road Association
Gravity-type retaining wall	Manual for Retaining wall,Japan Road Association

(2)Sta.17+600

Table 5.1.2 Each Countermeasure conformed to the following standards

Plan1	
Countermeasure work	Standard
Gravity-type retaining wall	Manual for Retaining wall,Japan Road Association
Reinforced soil wall	Manual for embankment,Japan Road Association
Shotcrete	Manual for slope protection,Japan Road Association
Rock bolt works	Manual for slope protection,Japan Road Association
Anchor workst type1	Standard for design and construction of anchor works,The Japanese Geotechnical Society
Anchor works type2	Standard for design and construction of anchor works,The Japanese Geotechnical Society
Plastering concrete work	Manual for Retaining wall,Japan Road Association
Gabion wall	Mamual for river works in japan ,River Bureau,Ministry of Land,infrastraucture,Transport and Tourism

Plan2	
Countermeasure work	Standard
Gravity-type retaining wall	Manual for Retaining wall,Japan Road Association
Reinforced soil wall	Manual for embankment,Japan Road Association
Shotcrete	Manual for slope protection,Japan Road Association
Rock bolt works	Manual for slope protection,Japan Road Association
Anchor workst type1	Standard for design and construction of anchor works,The Japanese Geotechnical Society
Anchor works type2	Standard for design and construction of anchor works,The Japanese Geotechnical Society
Plastering concrete work	Manual for Retaining wall,Japan Road Association
Gabion wall	Mamual for river works in japan ,River Bureau,Ministry of Land,infrastraucture,Transport and Tourism

Plan3	
Countermeasure work	Standard
Gravity-type retaining wall	Manual for Retaining wall,Japan Road Association
Reinforced soil wall	Manual for embankment,Japan Road Association
Shotcrete	Manual for slope protection,Japan Road Association
Rock bolt works	Manual for slope protection,Japan Road Association
Anchor workst type1	Standard for design and construction of anchor works,The Japanese Geotechnical Society
Anchor works type2	Standard for design and construction of anchor works,The Japanese Geotechnical Society
Anchor works type3	Standard for design and construction of anchor works,The Japanese Geotechnical Society
Plastering concrete work	Manual for Retaining wall,Japan Road Association
Gabion wall	Mamual for river works in japan ,River Bureau,Ministry of Land,infrastraucture,Transport and Tourism

(2) Sta.18+200

Table 5.1.3 Each Countermeasure conformed to the following standards

Plan1	
Countermeasure work	Standard
Cutting-works	Manual for slope protection,Japan Road Association
Shotcrete	Manual for slope protection,Japan Road Association
Rock fall prevention net	Manual for countermeasures against rock fall,Japan Road Association
Plan2	
Countermeasure work	Standard
Cutting-works	Manual for slope protection,Japan Road Association
Shotcrete	Manual for slope protection,Japan Road Association
Vegetation works	Manual for slope protection,Japan Road Association
Leaning wall	Manual for Retaining wall,Japan Road Association
Rock bolt works	Manual for slope protection,Japan Road Association
Anchor workst type1	Standard for design and construction of anchor works,The Japanese Geotechnical Society
Plastering concrete work	Manual for Retaining wall,Japan Road Association
Plan3	
Countermeasure work	Standard
Cutting-works	Manual for slope protection,Japan Road Association
Shotcrete	Manual for slope protection,Japan Road Association
Vegetation works	Manual for slope protection,Japan Road Association
Shotcrete	Manual for slope protection,Japan Road Association
Rock bolt works	Manual for slope protection,Japan Road Association
Caisson pile	Specigications for highway Bridges part4, Manual for pile design and construction,Japan Road Association

5.2 STABILITY ANALYSIS

5.2.1 STABILITY ANALYSIS

Stability analysis should be conducted to determine the scale and quantity of landslide countermeasure works required to maintain the stability of the landslide slope and so ensure the target safety factor. Modified Fellenius Method is used for stability analysis of a landslide slope, as follows:

$$Fs = \frac{\sum c \cdot l + (W - u \cdot b)\cos\alpha \cdot \tan\phi}{\Sigma W \sin\alpha} \quad \text{..........} (5.1)$$

Where, Fs= Initial Factor of Safety

C(kN/m^2) = Cohesion of sliding surface

φ (°) = Internal friction angle of sliding surface

l (m) = Length of sliding surface acting on the slice

u (kN/m) = Pore pressure acting on the base of the slice

b (m) =Width of the slice (m)

W (kN/m) =Weight of the slice

α (°) = Angle of the base of the slice to the horizontal

(1) Determination of Initial Factor of Safety

The initial factor of safety was estimated on the basis of the movement conditions, as given in Table 5.2.1.

Table 5.2.1 Determination of Initial Factor of Safety

Initial Factor of Safety	Movement Conditions
Fs = 0.95	- A large number of obvious potential landslide topography such as scarps, bulges, stepped land, ponds and swamps; and - Many visible ongoing and active movements of cracks, subsidence, upheaval, toe erosion, or small toe collapse as well as springs.
Fs = 0.98	- Obvious potential landslide topography such as bulges, stepped land, ponds and swamps, but - Few or small ongoing movements of cracks, subsidence, upheaval, or small toe collapse.
Fs = 1.00	- Potential landslide area is at rest, - Cracks, subsidence, upheaval, or small toe collapse are visible, but not progressing.

Source: Modification from reference MANUAL FOR RIVER WORKS IN JAPAN, Published by River Bureau, Ministry of land, infrastructure, transport and Tourism, November 1997.

(2) Determination of Proposed Factor of Safety

The proposed factor of safety (PFs) is the target value for enhancing the degree of safety of the slope and achieving the conservation of the slope by means of landslide countermeasure works. Considerations in determining the proposed factor of safety include the landslide phenomena and its scale, the degree of importance of the object to be protected, and the degree of damage that is likely to occur as a result of the landslide.

Table 5.2.2 Determination of Proposed Factor of Safety

Proposed factor of safety	Condition
PFs = 1.10 to 1.20	- Potential exists for sudden and severe movement; and - Landslide liable to cause significant damage to, houses, main roads or rivers or other public facilities or loss of human lives.
PFs = 1.05 to 1.10	- A large landslide would have little effect on houses or public facilities; or - The proposed prevention works are temporary countermeasures.

Source: Manual for river works in Japan, River Bureau, and Ministry of land, infrastructure, transport and tourism

It is noted that the proposed factor of safety mentioned indicates the degree of increase in the safety factor after completion of landslide prevention works on the assumption that the initial factor of safety before landslide is Fs=1.0.

It was determined Initial Factor of Safety in each area based on the field survey and the monitoring result. Also, it was determined Proposed Factor of Safety.

Table 5.2.3 Initial Factor of Safety and Proposed Factor of Safety

Site	Initial Factor of Safety	Proposed Factor of Safety
Sta.17+400	Fs0=1.00	Fs0=1.20
Sta.17+600（A Block）	Fs0=0.98	Fs0=1.20
Sta.17+600（B Block）	Fs0=1.00	Fs0=1.12
Sta.18+200	Fs0=0.95	Fs0=1.20

5.2.2 ANCHOR WORKS

Ground anchors are reliable, but costly compared with other countermeasures. This method has been applied increasingly to artificial landslides to cut off the toe of the landslide. Compared with rock bolts and soil nailing, ground anchors have a relatively large resistance to sliding force and are therefore used to stabilize relatively large-scale slope failures.

(1) Purpose

Ground anchors are intended to prevent landslides through the tensile strength of high tensile strength steel wire or bars installed across the slip surface.

(2) Design Considerations

When the slope of a landslide area or sliding surface is relatively steep, ground anchors are more effective. Figure 5.2.1 gives a conceptual diagram of a ground anchor installation.

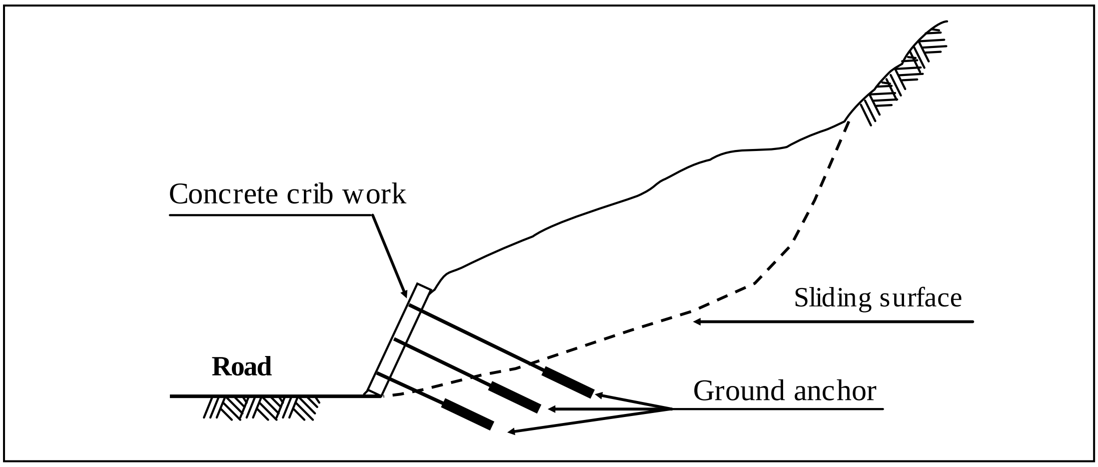


Figure 5.2.1 Landslide Stabilized with Ground Anchors

① Design procedure

Figure 5.2.7 shows the design flowchart for ground anchors. Important considerations for ground anchors are the bearing capacity of the ground under the bearing plate and the bond strength between the anchor grout and rock at the attachment point. In planning ground anchors, a bond strength test at the attachment is to be carried out.

Further, in planning and designing ground anchors, at least the following site tests should be performed at intervals of 20 to 30 m.

a) Bond strength test at fixation part (extraction test)

b) Bearing capacity test of soil mass under the bearing plate

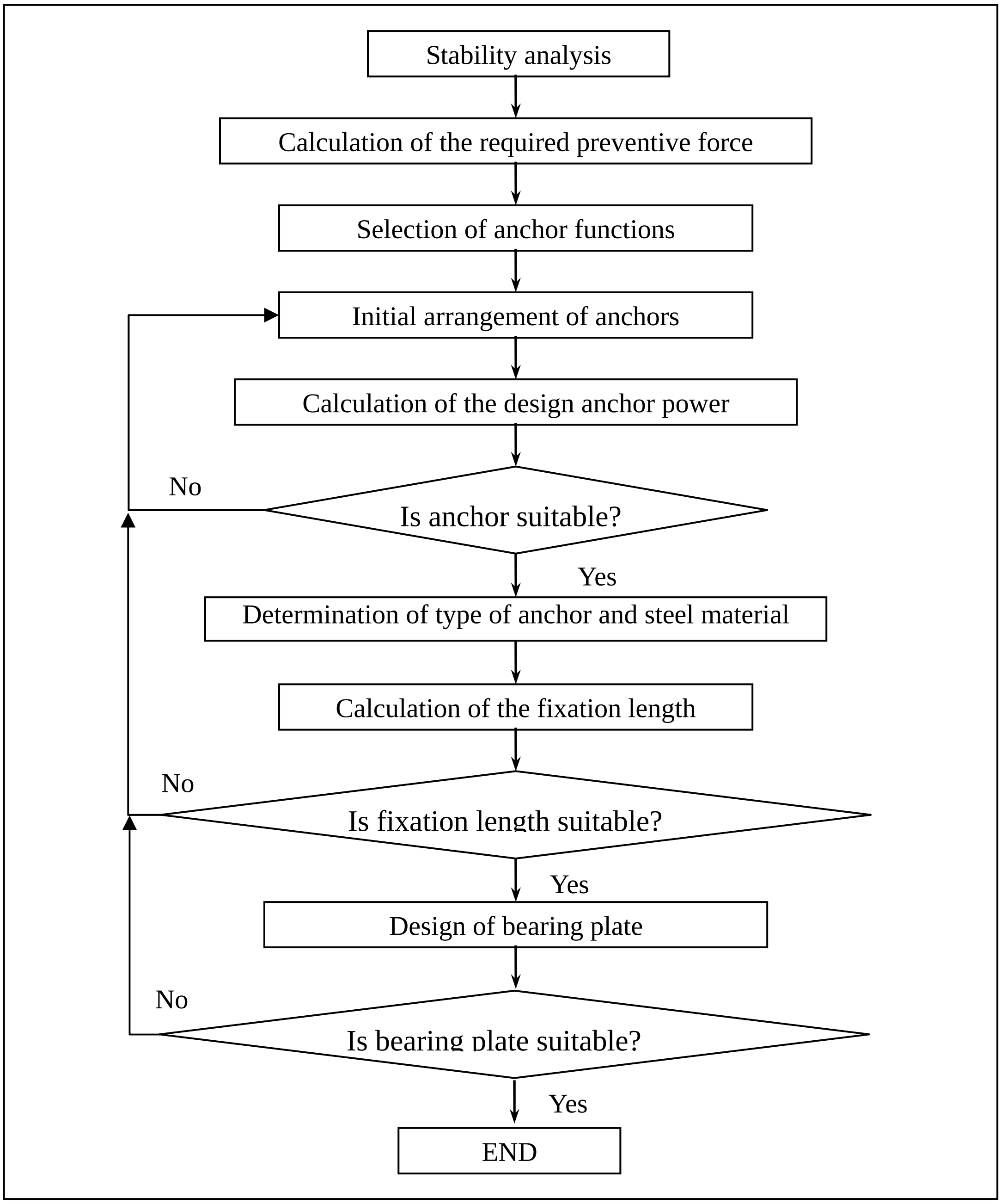


Figure 5.2.2 Design Flowchart for Ground Anchors

② **Anchor functions**

Anchors are installed to achieve two objectives (Figure 5.2.3):

a) Increase the resisting power against shear force by applying stress normal to the sliding surface (clamping effect), and

b) Decrease the sliding force of a landslide by using steel members as anchors (straining effect).

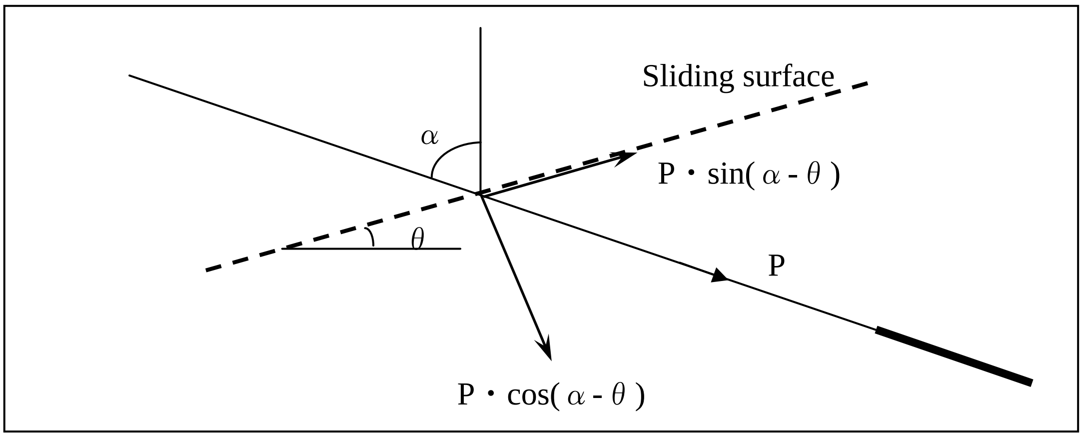


Figure 5.2.3 Functional Description of an Anchor

③ **Arrangement of anchors**

The position, direction and intervals of anchor installation shall be determined during the initial stage of design.

a) Ground anchors shall be installed at a spacing of at least 2 meters in 2 or more rows.

b) The inclination of the anchors in a range from + 10˚ to -10˚ from horizontal. It must be avoided for the reasons related to anchor installation, such as residual slime, bleeding of grout, etc.

c) The direction of anchoring is parallel to the direction of movement of the landslide.

d) Anchor interval is determined based on the interaction between anchors, which can be verified by reviewing anchor power, diameter of anchors, depth and ground properties.

④ **Calculation of the design anchor power**

The design anchor power (Td) is calculated by using the following formulas:

$$Td = \frac{P}{\sin(\alpha + \beta) \cdot \tan\phi + \cos(\alpha + \beta)} \cdot \frac{B}{N} \quad \cdots\cdots (5.2)$$

Where,

P (kN/m^2) = Required preventive power

α (degree) = Anchor setting angle (the angle to a perpendicular axis)

β(degrees)= Angle of slope of the sliding surface

φ (degrees) = Internal frictional angle of sliding surface

B (m) = Interval between anchors in horizontal direction

N= Number of anchors set in vertical direction

⑤ **Determination of type of anchor and steel material**

Generally, the type of anchor is determined by comparing the tension strength of steel material with the skin frictional resistance between the ground and the grout as well as the allowable adhesive stress between the tendon and the grout.

⑥ **Determination of fixation length**

Fixation length should be 3 to 10 meters, and the free length should be more than 4 meters. Figure 5.2.4 gives the structural description.

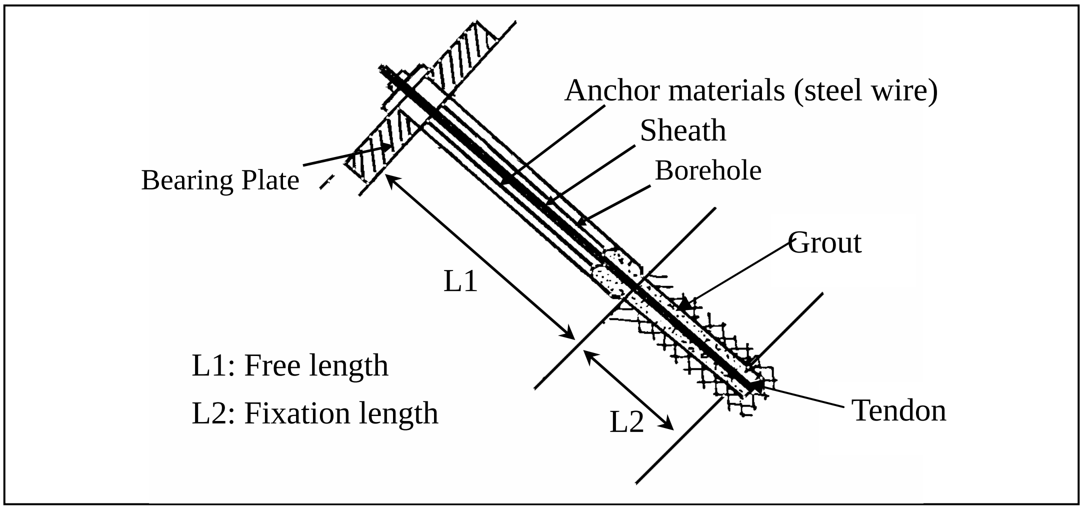


Figure 5.2.4 Outline of Anchor Structure

To allow the design anchor power to meet the allowable anchor extraction force, the length of contact between the ground and the grout must be compared with that between a tendon and grout. Whichever is longer should be defined as the fixation length.

$$l_{sa} = \frac{T_d}{3.14 \times D_s \times \tau_{ab}} \quad \cdots\cdots (5.2)$$

$$la = \frac{f \times T_d}{3.14 \times D_a \times \tau_{ag}} \quad \cdots\cdots (5.3)$$

Where,

lsa (m)= Required length between the tendon and the grout

la (m) = Required length of contact between the soil and the grout

Td (N/piece) = Design anchor power

D_S (m) = Diameter of a tendon

τab (N/m^2) = Allowable adhesive stress between the tendon and the grout (Table 5.2.3)

f = Safety factor (generally be defined as 2.5)

D_A (m) = Diameter of the anchor

τag (N/m^2)= Skin frictional resistance (Table 5.2.4)

Table 5.2.4 Recommended Allowable Adhesive Stresses

Standard Ground Design Strength (unit: N/mm^2)		24	30	40
Type of tendon	1. Prestressing steel wire 2. Prestressing steel bar 3. Standard prestressing steel wire 4. Multi-standard prestressing steel wire	0.8	0.9	1
	5. Deformed prestressing steel bar	1.6	1.8	2.0

Notes: (1) 1 kgf/cm^2 = 0.1 N/mm^2, (2) unit: N/mm^2.

Source: Modification from reference Standard for design and construction of anchor works, The Japanese Geotechnical Society

Table 5.2.5 Recommended Skin Frictional Resistance of Anchors

Type of Ground			Frictional Resistance (MN/m^2)
Bedrock	Hard rock		1.5to2.5
	Soft rock		1.0to1.5
	Weathered rock		0.6 to 1.0
	Mudstone		0.6 to 1.2
Sand and gravel	N value	10	0.10 to 0.2
		20	0.17 to0.25
		30	0.25 to 0.35
		40	0.35 to 0.45
		50	0.45 to 0.70
Sand	N value	10	0.10 to 0.14
		20	0.18 to 0.22
		30	0.23 to 0.27
		40	0.29 to 0.35
		50	0.30 to0. 40
Cohesive soil	Representative Cohesion C		1.0C

Source: Modification from reference Standard for design and construction of anchor works, The Japanese Geotechnical Society

⑦ Design of bearing plates

Cribs, plates or cross-shaped blocks set on the surface of the ground are used as pressure bearing plates. The most appropriate pressure bearing plate is selected in consideration of specifications, operational efficiency, cost-effectiveness, maintenance, landscape, etc.

Figure 5.2.5 shows a typical example of a landslide stabilized with ground anchors.

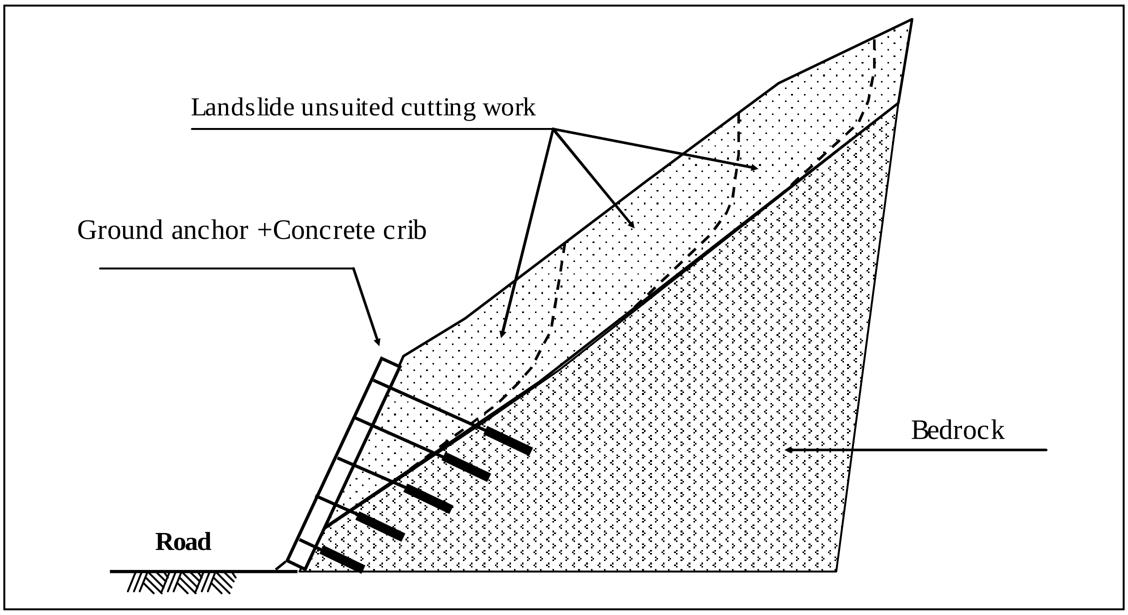


Figure 5.2.5 A Typical Example of a Landslide Stabilized with Ground Anchors.

5.2.3 STA.17+600

(1) Stability analysis

① A block

The calculation parameter of a block is shown below.

Table 5.2.6 Calculation parameter (Sta.17+600 B-2section)

elements	abbreviation	unit	Case1 before fill	Case2 after fill	case3 Splash raising
Equation		-	Modified Fellenius Method	Modified Fellenius Method	Modified Fellenius Method
Initial Factor of Safety	Fs	-	0.98	1.234	1.00
Proposed Factor of Safety	p･Fs	-	1.20	1.20	1.20
Required preventive force to be provided	Pr	KN/m	790.8	-125.7	338.7
Length of sliding surface	L	m	49.049	57.507	37.171
Area	A	m^2	233.570	287.26	110.66
Normal force attributable	N	KN/m	2892.100	3790.8	1396.7
Pore pressure acting on the base of the slice	U	KN/m	0.00	0.00	0.00
Resistance force	S	KN/m	3539.548	4438.248	1697.782
Tangential force attributable to gravity of the slice	T	KN/m	3608.610	3593.749	1696.993
Unit wight of landslide	γ	KN/m^3	20.0	20.0	20.0
Unit wight of fill	γ	KN/m^3	20.0	20.0	29.0
Cohesion of sliding surface	C	KN/m^2	13.2	13.2	13.2
Cohesion of fill	C	KN/m^2	0.0	0.0	0.0
Internal friction angle of sliding surface	φ	°	45.0	45.0	45.0
Internal friction angle of fill	φ	°	45.0	45.0	45.0

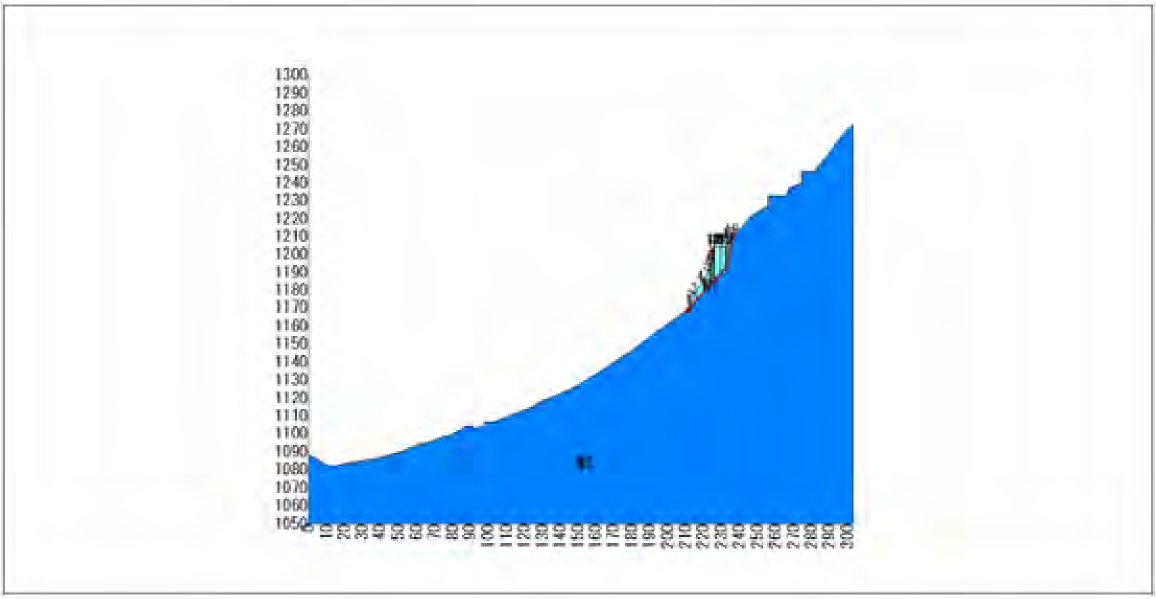


Figure 5.2.6 Case1

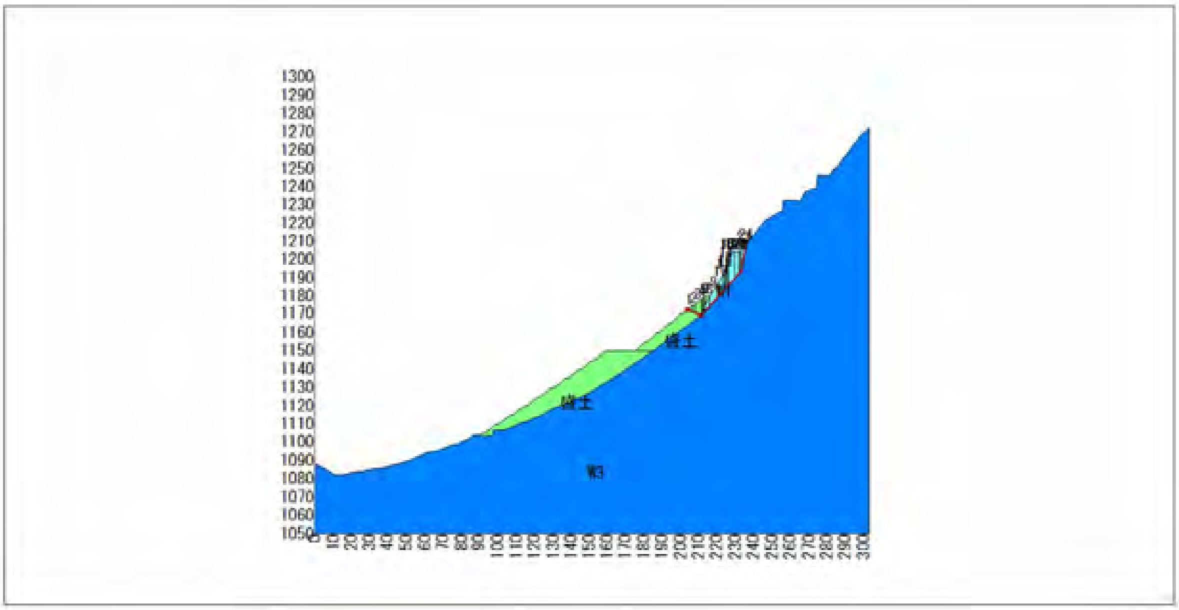


Figure 5.2.7 Case2

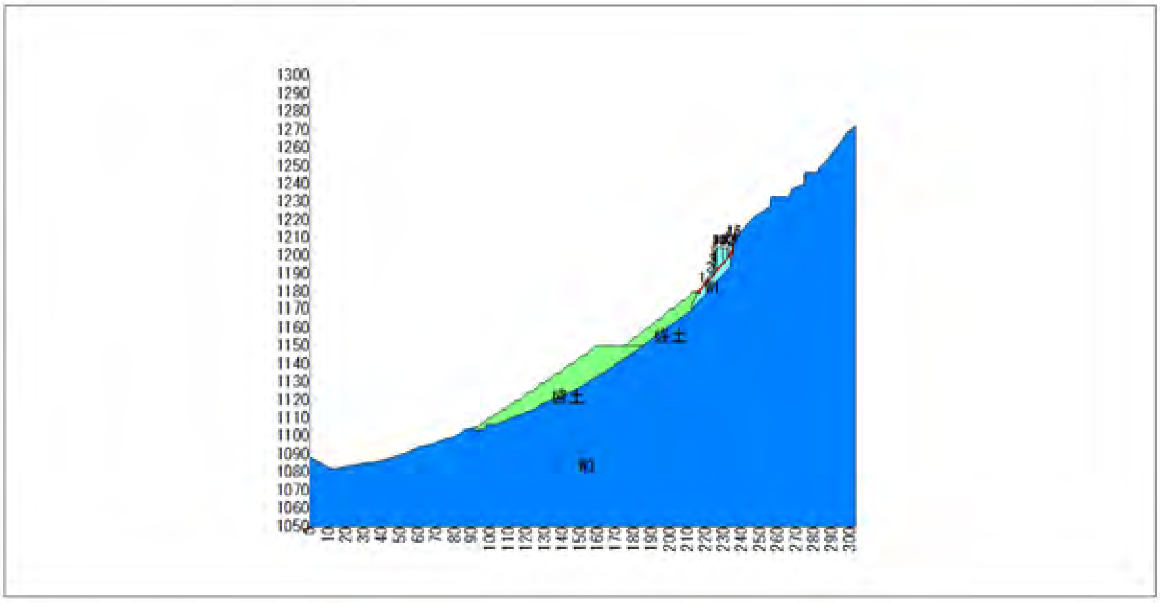


Figure 5.2.8 Case3

② B block

The calculation parameter of B block is shown below.

Table 5.2.7 Calculation Parameter (Sta.17+600 B-3section)

elements	abbreviation	unit	Case1 before fill	Case2 after fill
Equation		-	Modified Fellenius Method	Modified Fellenius Method
Initial Factor of Safety	Fs	-	1.00	1.234
Proposed Factor of Safety	p･Fs	-	1.12	1.12
Required preventive force to be provided	Pr	KN/m	1496.3	-60
Length of sliding surface	L	m	126.238	130.48
Area	A	m^2	1127.190	1510.65
Normal force attributable	N	KN/m	17500.300	24481.3
Pore pressure acting on the base of the slice	U	KN/m	0.00	0.00
Resistance force	S	KN/m	12460.527	16962.244
Tangential force attributable to gravity of the slice	T	KN/m	12460.491	15091.254
Unit wight of landslide	γ	KN/m^3	20.0	20.0
Unit wight of fill	γ	KN/m^3	20.0	20.0
Cohesion of sliding surface	C	KN/m^2	10.0	10.0
Cohesion of fill	C	KN/m^2	0.0	0.0
Internal friction angle of sliding surface	φ	°	32.6	32.6
Internal friction angle of fill	φ	°	40.0	40.0

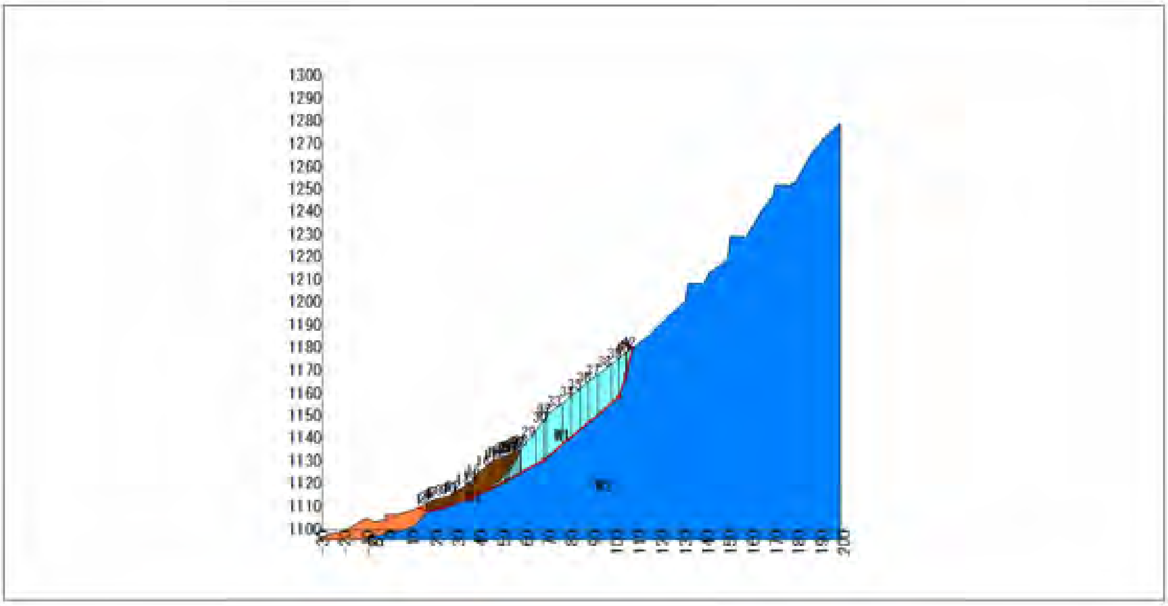


Figure 5.2.9 case1

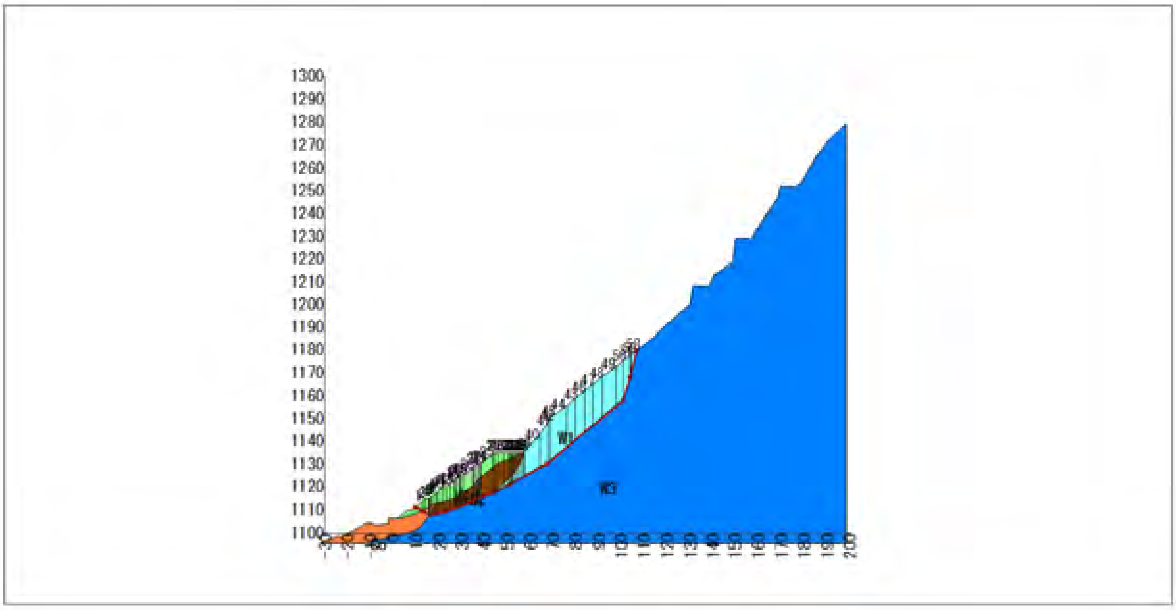


Figure 5.2.10 case2

(2) Structural Computation

① Ground Anchor lower stage

The calculation parameter is shown below.

Table 5.2.8 Calculation parameter Sta.17+600 lower stage

elements	abbreviation	unit	numerical number
Required preventive power	Pr	KN/m	338.7
Angle of slope of the sliding surface	θ	°	49.01
Internal friction angle of sliding surface	tan φ	−	1
Number of anchors set in vertical direction	a	m	3
Interval between anchors in horizontal direction	m		2
Anchor setting angle	α	°	20
Anchor function	Clamping and straining effect*1		
safty factor	f	−	2.5
design anchor power	Td	KN	393.3
perimeter of tendon	U	mm	169.6
Diameter of the drilling hole	dA	mm	90
Required length between the tendon and the grout	lsa	m	2.36
Required length of contract between the soil and the grout	la	m	3.48
Anchor length	La	m	3.5
Allowable adhesive stress between the tendon and thegrout	τ ab	N/mm2	1.6
Skin frictional resistance	τ ag	N/mm2	1

*1 Clamping effect: Increase the resisting power against shear force by applying stress normal to the sliding surface.

Straining effect: Decrease the sliding force of a landslide by using steel members as anchors.

② Ground Anchor upper stage

Required preventive power was calculated for the following.

A=44.2(m2), γ=23.0(kN/m3)
W1=44.2×23.0=1016.6(kN/m)

Wheel load 10.0kN/m
Width of road 6.3m
W2=10.0×6.3=63.0(kN/m)

ΣW=1016.6+63.0=1079.6(kN/m)
Horizontal seismic coefficient of deign Kh=0.12

Pr=1079.6×0.12=129.6(kN/m)

The calculation parameter is shown below.

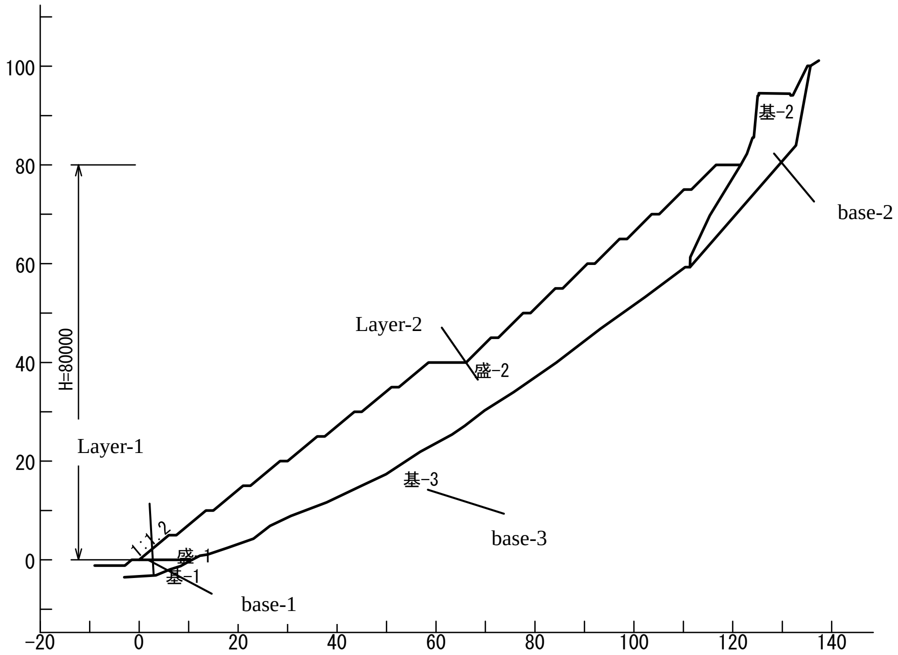
Table 5.2.9 Calculation Parameter Sta.17+600 upper stage

elements	abbreviation	unit	numerical number
Required preventive power	Pr	KN/m	129.6
Angle of slope of the sliding surface	θ	°	0
Internal friction angle of sliding surface	tanφ	–	0
Number of anchors set in vertical direction	a	m	3
Interval between anchors in horizontal direction	m	step	2
Anchor setting angle	α	°	0
Anchor function	straining effect*1		
safty factor (for earth pressure during earthquakes)	f	–	2
design anchor power	Td	KN	194.4
perimeter of tendon	U	mm	119.7
Diameter of the drilling hole	dA	mm	90
Required length between the tendon and the grout	lsa	m	1.39
Required length of contract between the soil and the grout	la	m	1.38
Anchor length	La	m	3
Allowable adhesive stress between the tendon and thegrout	τab	N/mm2	1.6
Skin frictional resistance	τag	N/mm2	1

*1 Straining effect: Decrease the sliding force of a landslide by using steel members as anchors.

③Reinforced soil wall

a) Plan geographical features



b) Height of embankment : H = 80.000 (m)

c) Layer thickness of tightening hardening : vo = 30.0 (cm)

d) External force for design: none

e) Design constant of soil material

number	H (m)	h (m)	γ (kN/m³)	γ’ (kN/m³)	c (kN/m²)	φ (°)
layer - 2	80.000	40.000	19.000	19.000	0.00	35.0
layer - 1	40.000	40.000	19.000	19.000	0.00	35.0
base- 1	—	—	20.000	20.000	0.00	40.0
base- 2	—	—	20.000	20.000	0.00	40.0
base- 3	—	—	24.000	24.000	0.00	45.0

H : height from base (m) h : thickness (m)

γ : unit weight (kN/m^3) γ’ : unit weight of water (kN/m^3)

c : Cohesion of soil (kN/m^2)

φ : Internal friction angle of soil (°)

f) Geotextile, friction correction coefficient of soil, and friction stress element

Layer number	Friction correction coefficient		Friction stress element	
	α1	α2	c* (kN/m^2)	φ* (°)
fill - 2	0.00	1.00	—	—
fill - 1	0.00	1.00	—	—

α1, α2 : Geotextile, friction correction coefficient of soil, and friction stress element

α1＝c*/c

α2＝tanφ*/tanφ

c* : Adhesive power of appearance of soil and geotextile (kN/m2)

φ* : Shearing resistance corner of appearance of soil and geotextile (°)

g) Material of Geotextile

Material No	Name	Standard	Unit price (¥/m^2)	Tmax (kN/m)	Material safety rate			
					Fcr	FD	FC	FB
32	Tenser	RE125	2,100	125.000	1.67	1.00	1.00	1.00

Tmax : Max hitching strength of geotextile (cm^2/s)

Fcr : Material safety rate considered creep

$F_{cr} = 1/\mu$

μ : Creep reduction factor

FD : Material safety rate considered durability

FC : Material safety rate considered damage under construction

FB : Material safety rate considered deterioration of strength in joint

h) Design safety rate

Kind of safety	Design safety rate	
	normal	seismic
Safety rate for circular slide	Fs ≧ 1.20	Fs ≧ 1.00
Safety rate for Pulling out	Fs ≧ 2.00	Fs ≧ 1.20

i) *Designed horizontal seismic acceleration*

Kh = CZKh0 = 0.12

Where ,

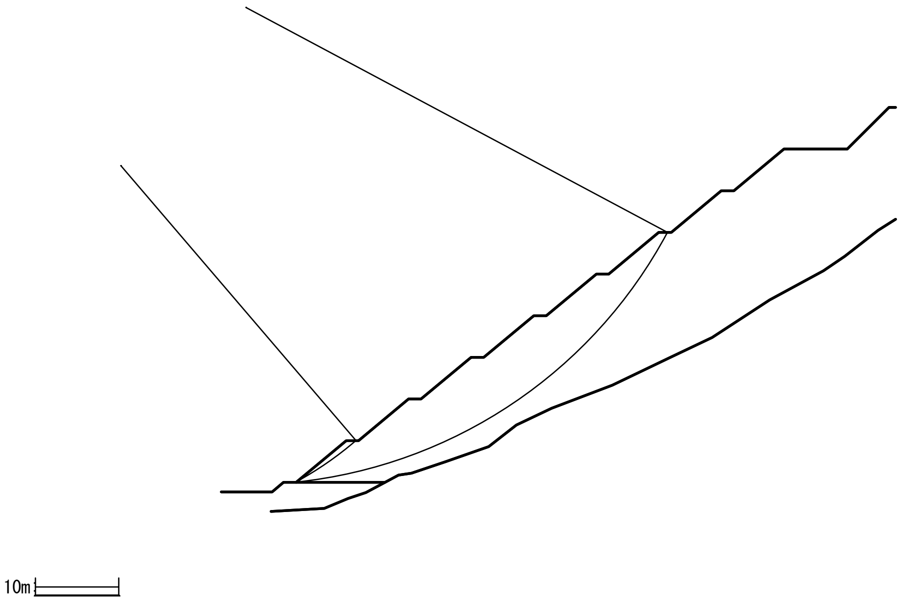
Kh : Deigned horizontal seismic acceleration

Kh0 : Standard deigned horizontal seismic acceleration = 0.12Moderate-size earthquake

CZ : Regional correction coefficient = 1.00

j) *Stability analysis in no protection*

Result of review : It is necessary to reinforce it by the geotextile.



k) *Circular slide stability calculation*

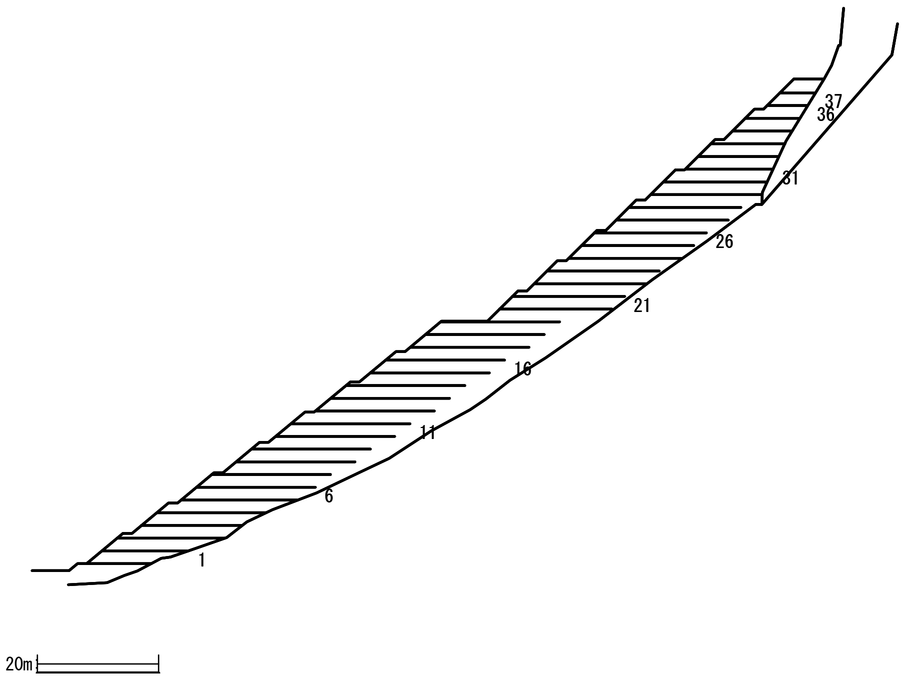
( ) Designed value

item	code	unit	normal		seismic	
			Numerical result	Judgment	Numerical result	Judgment
Safety rate	Fs Fsa	—	0.982 (1.200)	NG	0.883 (1.000)	NG
Center of a circle	X Y	m	-21.000 38.000		-6.000 57.000	
Radius	R	m	43.417		57.315	

l) Employed material and arrangement of material closely (normal:TA seismic TAE)

No	Name	Standard	T max (kN/m)	Material safety rate				TA (kN/m)	TAE (kN/m)
				FCr	FD	FC	FB		
32	Tenser	RE125	125.000	1.67	1.00	1.00	1.00	75.000	112.500

m) Arrangement of geotextile



n) The entire circular slide stability calculation after Reinforcement

Material, construction interval, and construction length of each steps

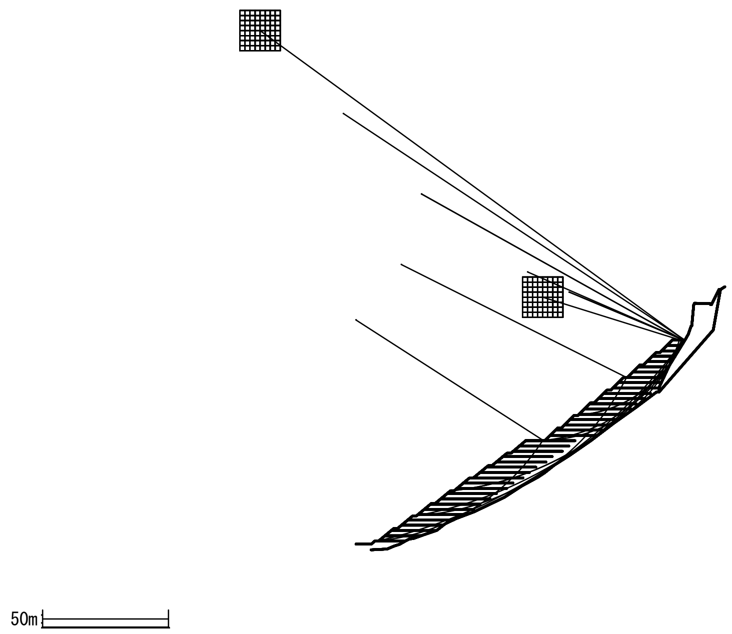
( ) Designed value

item	code	unit	normal	seismic
name	—	—	tensor	tensor
Standard	—	—	RE125	RE125
Max tensile strength	Tmax	kN/m	125.000	125.000
Tensile strength Necessary tensile tension	TA Treq	kN/m	75.000 (10.497)	112.500 (17.756)
Construction	SV	m	2.100	2.100

interval			(2.500)	(2.500)
Uppermost layer interval	Sv'	m	2.300 (0.500)	2.300 (0.500)
The number of sheets of construction	N	sheet	37	37
Length of construction	L	m		
No.37			5.893	5.893
No.36			6.708	6.708
No.35			9.023	9.023
No.34			9.839	9.839
No.33			12.222	12.222
No.32			13.348	13.348
No.31			14.474	14.474
No.30			17.100	17.100
No.29			18.392	18.392
No.28			18.500	18.500
No.27			18.500	18.500
No.26			18.500	18.500
No.25			18.500	18.500
No.24			18.500	18.500
No.23			18.500	18.500
No.22			18.500	18.500
No.21			18.500	18.500
No.20			18.500	18.500
No.19			19.600	19.600
No.18			19.600	19.600
No.17			19.600	19.600
No.16			19.600	19.600
No.15			19.600	19.600
No.14			19.600	19.600
No.13			19.600	19.600
No.12			19.600	19.600
No.11			19.600	19.600
No.10			19.600	19.600

No. 9			19.600	19.600
No. 8			19.600	19.600
No. 7			19.600	19.600
No. 6			19.600	19.600
No. 5			19.262	19.262
No. 4			18.024	18.024
No. 3			16.611	16.611
No. 2			17.792	17.792
No. 1			14.289	14.289
Total length	ΣL	m	633.876	633.876

o) Circular slide shape



p) Circular slide stability calculation

case	Circular arc center coordinates		Radius R(m)	Fs min	Fsa	Judgment
	X(m)	Y(m)				
normal - 1	-9.000	88.000	88.459	1.394	1.200	○
normal - 2	-14.000	170.000	162.607	1.240	1.200	○
normal - 3	17.000	138.000	118.714	1.240	1.200	○
normal - 4	65.110	97.000	57.009	1.207	1.200	○
normal - 5	75.610	99.000	49.125	1.278	1.200	○
seismic - 1	-47.000	203.000	208.370	1.023	1.000	○
seismic - 2	9.000	110.000	100.180	1.094	1.000	○
seismic - 3	17.000	138.000	118.714	1.037	1.000	○
seismic - 4	59.110	107.000	67.365	1.086	1.000	○
seismic - 5	75.610	99.000	49.125	1.133	1.000	○

APPENDIX 6 PHOTOS OF PROJECT SITE

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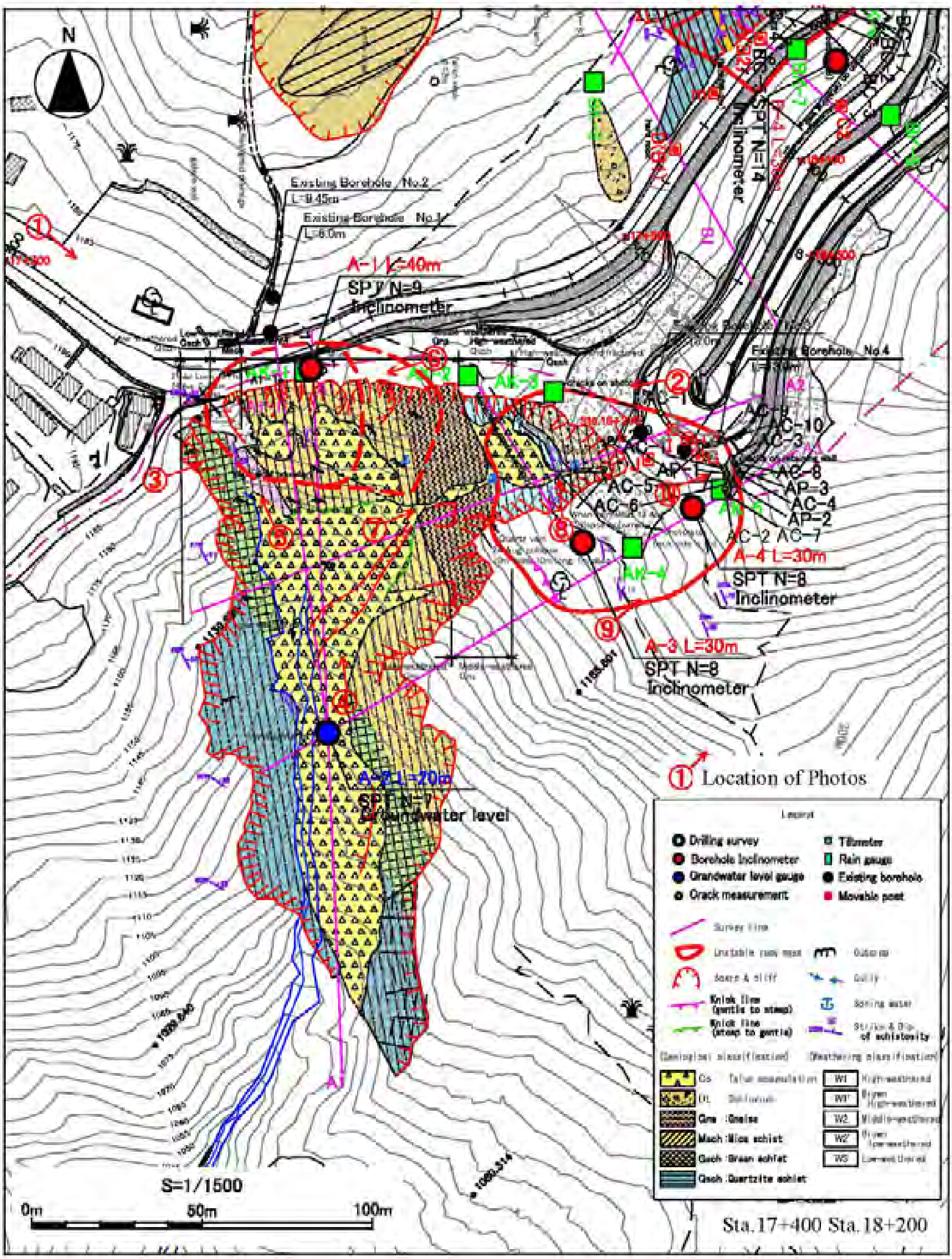
N
Existing Borehole No.2
L=9.45m
Existing Borehole No.1
L=6.0m
A-1 L=40m
SPT N=9
Inclinometer
Existing Borehole No.4
AC-10
AC-3
AC-8
AP-3
AC-4
AP-2
AC-2 AC-7
AC-5
AC-6
A-4 L=30m
SPT N=8
Inclinometer
A-3 L=30m
SPT N=8
Inclinometer
A-2 L=20m
SPT N=7
Groundwater level
SPT N=14
Inclinometer
① Location of Photos
Drilling survey
Borehole Inclinometer
Grandwater level gauge
Crack measurement
Tiltmeter
Rain gauge
Existing borehole
Movable post
Gns :Gneiss
Msch :Mica schist
Gsch :Green schist
Qsch :Quartzite schist
S=1/1500
0m
50m
100m
Sta.17+400 Sta.18+200

Photo.1 Full view at Study Site.

Photo.2 Full view at Sta.17+400.（from Sta.18+200）


Photo.3　　Full view of a failure at Sta.18+200 site.（from Sta.17+400）


Photo.4　　Failure at Sta.17+400.

Photo.5-1 A geological boundary between slightly weathered green schist and highly weathered mica schist.

Photo.5-2 Close up view of Photo.5-1.

Photo.6 Surface failures at Sta.17+400.

Photo.7 The lower of failure at Sta.18+200.


Photo.8 Unstable bedrock due to creep at Sta.18+200.


Photo.9 The side of unstable zone at Sta.18+200

Photo.10   Cracks on the wall at Sta.18+200

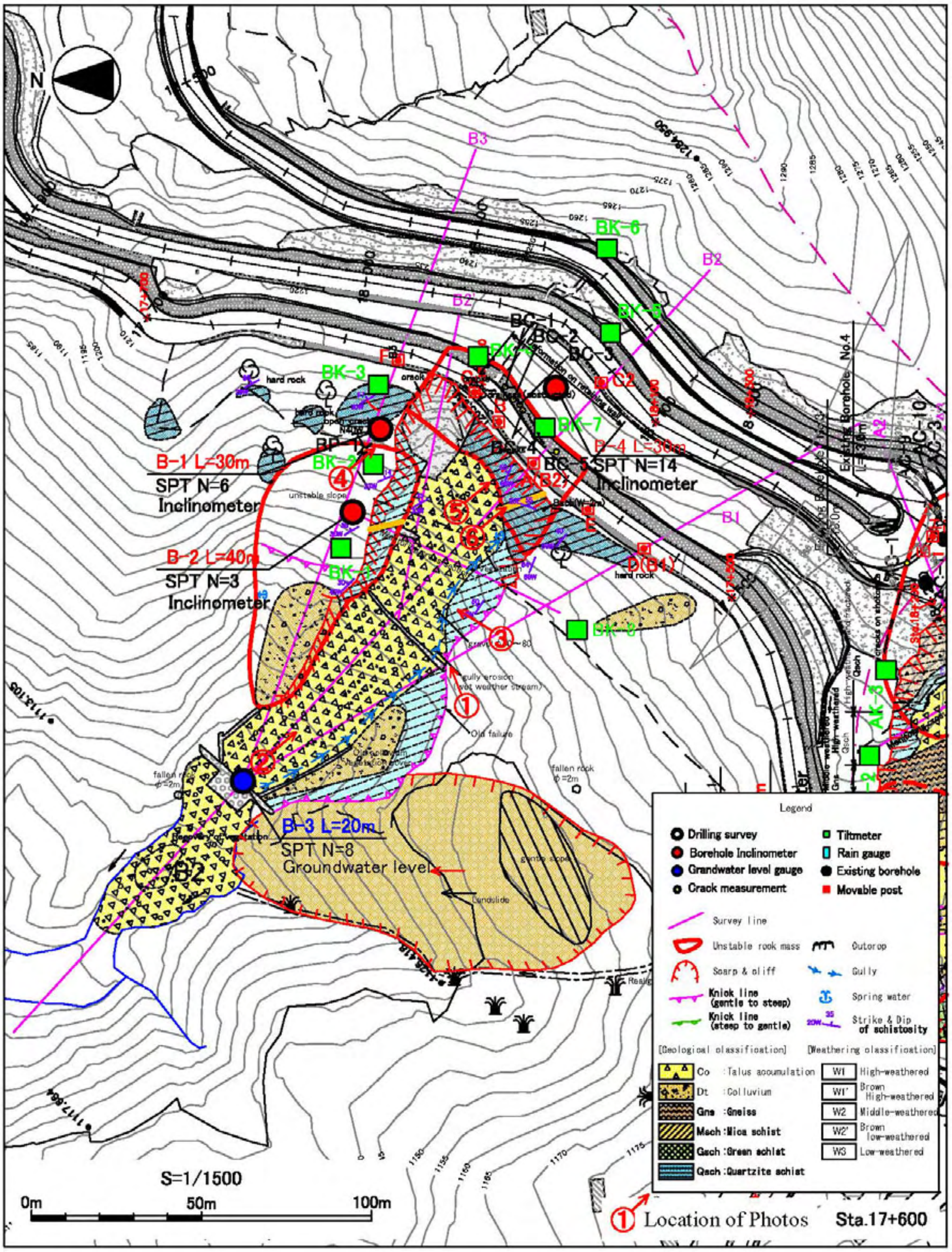
B-1 L=30m
SPT N=6
Inclinometer
B-2 L=40m
SPT N=3
Inclinometer
B-3 L=20m
SPT N=8
Groundwater level
B-4 L=30m
SPT N=14
Inclinometer
BK-1
BK-2
BK-3
BK-6
BK-7
BK-8
Legend
Drilling survey
Borehole Inclinometer
Groundwater level gauge
Crack measurement
Tiltmeter
Rain gauge
Existing borehole
Movable post
Survey line
Unstable rock mass
Outcrop
Scarp & cliff
Gully
Knick line (gentle to steep)
Spring water
Knick line (steep to gentle)
Strike & Dip of schistosity
[Geological classification]
Co :Talus accumulation
Dt :Colluvium
Gns :Gneiss
Msch :Mica schist
Gsch :Green schist
Qsch :Quartzite schist
[Weathering classification]
W1 High-weathered
W1' Brown High-weathered
W2 Middle-weathered
W2' Brown low-weathered
W3 Low-weathered
S=1/1500
0m
50m
100m
Location of Photos
Sta.17+600

Photo.1　Full view of a failure at Sta.17+600 site.

Photo.2　Full view of a failure at Sta.17+600 site. (from the lower of slope)

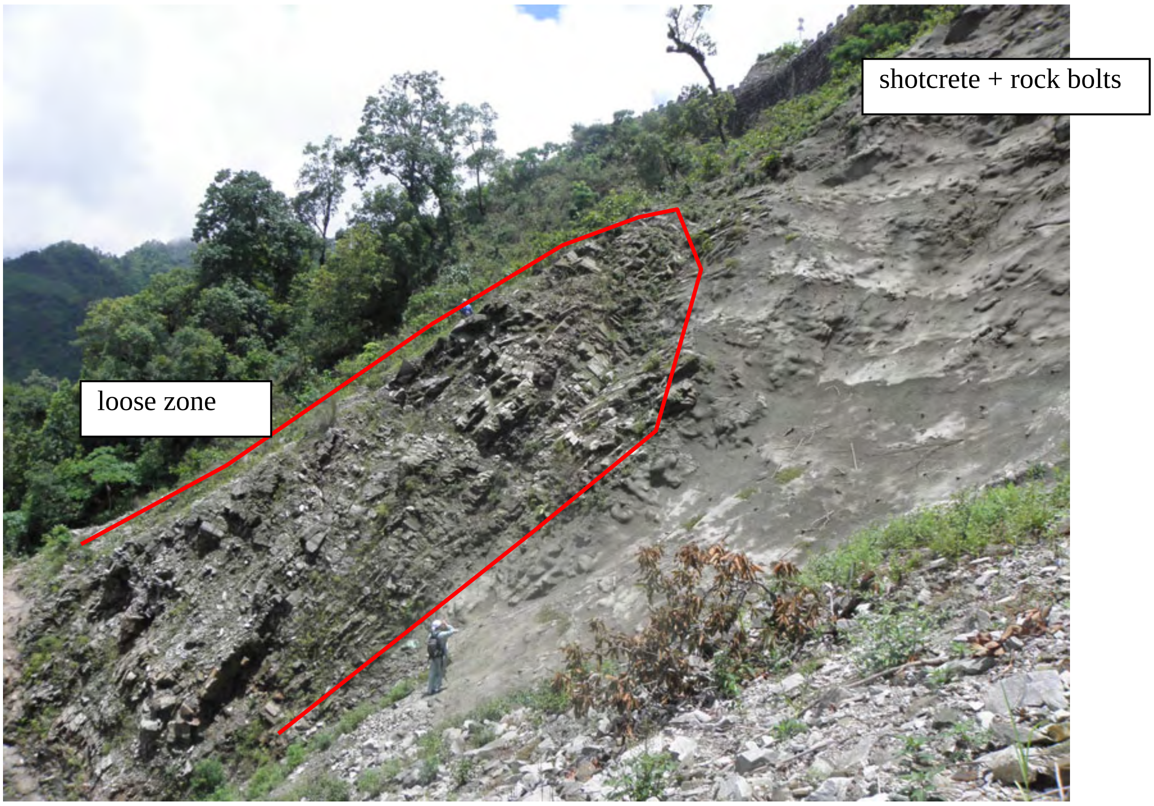

Photo.3　Loose zone under the failure at Sta.17+600.

Photo.4　Crack on loose zone under the failure at Sta.17+600.(crack wide:43cm, N20W)

Photo.5　Cracked Quartz Schist at the upper part of the failure.

Photo.6　Geological outcrop at Sta.17+600 site. (Cracked Quartz Schist)

Runoff water during heavy rain　20 August 2010（Rainfall 35mm/h）

Sta.17+400

Runoff water during heavy rain　20 Aug 2010（Rainfall 35mm/h）

Sta.17+600

Runoff water during heavy rain　20 Aug 2010（Rainfall 35mm/h）

Sta.18+200

APPENDIX 7 M/D: MINUTES OF DISCUSSION

Minutes of Discussions
on the Preparatory Survey
on the Project for Countermeasure Construction for the Landslides
on Sindhuli Road (Section II)
in Nepal
(Explanation of Draft Final Report)

In June and November 2010, the Japan International Cooperation Agency (hereinafter referred to as "JICA") dispatched the Preparatory Survey Team on the Project for Countermeasure Construction for the Landslides on Sindhuli Road (Section II) (hereinafter referred to as "the Project") to Nepal and through discussions, field survey and technical examination of the results in Japan, JICA prepared a draft final report of the survey.

In order to explain and to consult with the concerned officials of the Government of Nepal on the contents of the draft final report, JICA sent to Nepal the Explanation Team (hereinafter referred to as "the Team"), which is headed by Mr. Toru Take, Senior Representative of JICA Nepal Office, from January 18 to 25, 2011.

As a result of discussions, both sides confirmed the main items described in the attached sheet.

Kathmandu, January 20, 2011

Toru TAKE Leader Preparatory Survey Team Japan International Cooperation Agency (JICA)	Deputy Director General Hari Bhakta SHRESTHA Deputy Director General Foreign Cooperation Branch Department of Roads (DOR) Ministry of Physical Planning & Works (MOPPW) The Government of Nepal

Government of Nepal
Ministry of Physical Planning & Works
Department of Roads
Foreign Co-operation Branch

ATTACHMENT

1. Components of the Draft Final Report

The Nepalese side understood and accepted in principle the countermeasure works proposed and explained by the Team.

2. Countermeasure Works at Sta. 17+400

The Team explained to the Nepalese side that the Team judged the DoR has enough capacity in the aspect of finance and technical standard to implement the countermeasure works at Sta. 17+400 based on the result of the Survey, and requested to examine the possibilities for the Nepalese side to implement the works at their own expenses.

The Nepalese side responded that the Nepalese side intended to implement the countermeasure works at Sta. 17+400 with their own expenses, in case the Japanese side would accept a request for the implementation of countermeasure works at the two (2) other sites (Sta. 17+600, Sta.18+200) with grant.

The both sides confirmed that the Nepalese side would prepare and submit the application of the request to the Government of Japan within a few months.

3. Schedule of the Survey

JICA will complete the Final Report in accordance with the confirmed items and send it to the Nepalese side by the end of April 2011.

4. Implementation Schedule

Both sides confirmed that the implementation schedule of the rehabilitation works should be examined again on the stage of next survey in consideration of the timing of the full opening of the Sindhuli Road.

END

Deputy Director General

Government of Nepal
Ministry of Physical Planning & Works
Department of Roads
Foreign Co-operation Branch

APPENDIX 8 REQUEST FOR THE TRANSFER FOR SLOPE MONITORING

Government of Nepal
MINISTRY OF PHYSICAL PLANNING & WORKS
DEPARTMENT OF ROADS
Banepa-Sindhuli-Bardibas Road Project

Phone: 4253938 | 4253786 | 4250680
Fax: 4260940

Thapathali
Kathmandu, Nepal

Ref. No. 1/067-68 Cha.no.451
Your ref. No.

Date: 24.01.2011

Mr. Toru Take
Senior Representative
Japan International Cooperation Agency
Nepal Office

Subject: Request for the Transfer for Slope Monitoring

Dear Sir

First of all we would like to express my sincere thanks for your utmost cooperation in successfully carrying out the Preparatory Survey on the project for Countermeasure Construction for the Landslides on Sindhuli Road (Section II).

DoR has been asked on the importance of slope monitoring for the landslide slopes in the project area during the field survey. And, we have come to know its importance for the safe traffic movement.

We have also come to know that the monitoring in the project area had been done until the end of November by the study team. We, therefore, would like to request you to transfer the equipments listed in the attached table to DoR so that we can continue the monitoring in the project site.

Sincerely yours

Bindu Shamser Rana

Project Manager

Bindu Shamser RANA
Project Manager of Banepa Sindhuli Bardibas Road Project

Government of Nepal
MINISTRY OF PHYSICAL PLANNING & WORKS
DEPARTMENT OF ROADS
Banepa-Sindhuli-Bardibas Road Project

Phone: 4253938, 4253786, 4250680
Fax: 4260940

Thapathali
Kathmandu, Nepal

Ref. No.
Your ref. No.

Date: 24-01-2011

List of Equipment for Slope Monitoring

No.	Description	Unit	Quantity
1	Portable Ground Water Gauge (Sakatadennki, STC-2C-50A)	piece	1
2	Aluminum pipes for Borehole Inclinometer	m	156m (6 nos bore hole)
3	Borehole Inclinometer (Chibasokki Corp, DRK-40DF)	Set	1
4	Ground surface tiltmeter (Manriki Survey Ltd)	Set	16 13 : installed 3:reserves
5	Rainfall gauge (Instrument and Data Logger) (Yoshino Keisoku Co., Ltd, No.OW-34-BP and RF-3	Set	1

Bindu Shamser RANA
Project Manager
Project Manager

APPENDIX 9 SUMMARY OF ESC STUDY FOR THE PROJECT FOR COUNTERMEASURE CONSTRUCTION FOR THE LANDSLIDES ON SINDHULI ROAD (SECTION II)

Summary of ESC Study for the Project for Countermeasure Construction for the Landslides on Sindhuli Road(Section II)

1 Title of the Cooperation Project

The Project for Countermeasure Construction for the Landslide on Sindhuli Road (Section II)

- ✧ Relevant Report: Report on The preparatory Survey on The Project for Countermeasure Construction for Landslide on Sindhuli Road (Section II)

2 Categorization and its reason

Category B

Reason::

(1) The project is a rehabilitation work for sections where are being affected by landslides. So, landslide areas will be stabilized after the project completion. According to “Policy Document; Environmental Assessment in the Road Sector” this type of project correspond to category “f” that is “Routine, recurrent, emergency maintenance” which is exempted from environmental assessment, generally.

(2) There will be no Project Affected Persons (PAPs) who is needed to remove due to implementation of the project.

(3) But, some slope will be cut where suitable protection should be required and some social problems will come up during construction stage.

3 Proposed Project and Location

3.1 Background and objective of the project

Sindhuli Road has been constructed carefully to cope with sediment-related disasters. However, in the process and after construction, the road remains affected by many sediment-related disasters. Most of its damaged sections have been rehabilitated suitably. Nevertheless, since some sections have not yet been repaired sufficiently, full traffic operations will not be sustained even after the full opening of the road.

To improve the current traffic situation and strengthen the road maintenance system for the fully opened Sindhuli Road, the Government of Nepal requests the Government of Japan to grant technical assistance project. Japanese International Corporation Agency (JICA) implemented a brief study on strengthening the maintenance system for Sindhuli Road in August 2009. During the study, the present condition of the completed I, II, IV sections of Sindhuli Road were inspected. This is intended to identify portions which shall be improved before full opening. Most of the identified sites which could be improved through the common method adopted in Nepal. However, among the slope failures along the road, Sta. 17+400, Sta. 17+ 600 and Sta. 18+200 in Section II were found to be most serious where such failures could cause fatal impacts to road traffic in the future. It is judged in the study that permanent countermeasures for these three sites should be implemented by introducing advanced technologies that are necessary for maintaining sustainable and safe road traffic.

The objective of the project is implementation of permanent countermeasures for three portions above to keep traffic function and safety of Sindhuli Road.

3.2 Location

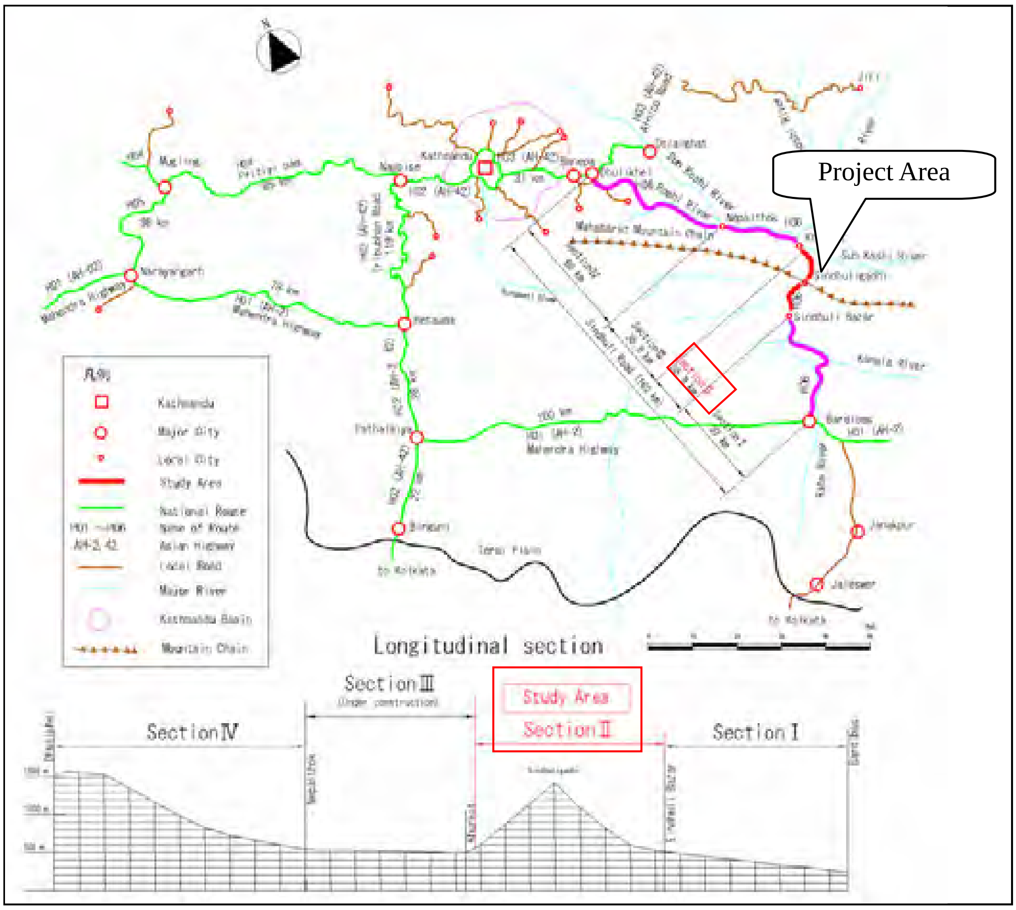

Figure1 Location of Project Site

The project area is located in Mahabarat Mountain around 60km from Bardibas where the starting point of Sindhuli Road is. And, it covers the surrounding areas of Sta. 17+400, Sta. 17+600 and Sta.18+200 where is situated in Dhungre Bhanjyan Village, Bhadrakali VDC, Sindhuli District.（see Figure1 and Figure 2）

3.3 Profile of Project Area

Topo-Geological Situation

The project area is located in the top of Mahabarat Mountain Range which is made up by successive geo-tectonic movement in Tertiary. The geology of the project site is composed of schistose rocks of Pre-Cambrian which is rather hard and sound. But they are sheared and fractured by MBT (Main Boundary Thrust) and MT (Mahabarat Thrust) partly which make slopes unstable.

Climate

Project site is situated in rich precipitation zone in Nepal where annual rainfall is around 1,800mm/year. Average annual maximum and minimum temperature are 28℃ and 16℃ respectively.

Table 1.1 Monthly Rainfall of Project Site

Year	Jan to Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov to Dec	Total
2003	0			197.5	457.5	291	328.5	44.5	0	
2004	0	36	105.5	207.5	764	216.5	264	129.5	0	1,723
2005	0	0	56	86.5	362.5	746	239.5	142	0	1,633
2006	0	0	323.5	556.5	281.5	243	534.5	26.5	0	1966
2007	0	59.5	190.5	546	796	465	540	217.5	0	2,815
2008	0	14	205	554.5	540.5	475	339.5	138	0	2,267
2009	0	15	120	87	352.5	295.5	0	0	0	
Ave.	0	21	167	319	319	508	321	116	0	1,842

(source; study team, July 2010)

Population

Project site is located in Dungre Bhanjyan Villkage, Bhadrakali VDC, Sindridistrict, Janakapur Zone.

Total households and population of Dhungre Bhanjyan Village (project site) are 25 and 181 respectively. They are living with subsistence farming and only four house hold is engaging small scale store and trading business.

Table 1 Household and Population of Project Area

Ward No.	Household	Population		
		Total	Male	Female
1	18	132	62	70
2	7	49	25	24
Total	25	181	87	94

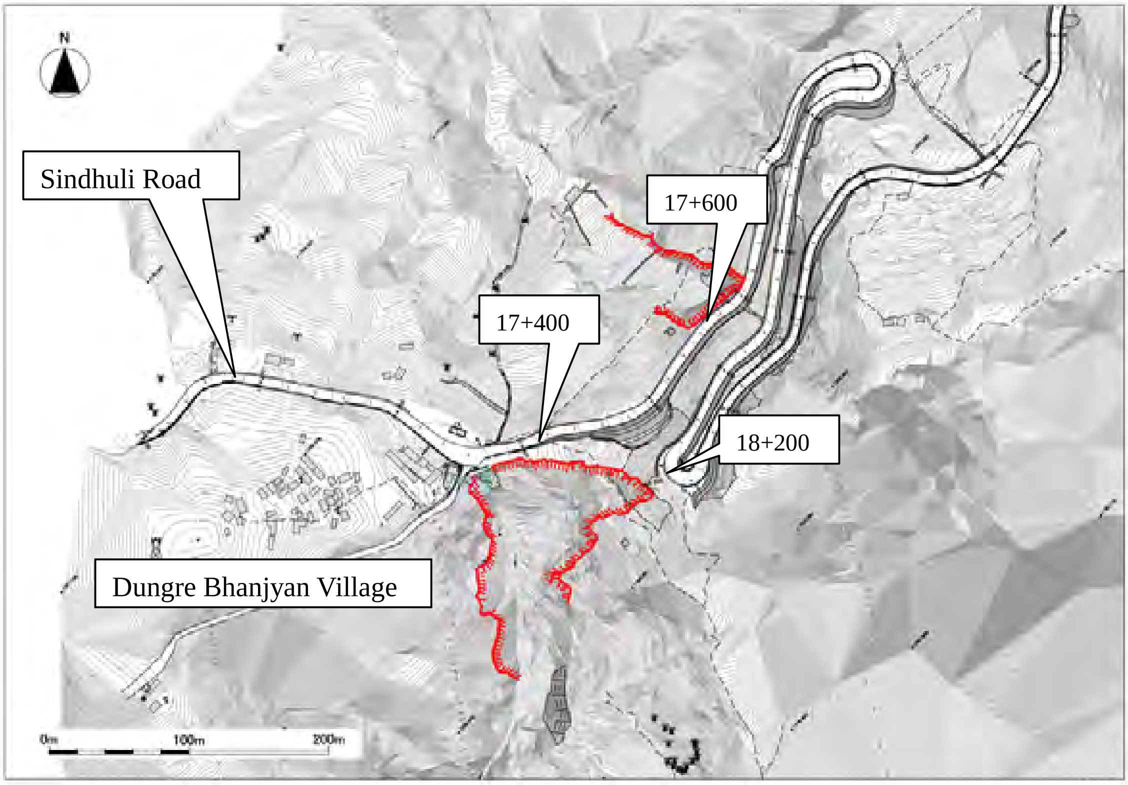

Figure 2 Project Area

Land Use

Project site is surrounded by denuded land and limited cultivate area. as shown in Figure 3. Inhabitant area is situated in the western part of project along the road.

Sal tree and chilaune is growing mainly in the forest area and millet is grown mainly in cultivated area.

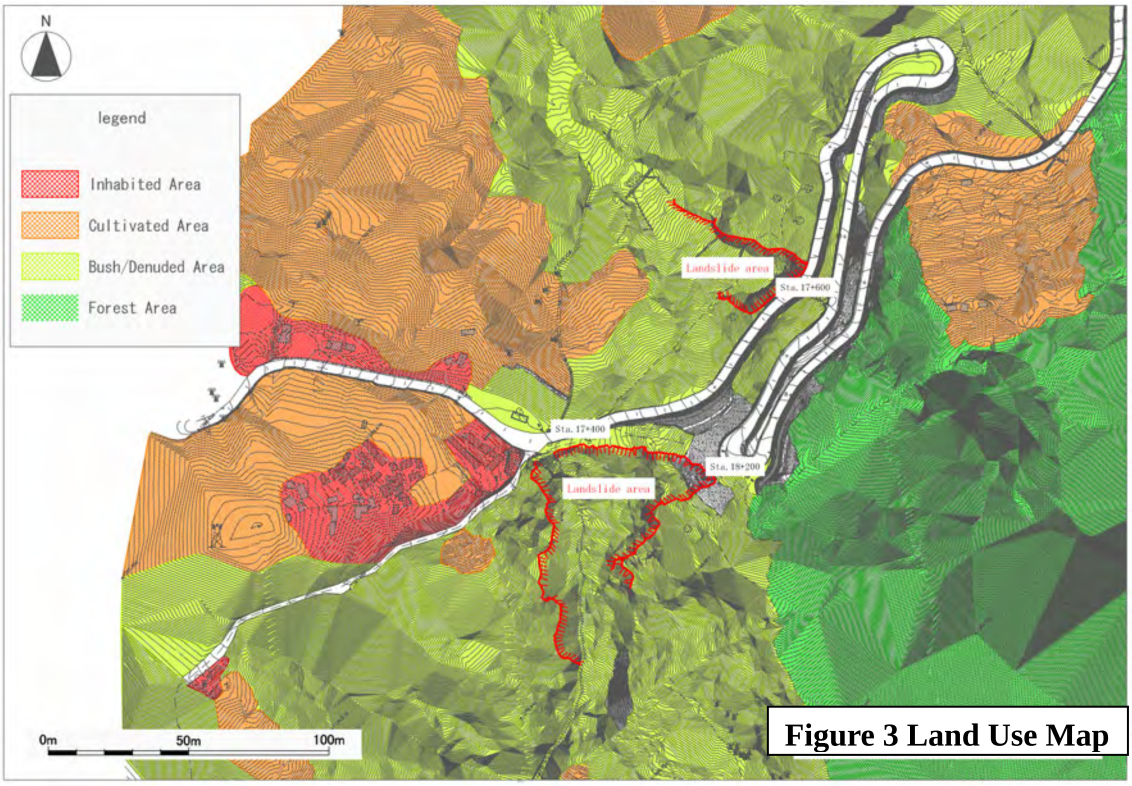

Figure 3 Land Use Map

4. Legal Framework of Environmental and Social Considerations (Laws and Regulation relevant Environment Impact Assessment)

3.1 Law and regulations

The following are Nepalese principal laws and guidelines for environmental and considerations.

(1) Laws

- Environmental Protection Act(EPA),1996
- Environmental Protection Rules(EPR),1997(amended 1999)
- Forest Act 1977 and Forest Rules 1995
- National Park and Wildlife Conservation Act 1982
- Soil and Watershed Conservation Act 1982
- Land Acquisition Act 1977

(2) Guidelines and manuals

- National Environment Impact Assessment Guidelines(National Planning Commission and with IUCN-The World Conservation Union,1993)
- Environmental Management Guidelines(Department of Roads,1997)
- Policy Document, Environmental Assessment in the Road Sector of Nepal(Geo0Environmental Unit, department of Roads,2000)
- Public Works Directives(Ministry of Physical Planning and Works,2002)
- Reference Manual for Environmental and Social Aspects of Integrated Road Development(Department of Roads,2003)

3.2 Procedures and requirement for Environmental Assessment

The implementing organization for the project is Department of Road (DOR), Ministry of Physical Planning and Works (MOPPW). DOR which is the proponent for this project should obtain the approval on IEE for this project from MOPPW.

According to the EPA and EPR, DOR should obtain the approval from the Ministry of Environment, Science and Technology (MOEST) in the case of EIA process. But, it is judged that EIA will not be required for this project.

DOR should carry out Initial Environmental Examination (IEE) in line with the Guideline "Policy Document Environmental Assessment in the Road Sector" which shall be approved by relevant organizations and stakeholders. But, according to "Policy Document; Environmental Assessment in the Road Sector" this type of project correspond to category "f" that is "Routine, recurrent, emergency maintenance" which is exempted from environmental assessment, generally. Only tree cutting matter shall be approved by District Forest Office(DFO).

Geo-Environmental Unit of DOR is expected for implementing the environmental management and monitoring plan of the project

4. Outline of the Project, Alternatives (Proposed Project, Comparative Examination of Alternatives, Selected Project on the Basis of the Preliminary Study)

The road construction of Sindhuli Road has been affected by landslides in the process and after completion. Although most of damaged parts by landslide have been repaired suitably, landslides in sta.17+400, 17+600 and 18+200 are still threatening the traffic function of the road seriously.

This project is intending implementation of permanent countermeasures for three sites above to keep sustainable traffic function of the road.

Major countermeasures for the three sites are as follows.

- 17+400: Slope protection with concrete gravity wall, gabion wall and mortar masonry for upper slope + check dams for the valley
- 17+600: Anchoring for the slope just below the road + embankment for the unstable slope s in the valley
- 18+200: Shifting the road to mountain side

Without implementing permanent countermeasures for three parts of Sindhuli Road Section II above, serious landslides damages would break out in the near future which would give significant impact for the socio-economic activity of Nepal. So, it is recommended to implement permanent countermeasures for the three sites of Section II before full opening of Sindhuli Road.

For further details, refer to “The preparatory survey on the Project for Construction for the Lansslides on Shindhuli Road (Section II)

5. Adverse Environmental and Social Impact (Result of Scoping and Social Consideration Studies)

Environmental and Social impact by implementation of the project is checked along with “Policy Document; Environmental Assessment in the Road Sector of Nepal” which is shown in Table 2.

It is judged that no serious environmental and social impact is found by implementing countermeasure construction for the three sites.

Table 2 Environmental Checklist (construction phase)

Potential Problem	Mitigation action taken by project
1. Slope stability	Slope will be stabilized by the project
2. Spoil disposals ➢ Can spoil be reduced? ➢ Is spoil being tipped away from designated area?	Cut soil will be utilized for embankment. Spoiled will be limited. Spoil will be tipped away from designated area
➢ Is spoil falling or being washed on to farm land?	Spoil is not falling or washing to farm land
3. Water management	
➢ Are slope drainage designs inadequate?	Slope drainage will be implemented adequately
➢ Are drainage outfalls unprotected against score and erosion?	Drainage outfall will be protected by check dams
➢ Is there any disruption of drinking or irrigation water supplies	No disruption for drinking water and irrigation water supply
4. Land use ➢ Has there been any loss of land for which landowners should be compensated	No land loss will occur.
5. Plants and wildlife	
➢ Are large numbers of trees being removed?	Limited numbers of trees will be removed
➢ Is any form of wildlife being disturbed	No wild life will be disturbed.
6. Quarries and borrow pits ➢ Are there any abandoned quarries or borrow pits	No abandoned quarry or borrow pit
7. Stone crushing and asphalt plants ➢ Is the project operating stone crushing or asphalt plants?	No crushing or asphalt plants
8. Hazardous materials ➢ Is the project using any type of hazardous materials (e.g. bitumen, cement, paint, explosives, fuels, lubricants)?	Cement will be used for protection measures. But, protective measures to reduce impact for environment.
9. Camp operation ➢ Does the project have work and labor camp? ➢ Are laborers cutting trees for firewood?	Mostly local labors will be utilized. Hence, no labor camp is necessary.
10. Dust ➢ Is dust generated from construction works or construction traffic? ➢ Does the road have been earth or gravel surface?	Dust and noise will be generated during the construction term. The road is black topped.
11. Social issues ➢ Are there any PAPs? ➢ Are local people being excluded in the project activities? ➢ Were promises made to local people during planning? ➢ Are there conflicts between the project and local people?	No PAPs Local people will have opportunity to be employed as a labpour. No promise with local people. No conflict between the project an local people.
12. Road safety	

➢ **Does the construction disturb the road traffic?**	**The project will disturb the road traffic to some extent.**

8. Mitigation and Monitoring for Key Impacts

The project is the rehabilitation and repairing for landslide hazard slopes in limited area, 17+400, 17+600 and 18+200 in the Section II. So, risk of landslide will be reduced completely after Project completion. And impact to environment and social are also limited in the duration of construction as follows.

- ✓ New cut slope will be formulated by road shifting at sta.18+200
- ✓ Traffic disturbance and safety
- ✓ Degradation of social condition by operating labor camp

Impact generated by the project should be covered designing of countermeasures and implementation management. Countermeasures for the slopes shall be designed carefully considering environment and social impact and construction shall be managed properly and severely.

11. Important Notice on Basic Design Research

The following matters should be noted on environmental and social consideration during the Basic Design Study and Implementation duration.

- ➢ Countermeasure designing and execution scheme shall be reexamined from view point of effectiveness of countermeasures and impact of environmental and social considerations.
- ➢ As per DOR Policy Document environment study is exempted. If tree cutting is necessary, DOR should conduct IEE on the project.