CHAPTER 2 CONTENTS OF THE PROJECT

2.1 BASIC CONCEPT OF THE PROJECT

2.1.1 CURRENT SITUATION

The main road under the jurisdiction of Department of Roads (DOR) in Nepal comprises national highway, branch road and urban highway, which are in service as part of Strategic Road Network (SRN). Known as the No.6 National Road, Sindhuli Road is one of the most important national highways among them.

On April 25, 2015, a magnitude 7.8 earthquake occurred in Nepal. Because the earthquake intensity has exceeded the designed earthquake resistance standards, damaged by this earthquake, road subsidence, cracks and slope failures have arisen at about 24 locations, though the road had been properly maintained. After the earthquake, emergency rehabilitation work was conducted preferentially on 12 damaged locations with the support of Japan International Cooperation Agency (JICA). Though the emergency rehabilitation work, such as waterproof measurement and detour setting up have been taken to prevent hindrance to the traffic temporarily, the road may still be blocked due to heavy rainfall which may induce erosion and road collapse. Therefore, a full-fledged rehabilitation work is needed for permanent countermeasure.

2.1.2 OVERALL GOAL AND PROJECT GOAL

The Thirteenth Plan (2013/14~2015/16) of the national development plan of Nepal has set the goal of developing a safe and reliable transportation network with the social and economic development of the whole country in mind. In the Fourteenth Plan (2016/17~2018/19), it still aims an expansion of a sustainable and safe road network.

This project aims to contribute to the development of social economy by ensuring the traffic safety for road users through carrying out the rehabilitation work of Sindhuli Road damaged by the earthquake in 2015.

2.1.3 OUTLINE OF THE PROJECT

The outline of the project is shown in **Table 2.1.1**.

Table 2.1.1 General Outline of Countermeasures

Site	Countermeasure	Quantity
Sta.17+400 Section II	Ground anchors	Ground anchor, 158 pieces
	Crib works F500	A=1,270 m^2, Shotcrete in the frame A= 860 m^2
	Crib works F300	A=1,060 m^2, Shotcrete in the frame A= 710 m^2
	Rock bolts	L=3 m/each, 300 pieces
	Excavation works	V=370 m^3
	High intensity net	High intensity net, A=2,800 m^2 Rock bolts, L=3 m/each, 1,240 pieces
	Vegetation works	Vegetation bags, 4,140 pieces
	Gabion check dams	V=350 m^3
	Asphalt pavements	A=420 m^2
Sta.33+440 Section II	Ground anchors	Ground anchor 32 pieces
	Anchor plates	32 nos.
	H beam installation	Shotcrete A=160 m^2, H beams 32 pieces, Concrete V=25 m^3
	Restoration of side ditch	L=43 m
	Asphalt pavements	A=200 m^2
Sta.33+695 Section II	Ground anchors	Ground anchor 18 pieces
	Anchor plates	18 nos.
	H beam installation	Shotcrete A=95 m^2, H beams 18 pieces, Concrete V=19 m^3
	Restoration of side ditch	L=45 m
	Asphalt pavements	A=150 m^2
Sta.11+620 Section III	Ground anchors	Ground anchor 20 pieces
	Anchor plates	20 nos.
	H beam installation	Shotcrete A=90 m^2, H beams 10 pieces, Concrete V=10 m^3
	Side ditch	L=12 m
Sta.15+520 Section III	Ground anchors	Ground anchor, 40 pieces
	Anchor plates	40 nos.
	H beam installation	Shotcrete A=250 m^2, H beams 40 pieces, Concrete V=50 m^3
	High intensity net	High intensity net, A=2,500 m^2 Rock bolts, L=3 m/each, 1,100 pieces
	Asphalt pavements	A=210 m^2

Source: JICA Survey Team

2.2 OUTLINE DESIGN OF THE JAPANESE ASSISTANCE

2.2.1 DESIGN POLICY

2.2.1.1 BASIC POLICY

(1) Target Section

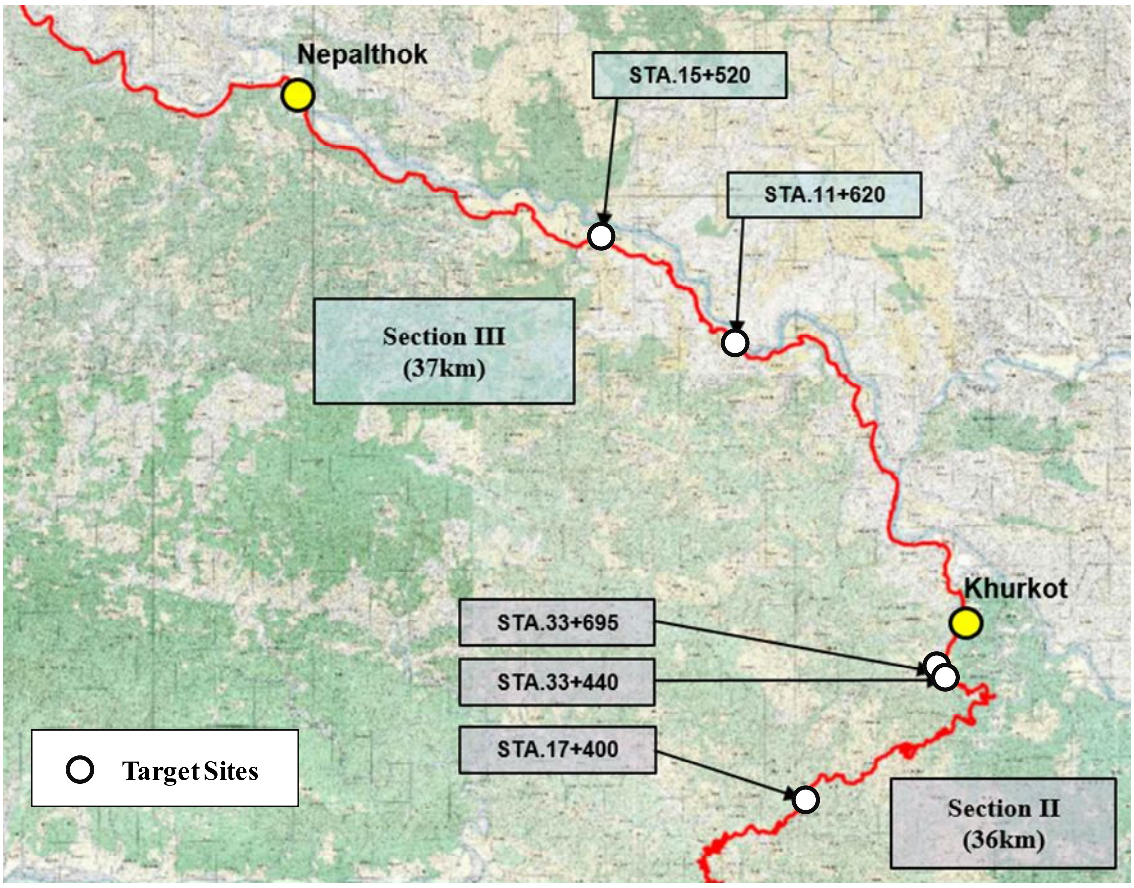
Table 2.1.1 shows the target sections of Japanese assistance. **Figure 2.2.1** shows the location of target sites.

Table 2.2.1 Target Sections of the Japanese Assistance

Sites	Target Sections
Sta.17+400, Section II	Sta.17+360 to 440 (Section is 80 m.) Natural slope below the road (Slope length is about 90 m.) Depth of unstable rock mass is about 10 m.
Sta.33+440, Section II	Sta.33+430 to 465 (Section is 35 m.)
Sta.33+695, Section II	Sta.33+680 to 710 (Section is 30 m.)

Sta.11+620, Section III	Sta.11+600 to 630 (Section is 30 m.)
Sta.15+520, Section III	Sta.15+520 to 560 (Section is 40 m.)

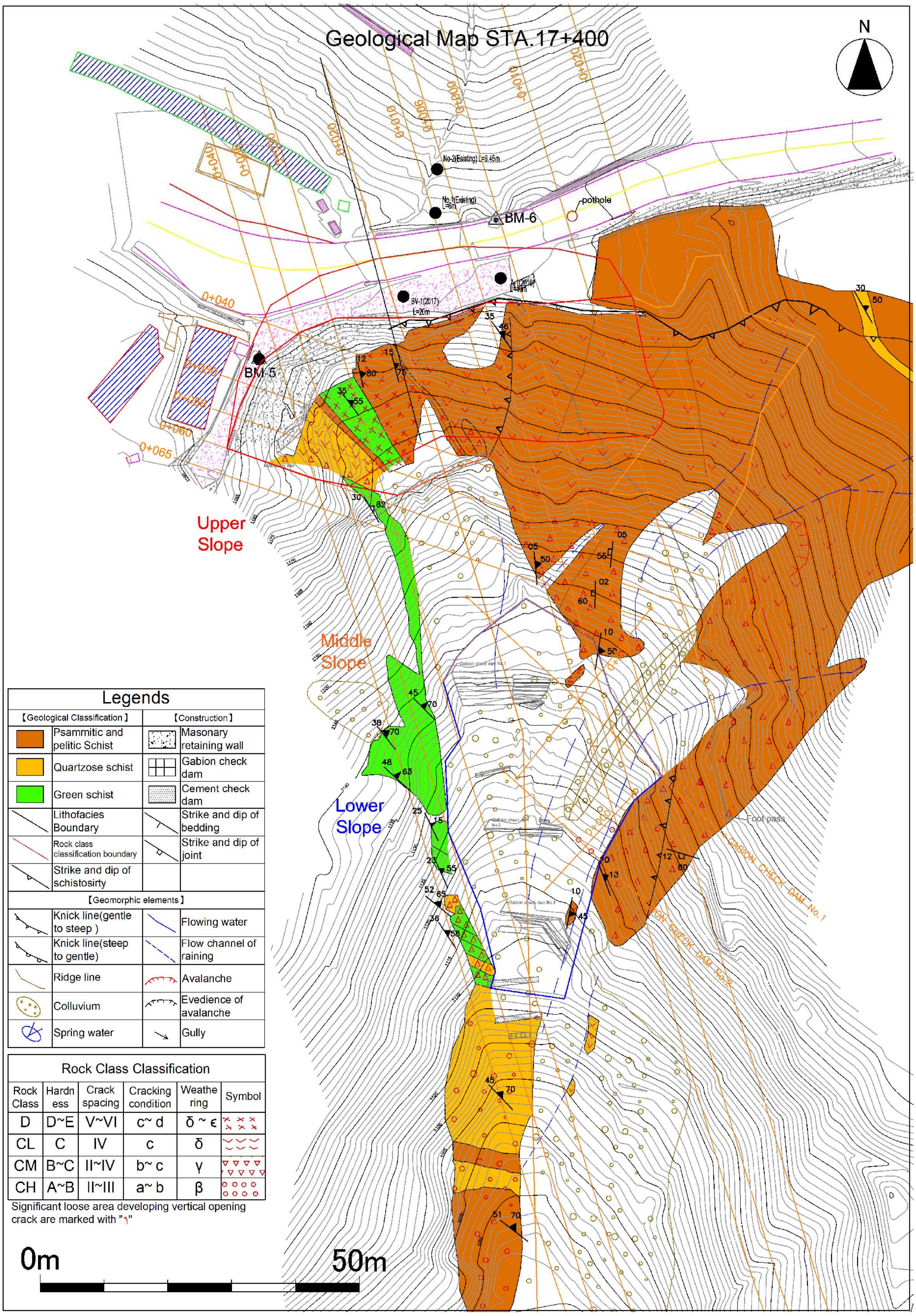
Source: JICA Survey Team



Source: JICA Survey Team

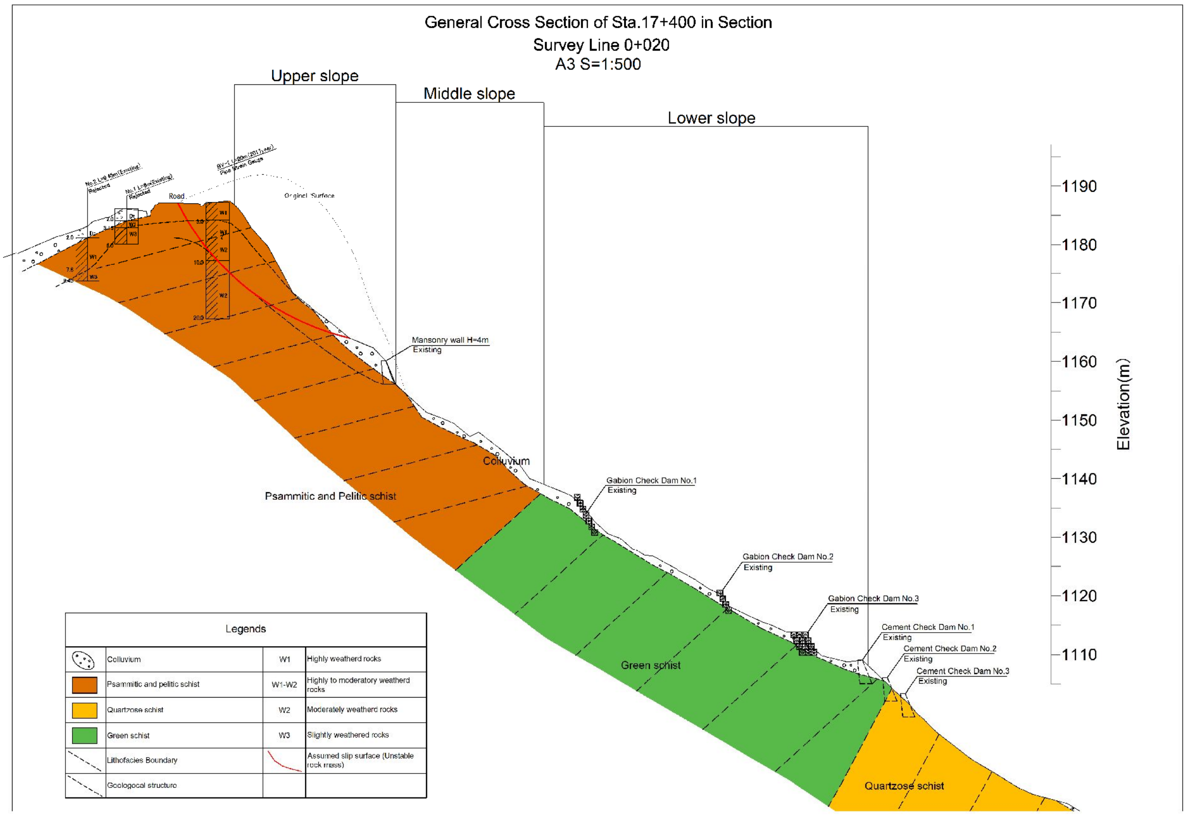
Figure 2.2.1 Location Map of the Target Sites

The below figures show the result of site reconnaissance for the target sites.



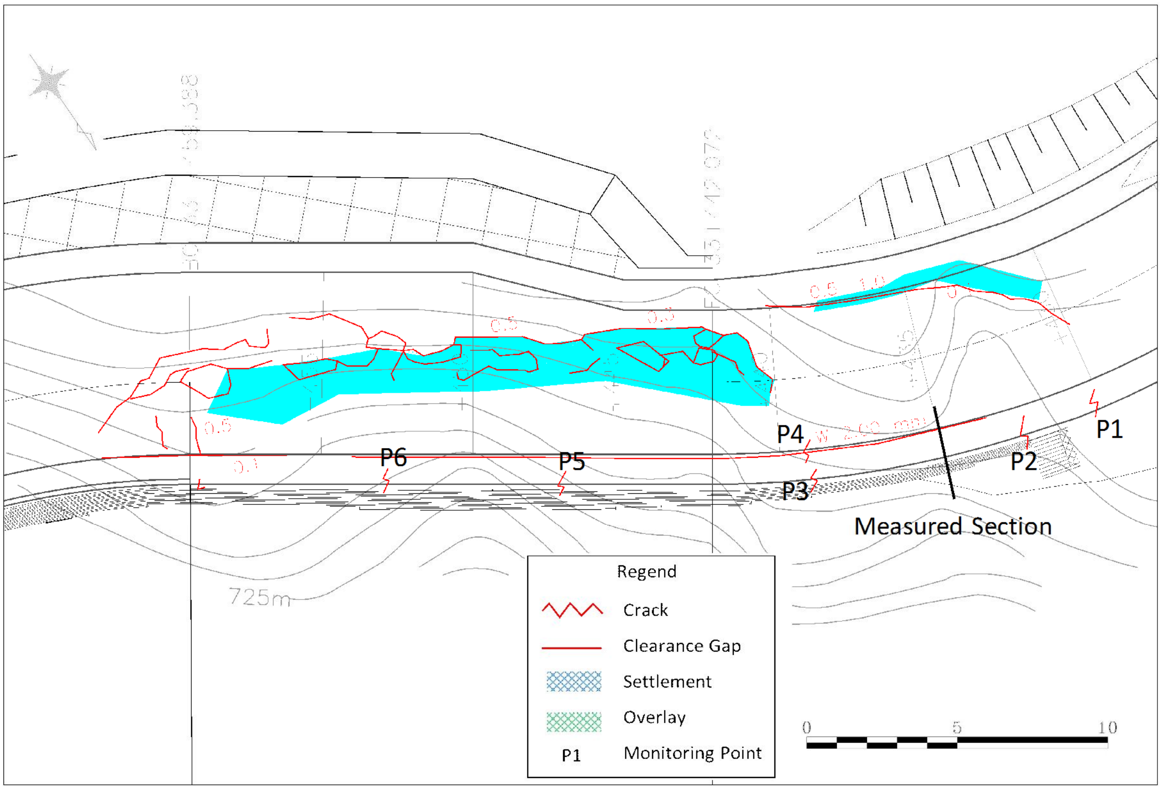
Source: JICA Survey Team

Figure 2.2.2　Site Investigation Map of Sta. 17+400



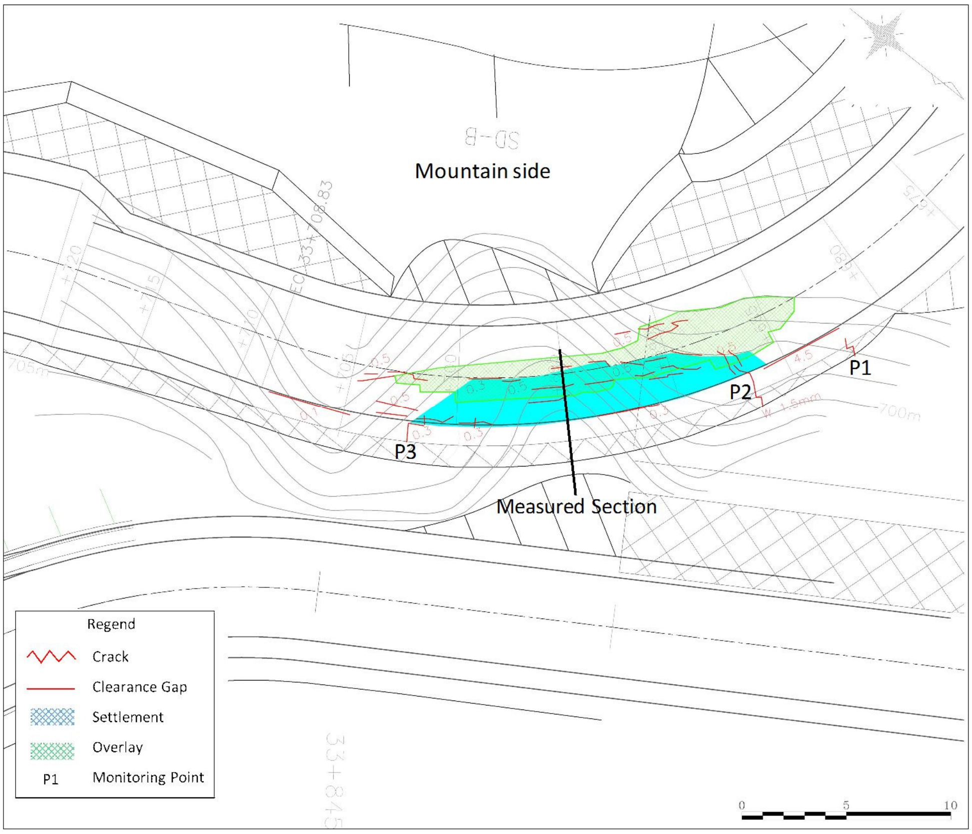
Source: JICA Survey Team

Figure 2.2.3 Geological Cross Section of Sta. 17+400



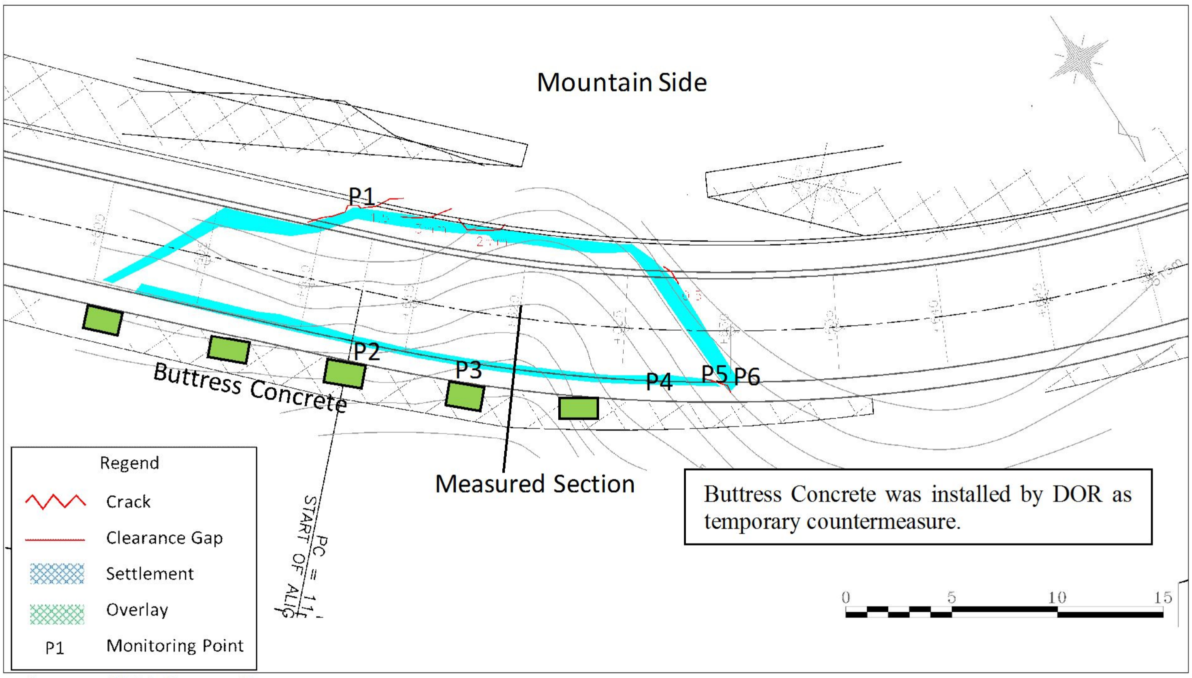
Source: JICA Survey Team

Figure 2.2.4 Site Investigation Map of Sta. 33+440



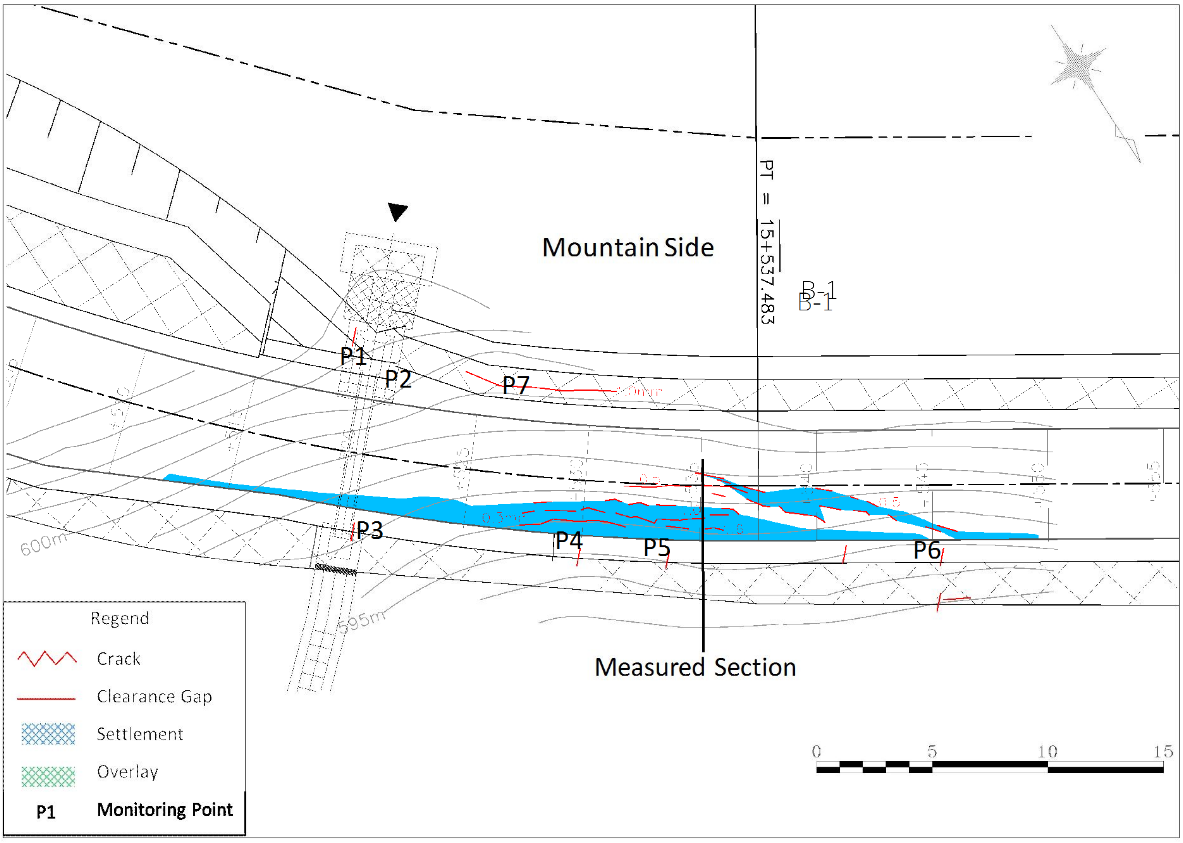
Source: JICA Survey Team

Figure 2.2.5 Site Investigation Map of Sta. 33+695



Source: JICA Survey Team

Figure 2.2.6 Site Investigation Map of Sta. 11+620



Source: JICA Survey Team

Figure 2.2.7 Site Investigation Map of Sta. 15+520

(2) Basic Policy

The risk evaluation indicated that road traffic functions would be seriously affected if these damaged sections were left unattended. Countermeasure alternatives have been examined to maintain sustainable road traffic function with the following policies:

- Permanent countermeasures will be introduced to achieve long-term stability on the target sections and slopes.

- The original function of damaged sections should be restored.

- The measured section should withstand an earthquake of the same scale as in 2015.

- The failure mechanism should be clarified, and the countermeasures adopted for the mechanism should be planned accordingly.

- The planned countermeasure should keep the stability of sliding, overturning and bearing capacity of foundation of gabion wall.

- The road should be trafficable even during construction time.

-The temporary countermeasures implemented by DOR shall be utilized for permanent countermeasure without demolition.

- Mitigation of impacts to natural and social environment should be considered in planning and selecting the countermeasures.

- Maintenance of the countermeasures after completion should be minimal.

2.2.1.2 POLICY ON NATURAL CONDITIONS

(1) Policy on rainfall

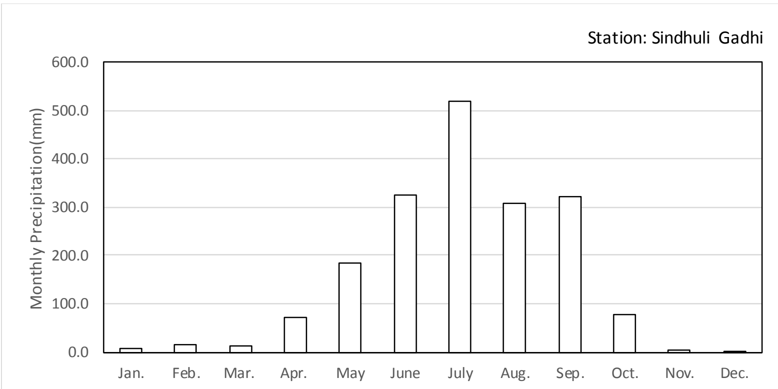
Climate data observed at Sindhuli Gadhi in Section II for the past seven years was used for the study. As shown in Figure 2.1.1, the station at Sta. 17+400 in Section II has an average annual rainfall of 1,850 mm. The maximum average monthly rainfall is 517 mm in July, while the minimum monthly average is less than 5 mm in November and December. The recorded annual rainfall in 2011 was 2,219.6 mm (Refer to **Table 2.2.2**). The period between late May and early October falls under the monsoon season. Pavement works should not be performed during the monsoon season in consideration of quality control and construction safety, respectively. The normal rate of operations was adopted for other works as there would be no large influence of rainfall.

Table 2.2.2 Monthly Rainfall (From 2010 to 2016)

Raingauge station Sindhuli Gadhi   Unit: mm/month

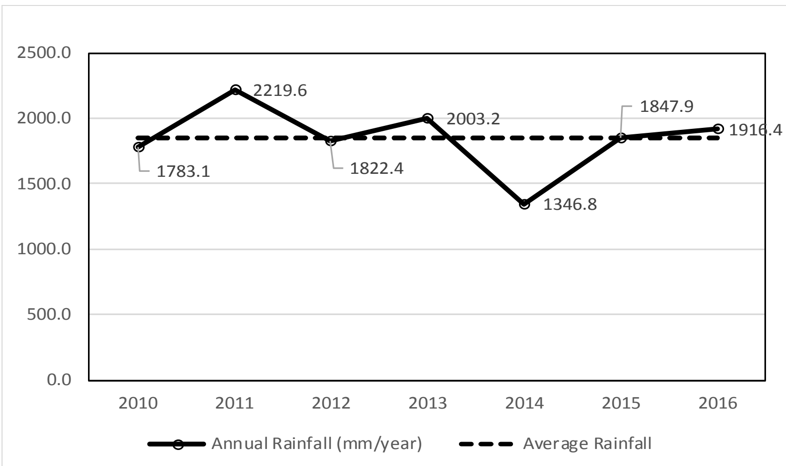
Month / Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Accumulation (mm/year)
2010	0.0	4.3	0.0	48.8	92.0	212.8	421.9	468.6	419.4	115.3	0.0	0.0	1783.1
2011	11.5	17.6	NA	139.7	347.6	392.6	455.6	352.7	400.9	71.6	29.8	0.0	2219.6
2012	12.8	5.5	0.0	66.5	205.4	409.3	462.4	310.8	319.2	30.5	0.0	0.0	1822.4
2013	2.2	42.8	2.6	66.8	185.1	305.5	610.6	266.5	382.7	136.2	1.0	1.2	2003.2
2014	0.0	11.4	11.6	48.5	NA	372.5	555.1	NA	282.0	62.7	0.0	3.0	1346.8
2015	6.0	16.5	67.1	117.8	92.0	229.6	517.6	753.8	NA	39.8	0.0	7.7	1847.9
2016	9.9	2.9	2.8	19.1	378.0	358.3	601.2	NA	448.3	95.9	0.0	0.0	1916.4
max	12.8	42.8	67.1	139.7	378.0	409.3	610.6	753.8	448.3	136.2	29.8	7.7	2219.6
min	0.0	2.9	0.0	19.1	92.0	212.8	421.9	266.5	282.0	30.5	0.0	0.0	1346.8
mean	6.1	14.4	12.0	72.5	185.7	325.8	517.8	307.5	321.8	78.9	4.4	1.7	1848.5

Source: Department of Hydrology and Meteorology



Source: Department of Hydrology and Meteorology

Figure 2.2.8 Average Monthly Rainfall



Source: Department of Hydrology and Meteorology

Figure 2.2.9 Annual Rainfall

1) Sta.17+400

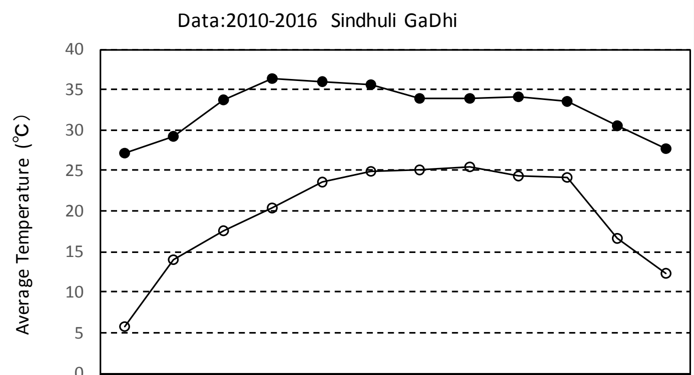
Because the target to be protected is the National Highway No.6, the planned safety factor is set to P·Fs = 1.2, in accordance with the Manual for Slope Protection in Japanese Standard. Conceptually, this corresponds to strengthening the slope stability to the 100-year disaster probability level. In order to strictly evaluate, how much probability rain can be dealt with, it is necessary to analyze the response of groundwater level and rainfall. Then we need to calculate the groundwater level in probability annual rainfall, and evaluate the safety factor at that time. However, detailed groundwater and rainfall observation and analysis are required, and only in landslides where large-scale damage is expected in Japan is considered. It is difficult to quantitatively evaluate the probability of rainfall that can be tolerated against the collapse of the site this time.

2) Sta.33+440, Sta.33+695 in Sec II and Sta.11+620, Sta.15+520 in Sec III

The project site has already been designed taking into account the rainfall conditions in the area. In the service period, there is no deformation due to rainfall, and the drainages such as side ditch have kept their function. However, it is considered that the deformation occurred due to the earthquake and looseness occurred in the ground. For this reason, asphalt shall be planned on the road surface to prevent the penetration of rainwater. However, in Sta.11 + 620 in Sec III, it is concerned that rainwater can penetrate from the mountain side slope, so the drainage system shall be planed.

(2) Policy on tempErature

Climate data observed at Sindhuli Gadhi in Section II for the past seven years was used for the study. In Sindhuli Gadhi, the highest average temperature is at 36.3ºC in April while the lowest average is at 5.8ºC in January, as shown in **Figure 2.2.10**. The Project site is in a continental climate, mainly warm with large temperature differences between day and night. Construction work is carried out during the day, so no special consideration is required for concrete and asphalt casting.



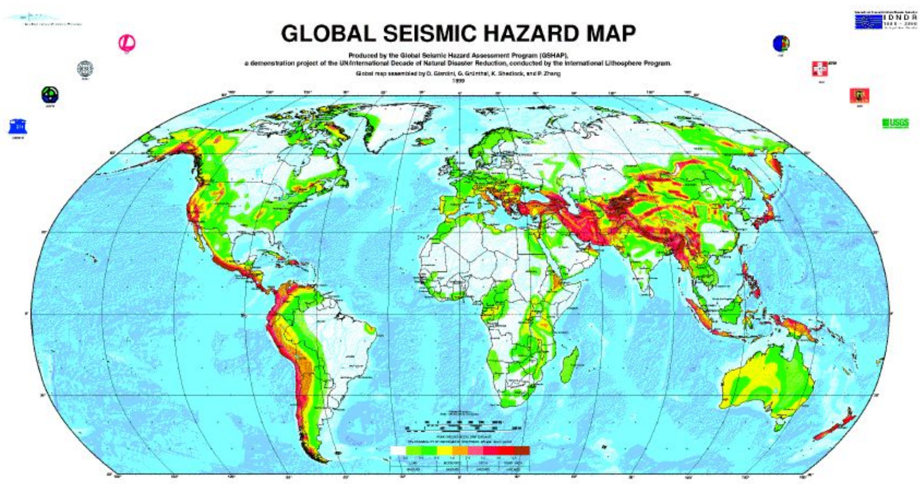
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
max temp	27.2	29.3	33.7	36.3	36.1	35.7	34.0	33.9	34.1	33.6	30.6	27.7
min tmp	5.8	14.1	17.6	20.4	23.7	25.0	25.0	25.5	24.3	24.2	16.7	12.3

Source: Department of Hydrology and Meteorology

Figure 2.2.10 Average Temperature in Sindhuli Gadhi

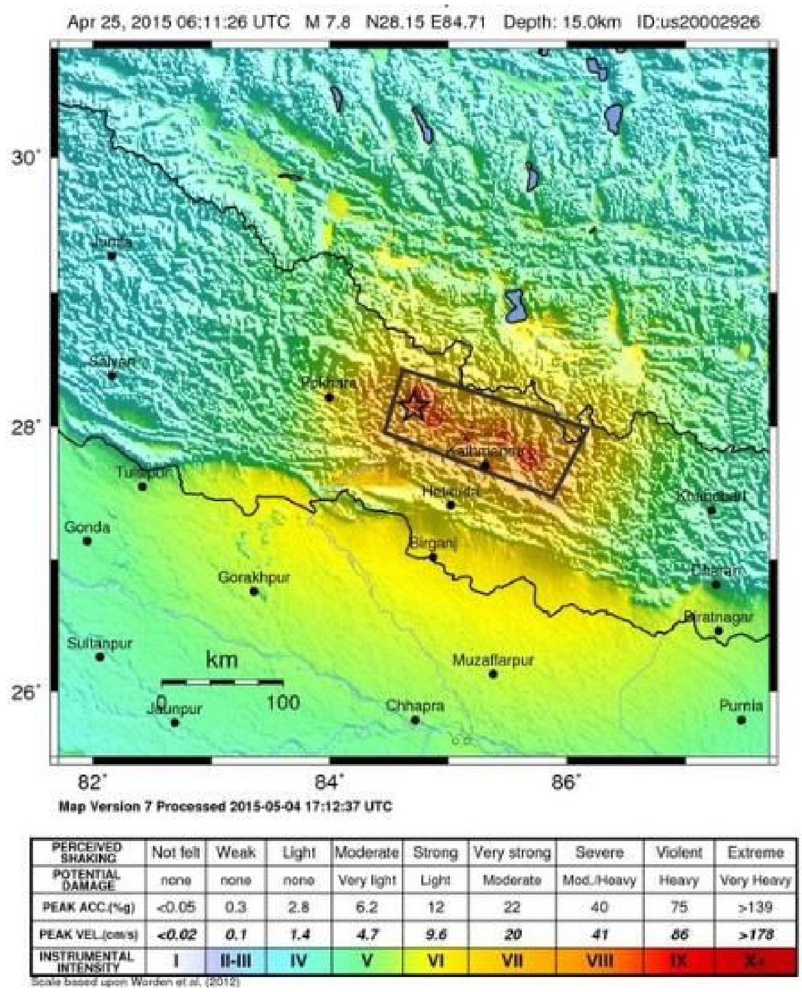
(3) Policy on earthquake

Figure 2.2.11 shows the seismic source distribution in the world. Nepal lies in areas with high seismic density. The most damaging earthquake in the recent years is the 2015 Gorkha Earthquake. Sindhuli Road also got damaged by this Earthquake. Nearly 9,000 deaths occurred, and about 8 million people, equivalent to about 30% of the population of Nepal, suffered damage. According to the US Geological Survey (USGS), the scale of this earthquake was MW 7.8. This scale was the second largest earthquake in Nepal, after the 1934 Bihar / Nepal Earthquake (M 8.1). **Figure 2.2.12** shows the seismic intensity distribution map of the Gorkha Earthquake.



Source: http://static.seismo.ethz.ch/GSHAP/global/

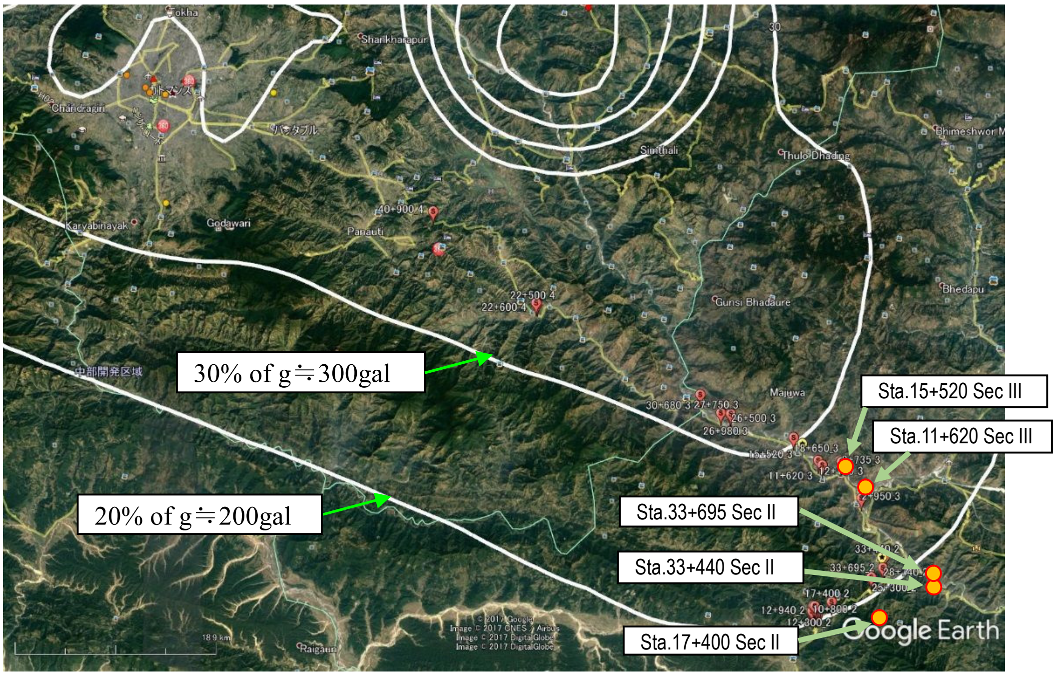
Figure 2.2.11 Distribution of Earthquakes in the World



Source: USGS

Figure 2.2.12 Seismic Intensity Distribution Map in the Gorkha Earthquake

USGS has released the estimated maximum acceleration contour of the Gorkha Earthquake by shakemap. **Figure 2.2.13** shows a plot of this contour and 24 points to consider on Google Earth.



Source: JICA Survey Team based on https://earthquake.usgs.gov/earthquakes/eventpage/us20002926#shakemap

Figure 2.2.13 Estimated Maximum Acceleration Contour of the Gorkha Earthquake by USGS and Point of Consideration

According to 2D seismic analysis which is attached in APPENDIX 5.3, it is estimated that the estimated maximum acceleration at the target location during the Gorkha Earthquake was around 200 gal.

1) Sta.17+400

"Report on the Evaluation Committee on Earthquake Resistant Facilities, etc., for Landslide Prevention Facilities" was implemented after the 1995 Hyogo ken Nanbu Earthquake (1995). "After the earthquake inspection, there was no damage that lost the prevention function in the landslide prevention facility, so it turned out that the design of the earthquake resistance prevention facility at the landslide prevention facility was sufficient under normal design". It is summarized as: for this reason, earthquakes are not taken into consideration for the study of landslide stability calculation and countermeasure work in Japan at present. From above, earthquakes are not considered for the collapse of Sta.17 + 400.

2) Sta.33+440, Sta.33+695 in Sec II and Sta.11+620, Sta.15+520 in Sec III

In Sindhuli Road, the seismic coefficient is designed according to the standard (IS: 1893-1984) of India, with horizontal design seismic intensity kh = 0.1 (100 gal). In the Gorkha Earthquake, it is estimated that the earthquake motion of about 200 gal exceeding the design seismic intensity has arrived. It seems that the Gabion retaining wall was partially changed due to this earthquake motion. For this reason, it is a design policy that can withstand same-scale earthquakes.

2.2.1.3 POLICY ON SOCIOECONOMIC CONDITIONS

Consideration should be taken not to cause resident relocation or land acquisition. The traffic volume of the target section is about 3,000 units/day, and it is necessary to ensure traffic under construction. It is necessary to implement construction at the lowest, one-way traffic regulation. When moving the boring machine, the roads will be closed, but should be planned to minimize the time to road closure.

2.2.1.4 BASIC POLICY ON CONSTRUCTION AND PROCUREMENT PLAN

As roads and bridges are actively being built in Nepal by GON budget, the local contractors are believed to have sufficient ability in general civil works. Besides, many local contractors, engineers, and labors gained necessary experiences through joining Sindhuli Road Construction Project which is under the Japan grant aid. Therefore, the labors engaging in this project are planned to be employed around the construction sites. General construction machines like bulldozer and backhoe, general construction materials like cement, aggregate and reinforcing bar are planned to be procured in Nepal. However, construction machines like rough-terrain crane (25t), boring machine for anchor work, SD drilling machine and air blast machine cannot be procured easily in Nepal. Furthermore, to insure the safety, workability and the maintenance of construction machines in mountainous region, as well as because of the 14 months long construction period, the construction machines are planned to be procured in Japan.

2.2.1.5 POLICY ON UTILIZATION OF LOCAL CONTRACTORS

According to a consultation with the local contractors, the construction record of the anchor workers in Nepal is not so much. However, there are many local contractors with construction experience of Japan Grand Aid, such as Sindhuli Road Construction projects so far, and it is considered that construction is possible if implemented under the guidance of Japanese engineers. The local consultant has abundant experience in design and construction supervision, and it can be inferred that construction supervision of the landslide countermeasure work is also possible if the Japanese engineer guides.

2.2.1.6 POLICY ON OPERATION AND MAINTENANCE

Road maintenance related to road construction and maintenance in Nepal is handled by the Department of Road (DOR) which belongs to the Ministry of Public Infrastructure and Transportation (MOPIT) which is the competent authority. The DOR had implemented Japan Grant Aid projects such as Sindhuli Road Construction Project for many years. The DOR has sufficient ability on road operation and maintenance for this project because it has a satisfactory record of accomplishment on Sindhuli Road Construction Project. However, repairs and maintenance after completion of the construction requires a well maintenance plan and sufficient budget allocation because there are many special slope protections works such as anchor works. Since anchor works are installed at Sta.17+400 on Section II, maintenance of anchor works is surely going to be carried out, so it is considered that maintenance of anchor works will be carried out reliably. Maintenance budget for Sindhuli Road is as shown in **Table 2.2.3**. The budget is also well allocated, and it is considered that maintenance will be carried out reliably.

Table 2.2.3 Maintenance Budget for Sindhuli Road

Unit : NRs.

Source of Budget	Maintenance Activity	Allocated Budget for FY2012/2013	Allocated Budget for FY2013/2014	Allocated Budget for FY2014/2015	Allocated Budget for FY2015/2016	Allocated Budget for FY2016/2017
RBN	Routine Maintenance	8,178,029	8,175,000	10,858,600	12,546,000	14,370,000
	Recurrent Maintenance	7,730,000	8,367,000	12,838,000	11,427,000	15,430,000
	Periodic Maintenance	22,500,000	0	49,200,000	0	100,000,000
	Emergency Maintenance	500,000	10,500,000	0	2,500,000	1,000,000
	Specific Maintenance	4,500,000	9,810,000	10,000,000	6,000,000	10,000,000
	Road Traffic Safety	0	0	0	1,000,000	1,000,000
	Bridge Maintenance	0	0	0	0	0
	Bio Engineering	0	0	0	500,000	0
GON	GON budget is for ongoing project work having activities such as resettlement road widening, major repair	247,323,557	207,149,000	147,317,000	189,500,000	101,323,000

	works including administrative expenses					
Total		290,731,586	244,001,000	230,213,600	223,473,000	243,123,000

Source：DOR

2.2.1.7 DESIGN STANDARDS TO BE ADOPTED

The Nepalese standards for slope protection have not been consolidated yet, therefore, Japanese standards will be adopted in the Project. For consistency purposes, the standards adopted in Section II and Section III would also be followed. **Table 2.2.4** and **Table 2.2.5** lists the standards that will be adopted for the Project.

Table 2.2.4 List of Adopted Standards

Main Countermeasure	Adopted Standards
a) Ground anchors	-Manual for Slope Protection, Japan Road Association -Manual for Temporary Structure, Japan Road Association -Standard for Design and Construction of Anchor Works, Japanese Geotechnical Society
b) Crib works	-Manual for Design and Construction of Crib Works, Japan Slope Protection Association
c) High-intensity net and Rock bolt	-Standard for Design and Construction of Reinforced Earth Method, Nippon Expressway Company, January 2017

Source: JICA Survey Team

Table 2.2.5 Standard of Road Design

Item	Standard
Design Speed	20 km/h
Standard Width	4.75 m

Source: JICA Survey Team

2.2.1.8 POLICY FOR CONSTRUCTION METHOD AND PERIOD

(1) CONSTRUCTION METHOD

1) Sta.17+400, Section II

Countermeasures against assumed slope failure with rock class classification D to CL at the downside of road are planned. The geological layer of the rock class is laid up to about 10 m in depth. Result of the countermeasure, a comparative analysis is discussed below show that the crib works with ground anchors is best suited to this site. In addition, high intensity net is planned for middle slope against surface failure. Likewise, vegetation and gabion check dams are planned for the lower part of the slope against surface erosion.

Construction materials for ground anchors and high intensity net and drilling machines are planned to be procured from Japan.

2) Sta.33+440, Section II

Countermeasures against unstable gabion walls are planned. Results of countermeasure comparative analysis discussed below show that the ground anchors are best suited to this site. Precast steel plate is selected for the anchor plate because of its advantages of workability and cost. Installation of H beams between gabion walls and anchor plates are planned for the purpose of combination of gabion baskets and planate tension from ground anchors.

3) Sta.33+695, Section II

Construction methods of this site are similar to Sta.33+440.

4) Sta.11+620, Section III

Buttress concrete walls were installed by DOR as an emergency countermeasure. JICA Survey Team considered that these buttresses concrete wall shall be utilized as temporary countermeasure. Results of countermeasure comparative analysis discussed below show that the ground anchors are the best suited to this site. The concept of precast steel plate and installation of H beams are similar to Sta.33+440. A side ditch is also planned in order to avoid surface water into road structure.

5) Sta.15+520, Section III

Construction methods of this site are similar to Sta.33+440. In addition, high intensity net is planned for rockfall at the upper road and for surface failure at the lower road.

(2) CONSTRUCTION PERIOD

The period between June and October falls under the monsoon season. Generally, July and August have the highest precipitation generally. As this project is for slope countermeasure construction, consideration of operating rate during the rainy season is required for construction process planning.

2.2.1.9 POLICY FOR NATURAL AND SOCIAL ENVIRONMENT

The following measures are reflected in the design and construction plan because impacts to natural and social environment should be minimal.

- Securement of private and public vehicle transportation during construction
- Mitigation measures against air and water pollution
- Mitigation measures against noise and vibration

2.2.2 BASIC PLAN (CONSTRUCTION PLAN/EQUIPMENT PLAN)

2.2.2.1 OVERALL PLAN

(1) Area of construction works

Area of construction works is shown below.

Table 2.2.6 Area of Construction Works

Site	Target Section	Countermeasure	Quantity
Sta.17+400 Section II	80m (Sta.17+360 to 440)	Ground anchors	Ground anchor 158 pieces
		Crib works F500	A=1,270 m^2, Shotcrete in the frame A= 860 m^2
		Crib works F300	A=1,060 m^2, Shotcrete in the frame A= 710 m^2
		Rock bolts	L=3 m/each, 300 pieces
		Excavation works	V=370 m^3
		High intensity net	High intensity net, A=2,800 m^2 Rock bolts, L=3 m/each, 1,240 pieces
		Vegetation works	Vegetation bags, 4,140 pieces
		Gabion check dams	V=350 m^3
		Asphalt pavements	A=420 m^2
Sta.33+440 Section II	35m (Sta.33+430 to 465)	Ground anchors	Ground anchor 32 pieces
		Anchor plates	32 nos.
		H beam installation	Shotcrete A=160 m^2, H beams 32 pieces, Concrete V=25 m^3
		Restoration of side ditch	L=43 m
		Asphalt pavements	A=200 m^2
Sta.33+695 Section II	30m (Sta.33+680 to 710)	Ground anchors	Ground anchor 18 pieces
		Anchor plates	18 nos.
		H beam installation	Shotcrete A=95 m^2, H beams 18 pieces, Concrete V=19 m^3
		Restoration of side ditch	L=45 m
		Asphalt pavements	A=150 m^2
Sta.11+620 Section III	30m (Sta.11+600 to 630)	Ground anchors	Ground anchor 20 pieces
		Anchor plates	20 nos.
		H beam installation	Shotcrete A=90 m^2, H beams 10 pieces, Concrete V=10 m^3
		Side ditch	L=12 m
Sta.15+520 Section III	40m (Sta.15+520 to 560)	Ground anchors	Ground anchor 40 pieces
		Anchor plates	40 nos.
		H beam installation	Shotcrete A=250 m^2, H beams 40 pieces, Concrete V=50 m^3
		High intensity net	High intensity net, A=2,500 m^2 Rock bolts, L=3 m/each, 1,100 pieces
		Asphalt pavements	A=210 m^2

Source: JICA Survey Team

(2) condition of each site

1) Assumed Damage and Failure Mechanism

Assumed damage and failure mechanism for each site are shown below.

Table 2.2.7 Assumed Damage and Failure Mechanism

Site	Assumed Damage	Failure Mechanism
Sta.17+400 Section II	Head of slope failure is coming closer to the road shoulder. It has the possibility of long-term road closure with an area 60 m wide due to failure by heavy rains or earthquake. In that case, rehabilitation works would be in an extremely difficult situation due to topography of this site.	The foundation rocks are weathered, especially green schist distributed at centerline of the valley. Surface failures and surface erosions have repeatedly occurred in the rainy season. In addition, it has the possibility of acceleration of surface failure due to destabilization of the slope by earthquake.
Sta.33+440 Section II	It has the possibility of long-term road closure with the area 35 m wide due to road collapse by heavy rains or earthquake. In that case, rehabilitation works would be in an extremely difficult situation because this site is in winding section.	Gabion wall moved at the 2015 Gorkha earthquake. At that time, the upper part of gabion wall could not turn back to original position due to vibration amplitude. Gabion wall is almost vertical and unstable at the present.
Sta.33+695 Section II	It has the possibility of long-term road closure with the area 30 m wide due to road collapse by heavy rains or earthquake. In that case, rehabilitation works would be in an extremely difficult situation because this site is in winding section.	ditto
Sta.11+620 Section III	It has the possibility of long-term road closure with the area 30 m wide due to road collapse by heavy rains or earthquake.	ditto
Sta.15+520 Section III	It has the possibility of long-term road closure with the area 40 m wide due to road collapse by heavy rains or earthquake. In that case, rehabilitation works would be in an extremely difficult situation because this site is in winding section.	ditto

Source: JICA Survey Team

2) Consideration Points for Countermeasure Planning

Points to consider for countermeasure planning are presented below. As a whole site, securement of private and public vehicle transportation even during construction is required absolutely.

Table 2.2.8 Consideration Points for Countermeasure Planning

	Consideration Points for Countermeasure Planning
Sta.17+400 Section II	- Permanent countermeasure for natural slope of downside of the road is required. - If erosion develops in the lower slope, structural countermeasures of the upper area might be damaged. - Countermeasure is needed not only at the upper part of the slope but also at the middle and lower part because of the continuous slope. - Private and public vehicle transportation could be secured even during construction. - Impacts of noise and vibration of construction to close community should be minimal. - Alternative safety foot path should be prepared for local people during construction.
Sta.33+440 Section II	- Permanent countermeasure for road structure is required. - Private and public vehicle transportation could be secured even during construction.
Sta.33+695 Section II	ditto
Sta.11+620 Section III	ditto
Sta.15+520 Section III	ditto

Source: JICA Survey Team

3) Selection of Applicable Countermeasures (Sta.17+400)

Selection of applicable countermeasures was conducted with considerations of the previous described failure mechanisms and points for countermeasure planning.

i. Classification of Countermeasures against Slope Failure

Classification of countermeasures against slope failure is shown as below, according to the "Design and Practical Example for Construction of Countermeasures against Slope Failure, Japan SABO Association". The countermeasures include control works and restraining works. Control works involve modifications of natural conditions related to landslides, such as topography and groundwater. Meanwhile, restraining works are the implementation of structures that mitigate slope movement.

Table 2.2.9 Classification of Countermeasures against Slope Failure

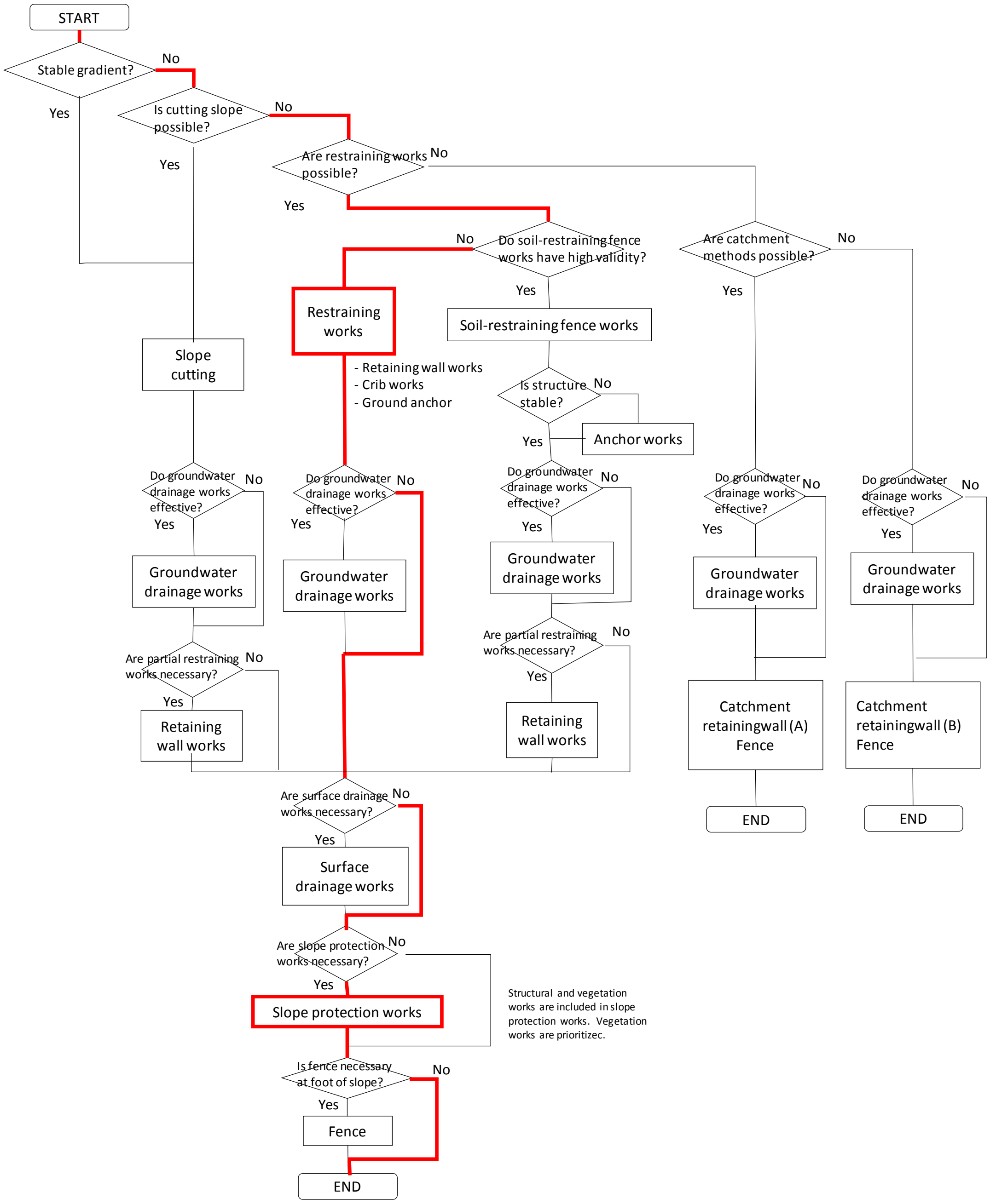
Type	Type of Countermeasure	Countermeasure Works
Control works	Drainage works	Surface drainage works, Groundwater drainage works
	Vegetation works	Vegetation works
	Shotcrete	Mortar shotcrete, Concrete shotcrete
	Plastering works	Stone pitching works, Block pitching works, Concrete pitching works
	Crib works	Precast crib works, Cast-in-place grating crib works
	Counterweight fill works	Counterweight fill works
	Slope cutting works	Slope cutting works
Restraining works	Retaining wall works	Stone pitching retaining wall works, leaning wall works, Concrete retaining wall works, Gravity-type retaining wall works
	Anchor works	Ground anchor works, Rock bolt works
	Pile works	Pile works
	Rock fall prevention works	Rock fall prevention works, Rock fall protection works

Source: JICA Survey Team based on the "Design and Practical Example for Construction of Countermeasures against Slope Failure, Japan SABO Association"

ii. Selection of Applicable Countermeasures

The slope of downside of the road is classified into three parts, upper, middle, and lower parts according to characteristic features such as slope gradient. The upper part with a gradient of 45 to 60 degree is the area of slope failure and directly affects road function. The middle part with a gradient of about 40 degrees is the area of small-scale surface failure and erosion. The lower part with a gradient of less than 40 degree is the area of sedimentation and erosion.

Flow chart for selection of countermeasures and applicability of each countermeasure to this site are presented below.



Source: JICA Survey Team based on "Design and Practical Example for Construction of Countermeasures against Slope Failure, Japan SABO Association"

Figure 2.2.14 Flow Chart for Selection of Countermeasures

Table 2.2.10 Applicability of Each Countermeasure to Sta.17+400

Type	Type of Countermeasure	Applicability
Control works	Drainage works	Groundwater drainage works are not effective because the groundwater is at a deep level in the target area. Roadside ditches had already constructed.
	Vegetation works	These works are effective for middle and lower area.
	Shotcrete	Shotcrete is not effective against slope failure with 10 m depth.
	Plastering works	These works are not effective against slope failure with 10 m depth.
	Crib works	These works are effective for surface slope failures. These works should add ground anchors for slope failure with 10 m depth.
	Counterweight fill works	These works cannot be constructed due to the landform.

Restraining works	Slope cutting works	These works cannot be constructed due to the landform.
	Retaining wall works	These works are not effective against slope failure with 10 m depth.
	Anchor works	These works are effective for surface slope failures with 10 m depth. Rock bolts are effective for surface slope failures.
	Pile works	These works are effective for surface slope failures with 10 m depth. These works should add ground anchors.
	Rock fall prevention works	There is not possibility of rock falls to the road.

Source: JICA Survey Team

Restraining works are best suited for the upper part of the slope which affects directly to road function. Crib works with ground anchors and pile works with ground anchors are selected for comparative methods because of highly weathered rock, which is distributed up to 10 m depth. In addition, bridge works are adapted to avoid the hazardous area. These applicable countermeasure areas were compared for the upper slope of Sta.17+400.

First Scheme: Ground Anchors and Crib Works

Second Scheme: Steel Piles with Ground Anchors

Third Scheme: Bridge

In this comparative analysis, countermeasures for middle and lower parts are included as common items. Selection of countermeasures for middle and lower part is hereinafter described.

4) Selection of Applicable Countermeasures (Sta.33+440, Sta.33+695, Sta.11+620, Sta.15+520)

Selection of applicable countermeasures was conducted with considerations of the previous described failure mechanism and points for countermeasure planning.

i. Classification of Reinforcement Countermeasures for Retaining Wall

Classification of reinforcement countermeasures for retaining wall is shown as below, according to the “Manual for Retaining Walls, Japan Road Association”.

Table 2.2.11 Classification of Reinforcement Countermeasures for Retaining Wall

Classification	Countermeasure Works
Reinforcement of retaining wall	Resin infusion into cracks of concrete retaining walls
	Restoration of deflection part of block-type retaining walls
	Levee widening by concrete retaining walls
	Ground anchor works
Reinforcement of bearing capacity	Sheet piling
	Steel pile works, Concrete piles
	Underground continuous walls
	Chemical grouting into foundation ground

Source: JICA Survey Team based on “Manual for Retaining Walls, Japan Road Association”

ii. Selection of Applicable Countermeasures

Applicability of each countermeasure to these sites is below.

Table 2.2.12 Applicability of Each Countermeasures to Target Sites

Classification	Countermeasure Works	Applicability
Reinforcement of retaining wall	Resin infusion into cracks of concrete retaining walls	These works are not effective against gabion walls.
	Restoration of deflection part of block-type retaining walls	These works require full road closure during construction works.
	Levee widening by concrete retaining walls	These works are effective in case of the site which has enough space for additional

		concrete retaining walls.
	Ground anchor works	These works are effective.
Reinforcement of bearing capacity	Sheet piling	These works are not effective against assumed earth pressure.
	Steel pile works, Concrete piles	Steel piles with ground anchors into road structure are effective.
	Underground continuous walls	These works are not effective.
	Chemical grouting into foundation ground	These works are not effective.

Source: JICA Survey Team

Ground anchor works and steel piles with ground anchors works are applicable countermeasures. For Sta. 33+695, there is a space for levee widening by concrete retaining walls below the target road section.

These applicable countermeasures were compared for Sta.15+520, as a representative for four target sites.

First Scheme: Ground Anchors

Second Scheme: Steel Piles with Ground Anchors

Third Scheme: Concrete Retaining Walls (only Sta.33+695)

Ground anchor of first scheme needs bearing plates. Precast anchor plate is best suited for the target sites because of the advantages of light-weight and workability. Installation of H beams between gabion walls and anchor plates is planned for the purpose of combination of gabion baskets and planate tension from ground anchors.

5) Selection of Countermeasures

Comparative analysis for selected applicable countermeasures was conducted. Evaluation items of the analysis are stability, workability, maintenance, and influence on road for construction, environment, and cost.

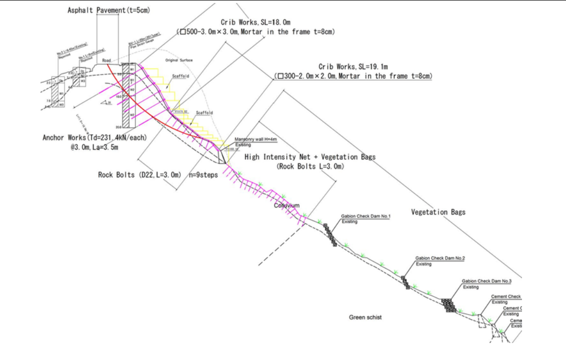
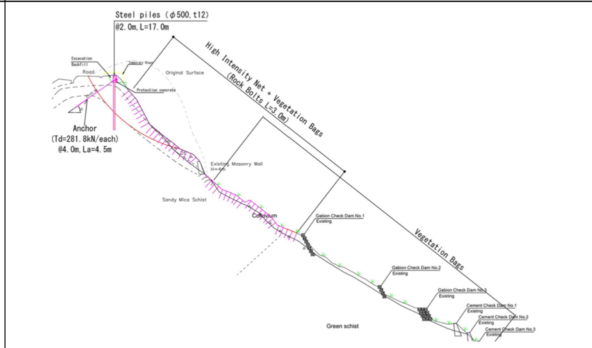
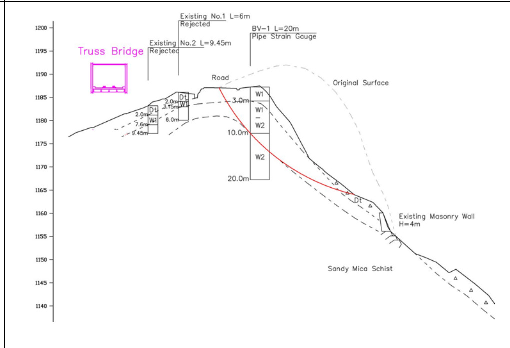
i. Sta.17+400 (Natural Slope)

Ground anchors and crib works of first scheme are best suited to Sta.17+400 as shown in the comparative analysis chart. Steel piles with ground anchors of second scheme are inferior in influence on road and cost. Bridge of the third scheme is inferior in all items.

ii. Sta.33+440, Sta.33+695, Sta.11+620 and Sta.15+520 (Gabion Walls)

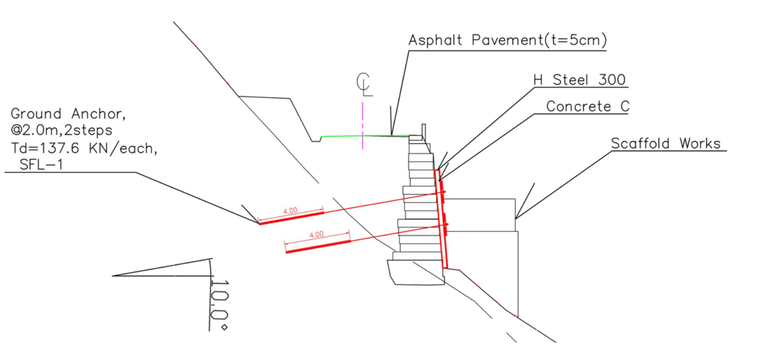
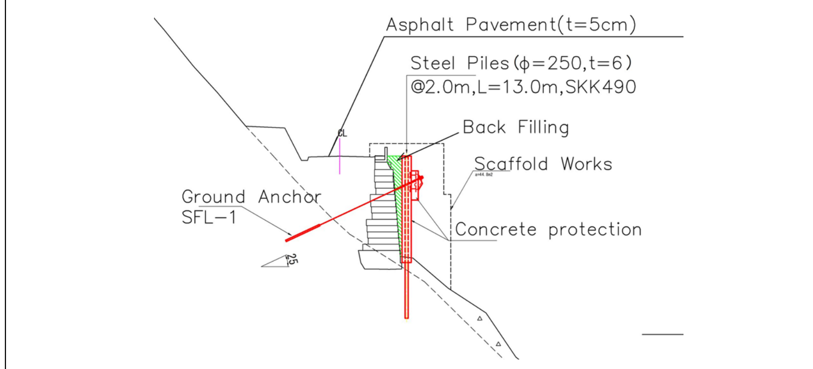
Ground anchors of first scheme are best suited to these sites as shown in the comparative analysis chart. Steel piles with ground anchors of second scheme are inferior in workability, influence on the road, and cost. In terms of Sta.33+695, counterfeited retaining wall of third scheme is inferior in all items.

Table 2.2.13 Countermeasure Comparative Analysis Chart for Sta.17+400

	1st Scheme : Ground Anchors and Crib Works						2nd Scheme : Steel Piles with Ground Anchors						3rd Scheme : Bridge					
Cross Section																		
Outline of Countrmeasure	Loose rock mass of the upper slope is pressed by tension force of ground anchors. Crib work is used for surface erosion and anchor pressure receiving. High intensity net is installed for the middle slope. Vegetation bags is installed for the lower slope.						The road is preserved by using the bending and shearing effect of steel piles. Ground anchor should be attached with a head of a pile to prevent the road from deformation. High intensity net is set for the middle slope. Vegetation bags is set for the lower slope.						This method is to avoid the hazardous area by bridge.					
Stability	Clamping and straining effect by anchor will increase in safety factor of the loose rock mass.					3	Clamping and straining effect by anchor will increase in safety factor of the loose rock mass.					3	If soil erosion and slope failure develop, countermeasure for base of bridge become nesessary.					2
Workability	Crib works for wide area and scaffolding works require long construction term.					2	Pile works have advantage for workability, but high intensity net work for wide area require long construction term.					2	This method require wide construction yard.					1
Maintenance & Operation	Ground anchor with anticorrosion coating is used. Only monitoring of load by using load measure is required for maintenance.					3	Ground anchor with anticorrosion coating is used.					3	Expansion device of bridge is required periodically.					2
Influence to road	Only occasional one way closure of road is required for hauling construction materials.					3	Continuous one way closure of road is required during pile works.					1	Continuous one way road closure is required during all works.					1
Environment	This method have a low impact to environment. Vegetation works is conducted at the lower slope.					3	This method have a low impact to environment. Vegetation works is conducted at the lower slope.					3	Removal of some houses is required.					1
Subtotal	1st scheme is ahead of other schemes in above veiwpoints.				Subtotal	14	2nd scheme is inferior to the 1st scheme in above veiwpoints, especially influence to road.				Subtotal	12	3rd scheme is inferior to the 1st scheme in above most veiwpoints.				Subtotal	7
Rough Construction Cost (Unit: JPY1,000)	Method	Specifications	Unit	Qty	Unit Price	Ammount	Method	Specifications	Unit	Qty	Unit Price	Ammount	Method	Specifications	Unit	Qty	Unit Price	Ammount
	Ground anchor	SFL-2, Td=231.4kN/each	m	2,103	31	65,193	Excavation		m3	562	1	562	Upper structure work		m3	525	350	183,750
	Crib work	F500, concrete in side frame	m2	1,271	16	20,336	Filling		m3	167	1	167	Lower structure work		set	3	30,000	90,000
	Crib work with bolts	F300, D22, L=3.0m/each	m2	1,062	25	26,550	Steel pile	φ500,t=13,L=17.0m/each	m	646	150	96,900	Foundation work		set	1	10,000	10,000
	Scaffolding		sp m3	3,915	6	23,490	Ground anchor	SFL-2, Td=281.8kN/each	m	304	31	9,424	Pavement		m2	280	15	4,200
	Installation of load meter		set	4	200	800	Retaining work		set	19	500	9,500	Ancillary works		L.S.	1		2,000
	High intensity net		m2	2,791	20	55,820	Scaffolding		sp m3	1,312	6	7,872						
	Vegetation bag		piece	4,271	1	4,271	High intensity net		m2	5,124	20	102,480						
	Check dam		m3	345	13	4,485	Vegetation bag		m2	4,271	1	4,271						
	Asphalt pavement		m2	419	0.3	126	Check dam		m3	345	13	4,485						
	Earth works		m3	300	0.6	180	Asphalt pavement		m2	419	0.3	126						
	Direct Construction Cost					201,251	Direct Construction Cost					235,787	Direct Construction Cost					289,950
	Overhead Cost（80% of Direct Construction Cost)					161,001	Overhead Cost（80% of Direct Construction Cost)					188,629	Overhead Cost（80% of Direct Construction Cost)					231,960
	Total Construction Cost					362,251	Total Construction Cost					424,416	Total Construction Cost					521,910
Cost	The lowest				Rate to 1st	1.00	The second lowest				Rate to 1st	1.17	The highest				Rate to 1st	1.44
Total Evaluation	1st scheme is the best suited to this site.				Priolity	First	2nd scheme is inferior to the 1st scheme totally.				Priolity	Second	3rd scheme is inferior to the 1st scheme totally.				Priolity	Third

Source: JICA study team

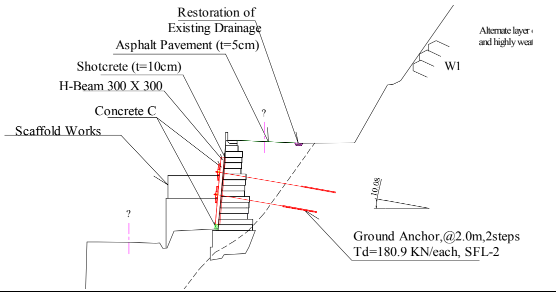
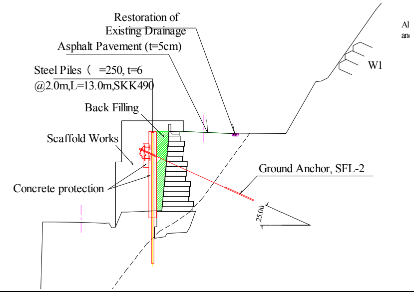
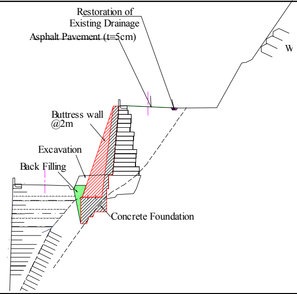
Table 2.2.14 Countermeasure Comparative Analysis Chart for Sta.15+200 (only for gabion wall)

	1st Scheme : Ground Anchors						2nd Scheme : Steel Piles with Ground Anchors					
Cross Section												
Outline of Countrmeasure	Gabion wall is pressed by tension force of ground anchors. Relatively-light steel anchor plates are used. H steel beams are installed between gabion wall and precast steel plate.						The road is preserved by using the bending and shearing effect of steel piles. Ground anchor should be attached with a head of a pile to prevent the road from deformation.					
Stability	Safety factor of earth pressure of gabion wall will increase.					3	Safety factor of earth pressure of gabion wall will increase.					3
Workability	Using precast steel plates can reduct construction period. The anchor can be fabricated at each sites.					3	Workability of installation of piles at steep slope is inferior.					2
Maintenance & Operation	Ground anchor with anticorrosion coating is used. Only monitoring of load by using load measure is required for maintenance.					3	Ground anchor with anticorrosion coating is used.					3
Influence to road	Only occasional one way closure of road is required for hauling construction materials.					3	Continuous one way closure of road is required during pile works.					2
Environment	This method have a low impact to environment.					3	This method have a low impact to environment.					3
Subtotal	1st scheme is ahead of 2nd scheme in above veiwpoints.				Subtotal	15	2nd scheme is inferior to the 1st scheme in above veiwpoints, especially workability.				Subtotal	13
Rough Construction Cost (Unit: JPY1,000)	Method	Specifications	Unit	Qty	Unit Price	Ammount	Method	Specifications	Unit	Qty	Unit Price	Ammount
	Ground anchor	SFL-1, Td=137.6kN/each	m	418	20	8,360	Steel pile	φ250,t=6,L=13.0m/each	m	260	120	31,200
	Steel plate	KIT16S-230	plate	40	170	6,800	Ground anchor	SFL-1	m	190	20	3,800
	H steel beam	H300	number	20	1,200	24,000	Retaining work		組	10	1,500	15,000
	Scaffolding		sp m3	1,160	5	5,800	Filling		m3	168	1	168
	Installation of load meter		set	2	200	400	Scaffolding		sp m3	2,060	5	10,300
	Asphalt Pavement	t=5cm	m2	260	0.3	78	Asphalt Pavement	t=5cm	m2	260	0.3	78
	Direct Construction Cost					45,438	Direct Construction Cost					60,546
	Overhead Cost（80% of Direct Construction Cost)					36,350	Overhead Cost（80% of Direct Construction Cost)					48,437
	Total Construction Cost					81,788	Total Construction Cost					108,983
Cost	The lowest				Rate to 1st	1.00	The highest				Rate to 1st	1.33
Total Evaluation	1st scheme is the best suited to this site.				Priolity	First	2nd scheme is inferior to the 1st scheme totally.				Priolity	Second

Source: JICA study team

Comparative analysis of Sta.15+520 was conducted on behalf of 33+440 and Sta. 11+620.

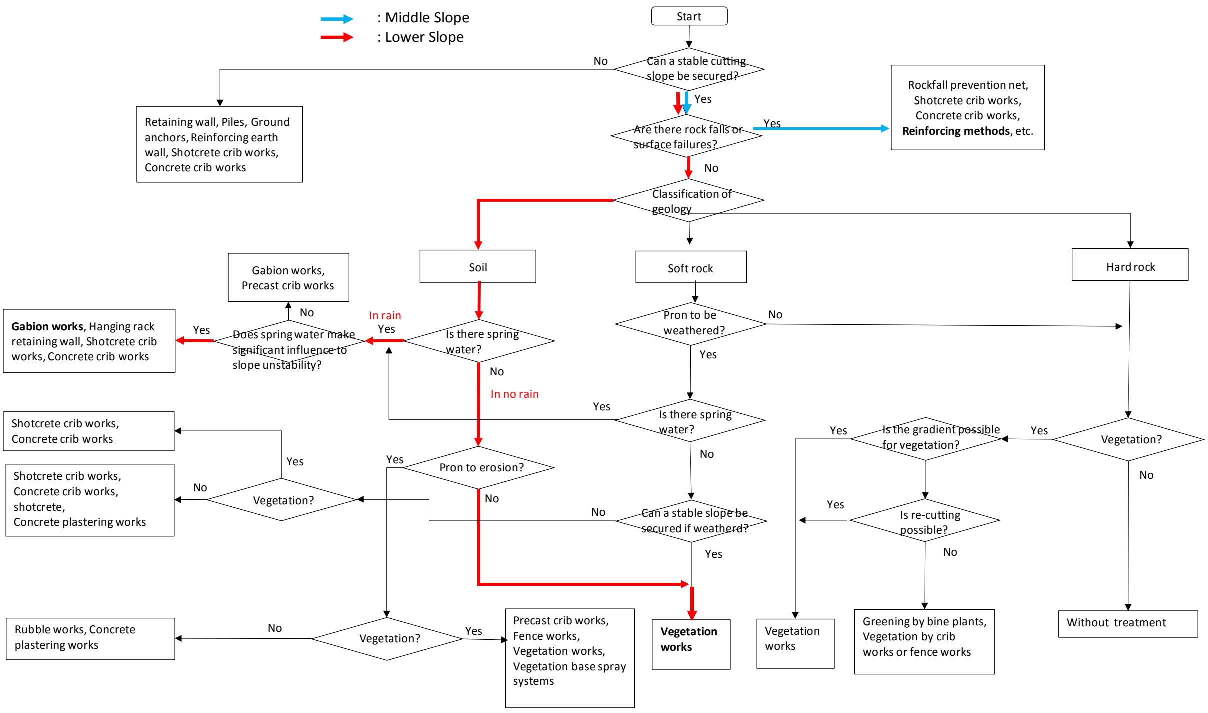
Table 2.2.15 Countermeasure Comparative Analysis Chart for Sta.33+695

	1st Scheme : Ground Anchors						2nd Scheme : Steel Piles with Ground Anchors						3rd Scheme : Counterforted Retaining Wall					
Cross Section																		
Outline of Countrmeasure	Gabion wall is pressed by tension force of ground anchors. Relatively-light steel anchor plates are used. H steel beams are installed between gabion wall and precast steel plate.						The road is preserved by using the bending and shearing effect of steel piles. Ground anchor should be attached with a head of a pile to prevent the road from deformation.						The road is preserved by counterforted retaining wall as counterweight.					
Stability	Safety factor of earth pressure of gabion wall will increase.					3	Safety factor of earth pressure of gabion wall will increase.					3	Tilting, sliding and bearing capacity of gabion wall is satisfied. However, the downside road consited by geotextile might be lead to become unstable because the section is affected by excavation for foundation of the retaining wall.					1
Workability	Using precast steel plates can reduct construction period. The anchor can be fabricated at each sites.					3	Workability of installation of piles at steep slope is inferior.					1	Workability is inferior because the construction space is limited.					1
Maintenance & Operation	Ground anchor with anticorrosion coating is used. Only monitoring of load by using load measure is required for maintenance.					3	Ground anchor with anticorrosion coating is used.					3	Periodical inspection is required.					2
Influence to road	Only occasional one way closure of road is required for hauling construction materials.					3	Continuous one way closure of road is required during pile works.					3	Continuous one way closure of the downside road is required as well as upper road section.					2
Environment	This method have a low impact to environment.					3	This method have a low impact to environment.					3	This method have a low impact to environment.					3
Subtotal	1st scheme is ahead of other schemes in above veiwpoints.				Subtotal	15	2nd scheme is inferior to the 1st scheme in above veiwpoints, especially workability.				Subtotal	13	2nd scheme is inferior to the 1st scheme in above veiwpoints.				Subtotal	9
Rough Construction Cost (Unit: JPY1,000)	Method	Specifications	Unit	Qty	Unit Price	Ammount	Method	Specifications	Unit	Qty	Unit Price	Ammount	Method	Specifications	Unit	Qty	Unit Price	Ammount
	Ground anchor	SFL-2	m	170	31	5,270	Steel pile	φ250,t=6,L=13.0m/本	m	130	120	15,600	Excavation		m3	340	1	340
	Steel plate	KIT19S-230	plate	18	210	3,780	Ground anchor	SFL-2	m	95	31	2,945	Filling		m3	50	1	50
	H steel beam	H300	number	9	1,200	10,800	Retaining work		組	5	1,500	7,500	Formworks		m2	800	2	1,600
	Scaffolding		sp m3	420	5	2,100	Filling		m3	130	1	130	Foundation	RC	m3	280	100	28,000
	Installation of load meter		set	2	200	400	Scaffolding		sp m3	1,100	5	5,500	Retaining wall		m3	120	17	2040
	Asphalt Pavement	t=5cm	m2	130	0.3	39	Asphalt Pavement	t=5cm	m2	130	0.3	39	Asphalt Paven	t=5cm	m2	130	0.3	39
	Restration of side ditch		m	45	1	45	Restration of side ditch		m	45	1	45	Restration of side ditch		m	90	1	90
	Direct Construction Cost					22,434	Direct Construction Cost					31,759	Direct Construction Cost					32,159
	Overhead Cost（80% of Direct Construction Cost）					17,947	Overhead Cost（80% of Direct Construction Cost）					25,407	Overhead Cost（80% of Direct Construction Cost）					25,727
	Total Construction Cost					40,381	Total Construction Cost					57,166	Total Construction Cost					57,886
Cost	The lowest				Rate to 1st	1.00	The second lowest				Rate to 1st	1.42	The highest				Rate to 1st	1.43
Total Evaluation	1st scheme is the best suited to this site.				Priolity	First	2nd scheme is inferior to the 1st scheme totally.				Priolity	Second	3rd scheme is inferior to the 1st scheme totally.				Priolity	Third

Source: JICA study team

iii. Middle and Lower Part of Sta.17+400 Slope

As previously described, countermeasures against surface failure and erosion are required for the middle part of Sta.17+400 slope. Also, countermeasures against erosion is also required for the lower part. These countermeasures were selected based on the following flow chart.



Source: JICA Survey Team based on "Manual for Slope Protection, Japan Road Association"

Figure 2.2.15 Flow Chart for Selection of Middle and Lower Parts of the Sta. 17+400 Slope

The conditions for selection of countermeasures of the middle slope are shown below.

- The assumed depth of surface failure is about 2 m.
- Flexible barrier structure is suitable because the surface of the part is irregular.
- Open structure is suitable because spring water occurs during the rainy season.

Considering these conditions, "high intensity net with rock bolts" and "wire rope with rock bolts" are selected for applicable countermeasures for the middle slope. Results of the comparative analysis suggest that high intensity net with rock bolts are selected. Wire rope with rock bolts are inferior in workability and cost.

Vegetation bag is selected for lower and middle slopes against erosion. Sheet type of vegetation is unfit for the surface of this area because the surface covered by rubble debris is uneven rock. In addition, existing gabion check dams have an effect on surface erosion. However, because the range is not sufficient, the extension of gabion check dams is planned next to the existing dams.

2.2.2.2 OUTLINE DESIGN OF THE COUNTERMEASURES

(1) Sta. 17+400

1) Stability Analysis for Upper Slope

For the stability analysis, the slice method is used as follows:

$$F_S = \frac{\Sigma\{c \cdot l + (W - u \cdot b)\cos\alpha \cdot \tan\phi\}}{\Sigma W \cdot \sin\alpha} \qquad \text{(Equation 2.2.1)}$$

Where, Fs : Factor of safety
c : Cohesion of sliding surface (kN/m^2)
φ : Internal frictional angle of sliding surface (°)
l : Length of sliding surface acting on the slice (m)
u : Pore pressure acting on the base of the slice (kN/m^2)
b : Width of sliding surface acting on the slice (m)
W : Weight sliding surface acting on the slice (kN/m)
α : Angle of the base of the slice to the horizontal (°)

Source: Manual for Slope Protection, Japan Road Association

The results of stability analysis are as follows:

Table 2.2.16 Results of Stability Analysis for Upper Slope of Sta17+400

Items	Adapted Value
Initial factor of safety	Fs = 1.00
Proposed factor of safety	PFs = 1.20
Unit weight of sliding mass	γ t= 18 kN/m^3
Cohesion of sliding surface	C = 10 kN/m^2
Internal frictional angle of sliding surface	ϕ = 33.38 degree
Required preventive force to be provided	Pr = 417.2 kN/m^2

Source: JICA Survey Team

2) Ground Anchors

The condition of ground anchors design is presented below.

Table 2.2.17 Conditions for Ground Anchors Design

Items	Value Adopted	Standard
Calculus equation	Refer to below	Manual for Slope Protection, Japan Road Association
Anchor function	Clamping effect and straining effect	ditto
Skin frictional resistance of anchor	0.6 N/mm^2	ditto
Design strength of grout	24 N/mm^2	ditto
Allowable adhesive stresses	Pre-stressing steel wire 0.8 N/mm^2 Deformed pre-stressing steel bar 1.6 N/mm^2	ditto
Soil bearing capacity	200 kN/m^2	Manual for Retaining Wall, Japan Road Association

Source: JICA Survey Team

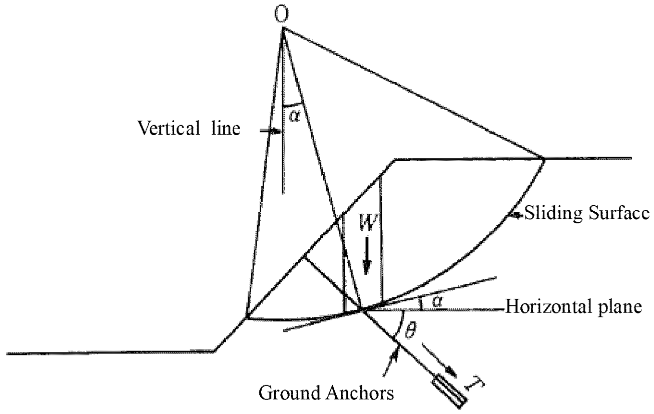
i. Calculus Equation

The calculus equation of stability analysis adopted in accordance with the manual is as follows:

$$F_s = \frac{\sum c \cdot l + \sum (W - u \cdot b)\cos\alpha \cdot \tan\phi + \sum T\{\cos(\alpha+\theta) + \sin(\alpha+\theta)\tan\phi\}}{\sum W \cdot \sin\alpha} \qquad \text{(Equation 2.2.2)}$$

Where, Fs : Factor of safety
c : Cohesion of sliding surface (kN/m^2)
ϕ : Internal frictional angle of sliding surface (°)
l : Length of sliding surface acting on the slice (m)

u : Pore pressure acting on the base of the slice (kN/m^2)
b : Width of the slice (m)
W : Weight of the slice (kN/m)
α : Angle of the base of the slice with respect to the horizontal (°)
θ : Angle of slope of sliding surface (°)
T : Tangential force attributable to gravity of the slice (kN/m)



Source: Manual for Slope Protection, Japan Road Association

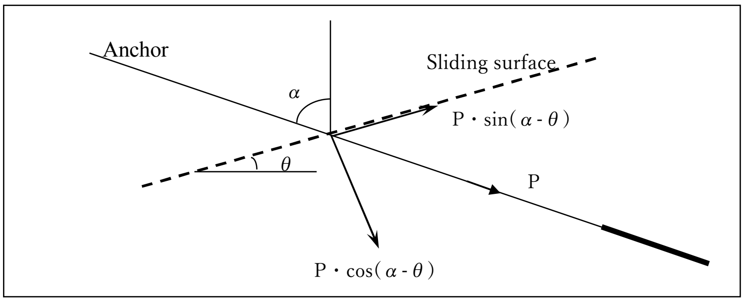
Figure 2.2.16 Calculus Method of Ground Anchors

ii. Anchor Functions

Anchors are installed to achieve the following two objectives:

- Increase the resistance against shear force by applying stress normal to the sliding surface.
  Clamping effect = P sin(α+θ)

- Decrease the sliding force of landslide using steel members as anchors.
  Straining effect = P cos(α+θ)



Source: Manual for Slope Protection, Japan Road Association

Figure 2.2.17 Functional Description of an Anchor

iii. Skin Frictional Resistance of Anchors

Skin frictional resistance of anchors was determined in accordance with **Table 2.2.18**. The geology of the friction zone is weathered rock, so the minimum value of 0.6 is adopted.

Table 2.2.18 Recommended Skin Frictional Resistance of Anchors

Type of Ground			Frictional Resistance (N/mm^2)
Bed rock	Hard rock		1.5 – 2.5
	Soft rock		1.0 – 1.5
	Weathered rock		0.6 – 1.0
	Mudstone		0.6 – 1.2
Sand and gravel	N Value	10	0.10 – 0.20

		20	0.17 – 0.25
		30	0.25 – 0.35
		40	0.35 – 0.45
		50	0.45 – 0.70
Sand	N Value	10	0.10 – 0.14
		20	0.18 – 0.22
		30	0.23 – 0.27
		40	0.29 – 0.35
		50	0.30 – 0.40
Cohesive soil	Representative Cohesion C		1.0 C

Source: Manual for Slope Protection, Japan Road Association

iv. Allowable Adhesive Stresses

Allowable adhesive stresses were determined in accordance with **Table 2.2.19**. The design strength of the grout is 24 N/mm^2, therefore, a value of 0.8 is adopted for prestressed steel wires and 1.6 is adopted for deformed prestressed steel bars.

Table 2.2.19 Recommended Allowable Adhesive Stresses

Standard Ground Design Strength (unit: N/mm2)		24	30	40
Type of tendon	1. Prestressed steel wire	0.8	0.9	1.0
	2. Prestressed steel bar			
	3. Standard prestressed steel wire			
	4. Multi-standard prestressed steel wire			
	5. Deformed prestressed 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 Standard for Design and Construction of Anchor Works, Japanese Geotechnical Society

v. Soil Bearing Capacity

Soil bearing capacity was determined in accordance with the values shown in **Table 2.2.20**.

Table 2.2.20 Allowable Bearing Capacity

Type of Ground		Allowable Bearing Capacity qa (kN/m^2(tf/m^2))	Remarks N value
Rock	Hard rock	1000 (100)	-
	Hard rock with many cracks	600 (60)	-
	Soft rock	300 (30)	-
Gravel layer	Constant	600 (60)	-
	Noncnstant	300 (30)	-
Sandy ground	Constant	300 (30)	30- 50
	Medium constant	200 (20)	20 – 30
Caly ground	Very stiff	200 (20)	15 – 30
	Stiff	100 (10)	10 -15

Source: Manual for Retaining Wall, Japan Road Association

vi. Bearing Plate

Bearing plate was selected in accordance with **Table 2.2.21**. The construction conditions of ground anchors in the Project are listed below. It is clear that the crib works are suitable for this slope.

- Slope condition is rock.
- Length of slope is long.
- Gradient of slope is steep.
- Irregularity of slope is high.
- Design strength of anchor is small.
- Instruction of construction materials is difficult.
- Height of slope for which ground anchors are designed is high.

Table 2.2.21 Selection of Bearing Plate

Condition / Kind of Plate		Condition of slope								Condition of anchors				Cnstruciton condition			
		Rock fall	Earth and sand slope	Rock slope	Spring	Weathered rock	Slope length	Steep	Irregularity is big	Anchor storegth is big	Anchor strength is small	Anchors degree is big	Placement sidisorder	Construciton period is short	Instration is difficult	Construction area is hgih	Inverted lining
Crib Works	Crib works concrete	○	○	○	○	△	○	△	△	△	◎	△	△	△	○	△	△
	Crib works	○	○	○	○	△	◎	○	◎	△	◎	△	○	○	◎	◎	○
Plate	Concrete Plate	△	○	○	○	○	△	△	○	◎	○	○	○	△	○	○	◎
	Precast Plate	△	○	○	○	○	△	△	△	◎	○	△	○	◎	△	△	◎
	Seel Plate	△	○	○	○	○	○	○	△	◎	○	△	○	◎	○	○	◎
	continuous plate	◎	○	○	○	△	△	△	△	○	◎	△	○	△	○	△	△

◎:Perfectly suit ○:Suit △:Depending on the situation

Source: JICA Survey Team based on Manual for Ground Anchors, NEXCO

vii. Specifications of Designed Ground Anchors

Specifications of designed ground anchors are presented below.

Table 2.2.22 Specifications of Designed Ground Anchors

Items			Adapted Value	Remarks
Ground Anchor	Type of ground anchor	-	Super Flotech	-
	Type of tendon	-	SFL-2	-
	Steps	m （step）	6	-
	Horizontal interval	a （m）	3.0	-
	Angle of ground anchor	α （°）	30.0	-
	Required preventive power	Td (kN/each)	231.4	-
	Fixation length	La （m）	3.5	-
Design condition for ground anchor	Anchor functions	-	Clamping and straining effect	-
	Allowable adhesive stress between the tendon and the grout	τ （N/mm^2）	0.8	-
	Skin frictional resistance of anchors	τ （N/mm^2）	0.6	Minimum value of weathered rock
	Safety factor of design	Fs	2.5	-
Bearing plate	Method	-	Shotcrete crib works	
	Girder	h×b(mm)	500×500	
	Length of span	l(m)	3.00	
	Required soil bearing capacity	q (kN/m^2)	100	
Design Condition for bearing plate	Soil bearing capacity	qa(kN/m^2)	200	-
	Design strength of mortar	σck(N/mm^2)	18	Manual for Design and Construction of Crib Works, Japan Slope Protection Association

Source: JICA Survey Team

3) Crib Works with Rock Bolts

Crib works with rock bolts were planned at the area of outside crib works with ground anchors in the upper part of Sta.17+400 slope for surface failures. The girder of crib works is 300 mm × 300 mm and the length of span is 2.0 m. The length of the rock bolt is 3.0 m. Calculation check of whether this structure could withstand adequately against all repeated rotational slips was conducted.

4) High Intensity Net

High intensity net with rock bolts was planned at the middle area of Sta.17+400 slope. The specification of rock bolt was determined according to the empirical method in the standard for design and construction of reinforced earth method by Nippon Expressway Company.

5) Others

Vegetation bags and gabion check dams were planned at the lower area of Sta.17+400 slope. Asphalt pavement with 5 cm on the road was also planned.

(2) Sta. 33+440, Sta. 33+695, Sta. 11+620 and Sta. 15+520

1) Calculation of Earth Pressure during Earthquake

Calculation of earth pressure during earthquake was conducted with Mononobe-Okabe Method on the assumption that designed horizontal seismic coefficient is 0.2.

Table 2.2.23 Results of Calculation of Earth Pressure during Earthquake

Site	Earth Pressure during Earthquake (kN/m)	
	Vertical	Horizontal
Sta.33+440	49.4	156.7
Sta.33+695	54.8	178.2
Sta.11+620	41.4	134.9
Sta.15+520	42.3	135.5

Source: JICA Survey Team

2) Ground Anchors

Ground anchors for gabion walls were designed as earth retaining of road structure.

i. Arrangement of Ground Anchors

Policies of arrangement of ground anchors are presented below.

- Two steps of ground anchors are appropriate to each site according to the Handbook for Disaster Rehabilitation, Japan Construction Engineers' Association.

- The Manual for Temporary Structure, Japan Road Association says that interval of each anchor is 1.5 m to 4.0 m generally. In the target sites, the interval should be narrowed to prevent gabion baskets bulging. According to the size of precast steel anchor plate, the interval was designed at 2.0 m. The interval for Sta.11+620 only was designed at 3.0 m due to interval of existing buttress concretes.

- The Manual for Temporary Structure, Japan Road Association says that angle of anchor is 10 to 45 degrees in principle. The angle was designed at 10 degrees because a low angle is effective to earth pressure.

- The Manual for Temporary Structure, Japan Road Association says that the horizontal angle of the anchor is 0 degree in principle. The horizontal angle was designed at 0 degree according this manual.

Table 2.2.24 Arranged Ground Anchors

Items	Sta.33+440	Sta.33+695	Sta.11+620	Sta.15+520
N: Step of anchors	2	2	2	2
S: Interval of anchors (m)	2.0	2.0	3.0	2.0
α : Angle of anchors (degree)	10	10	10	10
θ : Horizontal angle of anchors (degree)	0	0	0	0

Source: JICA Survey Team

ii. Calculation of Required Preventive Power

The required preventive power of anchor was calculated according to the following equation.

$$P_0 = \frac{RS}{\cos\alpha \cdot \cos\theta}$$

Where, P_0 : Required preventive power of anchor (kN/each)
R : Reaction of trench timbering (kN/m), In this case, horizontal earth pressure (kN/m)
S : Interval of anchors (m)
α : Angle of anchors (degree)
θ : Horizontal angle of anchors (degree)

Source: Manual for Temporary Structure, Japan Road Association

Table 2.2.25 Arranged Ground Anchors

Sites	Required Preventive Power of Anchor (kN/each)
Sta.33+440	159.1
Sta.33+695	180.9
Sta.11+620	205.5
Sta.15+520	135.5

Source: JICA Survey Team

iii. Selection of Tendon

Prestressed steel wires (Super Flotech, SFL) were selected for the reasons of high anti-corrosive performance and workability at the site. Grade of tendon was determined according to the tension and yield strength.

The required preventive power of anchor was calculated according to the following equation.

Table 2.2.26 Grade of Tendon

Sites	Grade of Tendon
Sta.33+440	SFL-2
Sta.33+695	SFL-2
Sta.11+620	SFL-2
Sta.15+520	SFL-1

Source: JICA Survey Team

iv. Skin Frictional Resistance of Anchors

Skin frictional resistance of anchors was determined in accordance with **Table 2.2.27**.

Table 2.2.27 Determined Skin Frictional Resistance of Anchors

Sites	Skin Frictional Resistance of Anchors (N/mm^2)	Reasons
Sta.33+440	0.25	Equivalent to N Value 30 of sand and gravel (based on site reconnaissance)
Sta.33+695	0.60	Minimum value of weathered rock (based on site reconnaissance)
Sta.11+620	0.60	Minimum value of weathered rock (based on geological survey)
Sta.15+520	0.60	Minimum value of weathered rock (based on site reconnaissance)

Source: JICA Survey Team

v. Soil Bearing Capacity

Soil bearing capacity was determined as 100 kN/m^2 for each site in accordance with the values shown in **Table 2.2.20**.

vi. Bearing Plate

Bearing plates should be lightweight because these plates are installed on an almost vertical gabion wall. Concrete or shotcrete crib works are high weight and might accelerate destabilization of the gabion walls. Precast steel bearing plates have an advantage for workability and safety for these sites.

According to the following comparison of precast bearing plates, the KIT anchor plate was selected because of weight and cost. Ground anchor materials including KIT anchor plates will be procured from Japan.

Table 2.2.28 Comparison of Precast Bearing Plate

Type	Weight of Each	Construction Cost of Each (JPY)
KIT Anchor Plate	162kg	171,000
ARC Frame	179kg	187,000
FFU Anchor Plate	151kg	198,000
KTB Super Frame	199kg	186,000

Source: JICA Survey Team

Installations of H beams between gabion walls and anchor plates are designed for the purpose of combination of gabion baskets and plate tension from ground anchors. Shotcrete is installed to the surface of the gabion walls and a space of pairs of H beam is filled in by concrete.

vii. Specifications of Designed Ground Anchors

Specifications of designed ground anchors are presented below.

Table 2.2.29 Specifications of Designed Ground Anchors for Sta.33+440

Items			Adapted Value
External force	Wheel load	(kN/m^2)	10.0
	Horizontal earth pressure	(kN/m)	156.7
Ground anchor	Type of ground anchor	-	Super fletch
	Type of tendon	-	SFL-2
	Steps	m (step)	2
	Horizontal interval	a (m)	2.0
	Angle of ground anchor	α (°)	10.0
	Required preventive power	Td (kN/each)	159.1
	Fixation length	La (m)	6.0
Design condition for ground anchor	Allowable adhesive stress between the tendon and the grout	τ (N/mm^2)	0.8
	Skin frictional resistance of anchors	τ (N/mm^2)	0.25
	Safety factor of design	Fs	2.5
Bearing plate	Type	-	Semi-square
	Size	-	KIT16S-230-L
	Required soil bearing capacity	q (kN/m^2)	100

Source: JICA Survey Team

Table 2.2.30 Specifications of Designed Ground Anchors for Sta.33+695

Items			Adapted Value
External force	Wheel load	(kN/m^2)	10.0
	Horizontal earth pressure	(kN/m)	178.2
Ground anchor	Type of ground anchor	-	Super fletch
	Type of tendon	-	SFL-2
	Steps	m (step)	2
	Horizontal interval	a (m)	2.0
	Angle of ground anchor	α (°)	10.0
	Required preventive power	Td (kN/each)	180.9
	Fixation length	La (m)	3.0
Design condition for ground	Allowable adhesive stress between the tendon and the grout	τ (N/mm^2)	0.8
	Skin frictional resistance of anchors	τ (N/mm^2)	0.6

anchor	Safety factor of design	Fs	2.5
Bearing plate	Type	-	Semi-square
	Size	-	KIT19S-230-L
	Required soil bearing capacity	q (kN/m^2)	100

Source: JICA Survey Team

Table 2.2.31 Specifications of Designed Ground Anchors for Sta.11+620

Items			Adapted Value
External force	Wheel load	(kN/m^2)	10.0
	Horizontal earth pressure	(kN/m)	134.9
Ground anchor	Type of ground anchor	-	Super fletch
	Type of tendon	-	SFL-2
	Steps	m (step)	2
	Horizontal interval	a (m)	3.0
	Angle of ground anchor	α (°)	10.0
	Required preventive power	Td (kN/each)	205.5
	Fixation length	La (m)	3.5
Design condition for ground anchor	Allowable adhesive stress between the tendon and the grout	τ (N/mm^2)	0.8
	Skin frictional resistance of anchors	τ (N/mm^2)	0.6
	Safety factor of design	Fs	2.5
Bearing plate	Type	-	Semi-square
	Size	-	KIT19S-230-L
	Required soil bearing capacity	q (kN/m^2)	100

Source: JICA Survey Team

Table 2.2.32 Specifications of Designed Ground Anchors for Sta.15+520

Items			Adapted Value
External force	Wheel load	(kN/m^2)	10.0
	Horizontal earth pressure	(kN/m)	135.5
Ground anchor	Type of ground anchor	-	Super fletch
	Type of tendon	-	SFL-1
	Steps	m (step)	2
	Horizontal interval	a (m)	2.0
	Angle of ground anchor	α (°)	10.0
	Required preventive power	Td (kN/each)	137.6
	Fixation length	La (m)	4.0
Design condition for ground anchor	Allowable adhesive stress between the tendon and the grout	τ (N/mm^2)	0.8
	Skin frictional resistance of anchors	τ (N/mm^2)	0.6
	Safety factor of design	Fs	2.5
Bearing plate	Type	-	Semi-square
	Size	-	KIT16S-230-L
	Required soil bearing capacity	q (kN/m^2)	100

Source: JICA Survey Team

These designed anchors can withstand a sliding force of each rotational slip with over 1.20 of safety factor.

3) Asphalt Pavement

Asphalt pavement of 5 cm thickness was designed in order to prevent surface water coming into the road earth from cracks on road, except Sta.11+620.

4) Restoration of Side Ditch

Restoration works of side ditch at Sta.33+440 and Sta.33+695 were designed.

5) Side Ditch

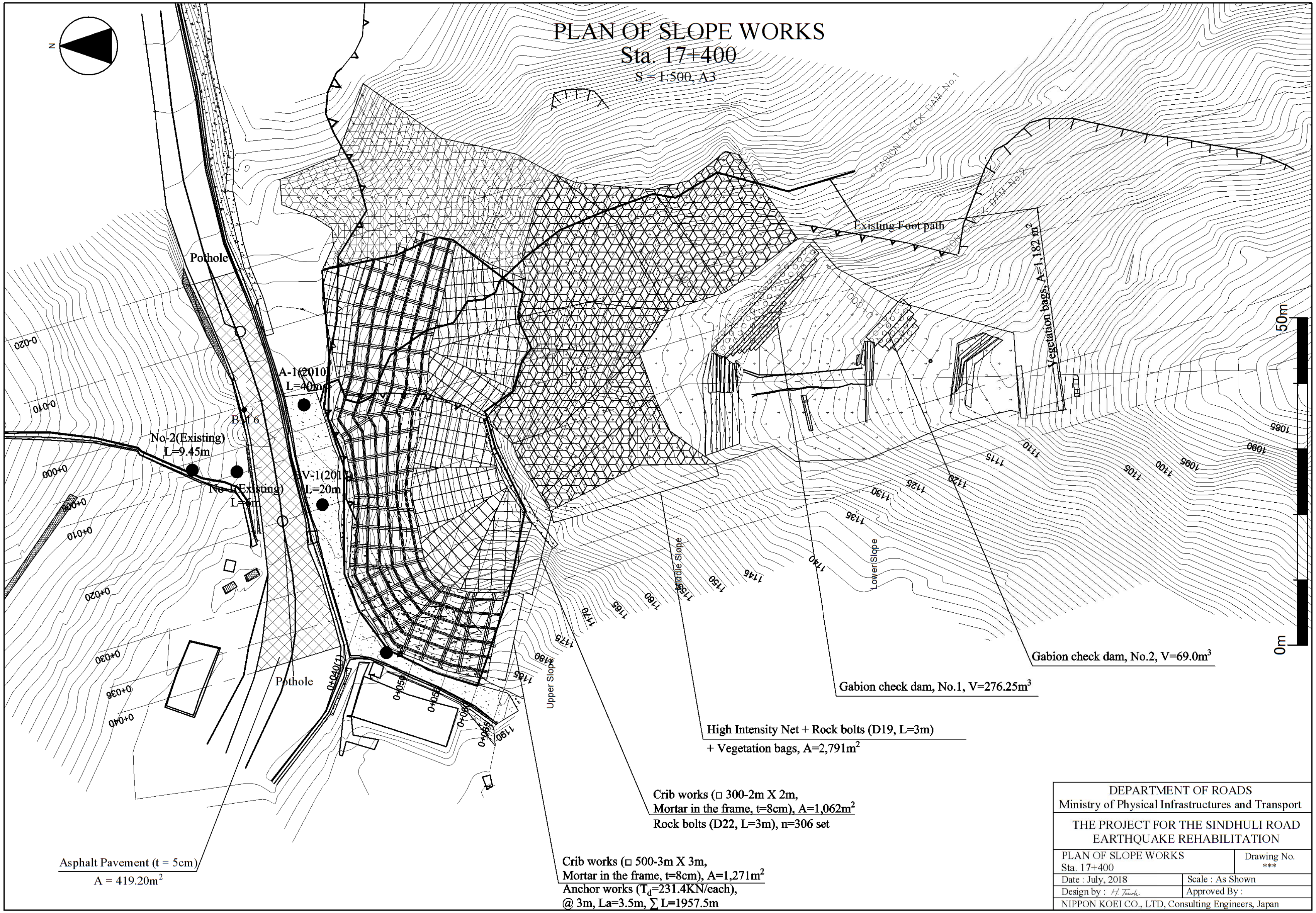
Installation of side ditch at Sta.11+620 was designed in order to prevent surface water coming into road earth from the mountain side.

6) High Intensity Net

High intensity net with rock bolts was designed for the upper slope from road against rock falls prevention and surface failures. This net was planned for lower slope from the road against surface failures.

2.2.3 OUTLINE DESIGN DRAWING

Outline design drawings for each site are shown in the next pages.



Source: JICA Study Team

Figure 2.2.18 Plan of Slope Protection Works of Sta.17+400 (Non-Scale)

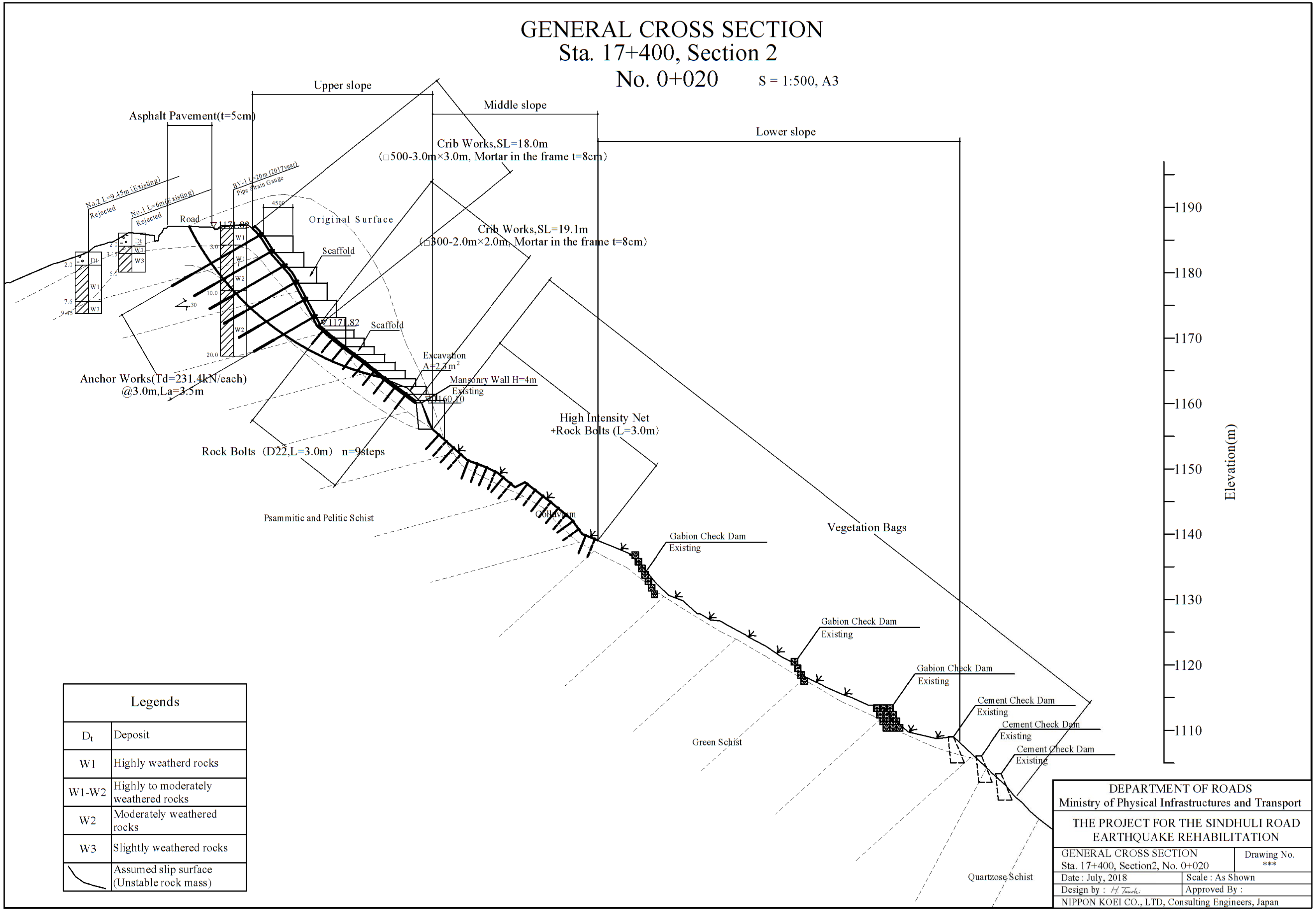
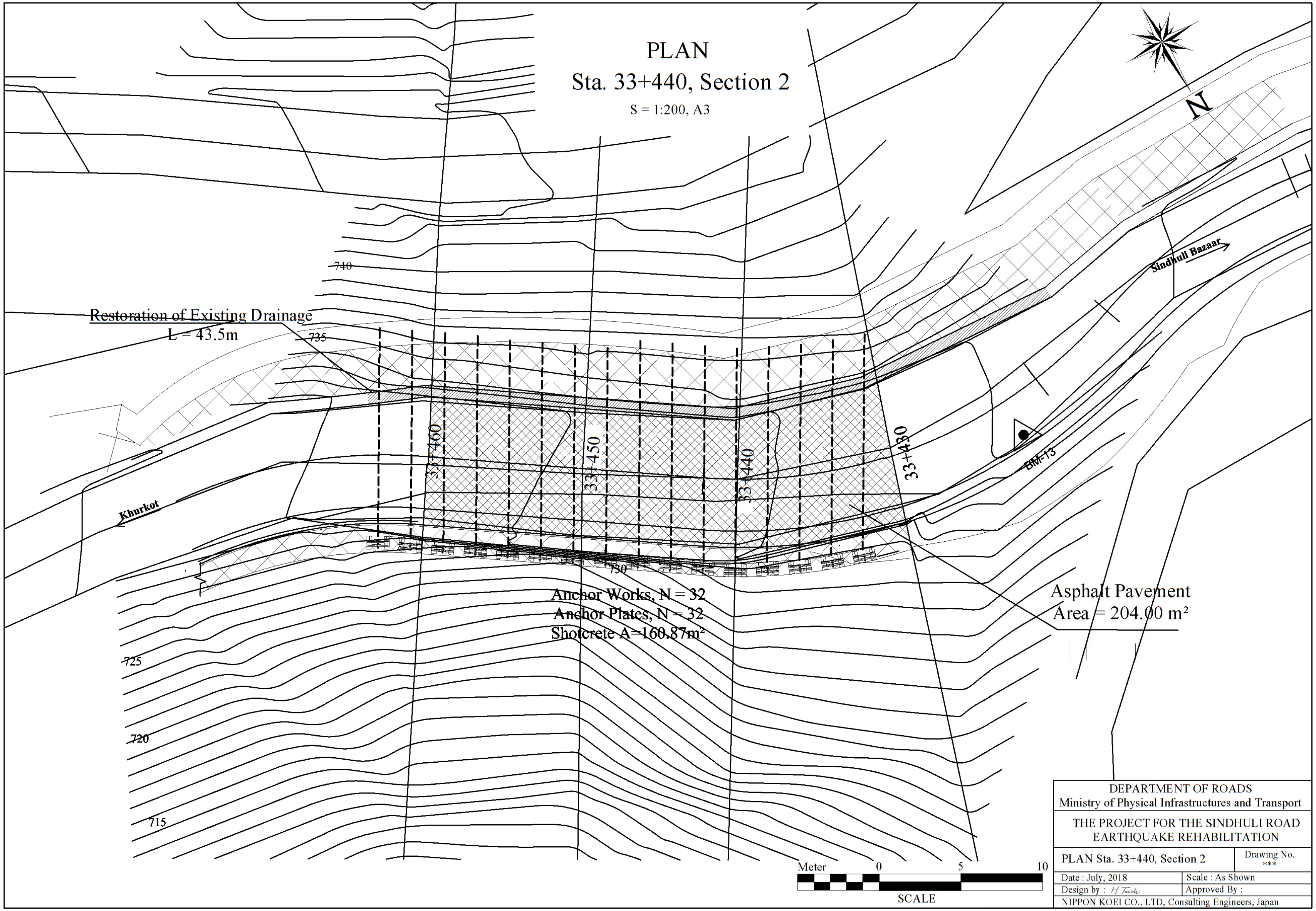


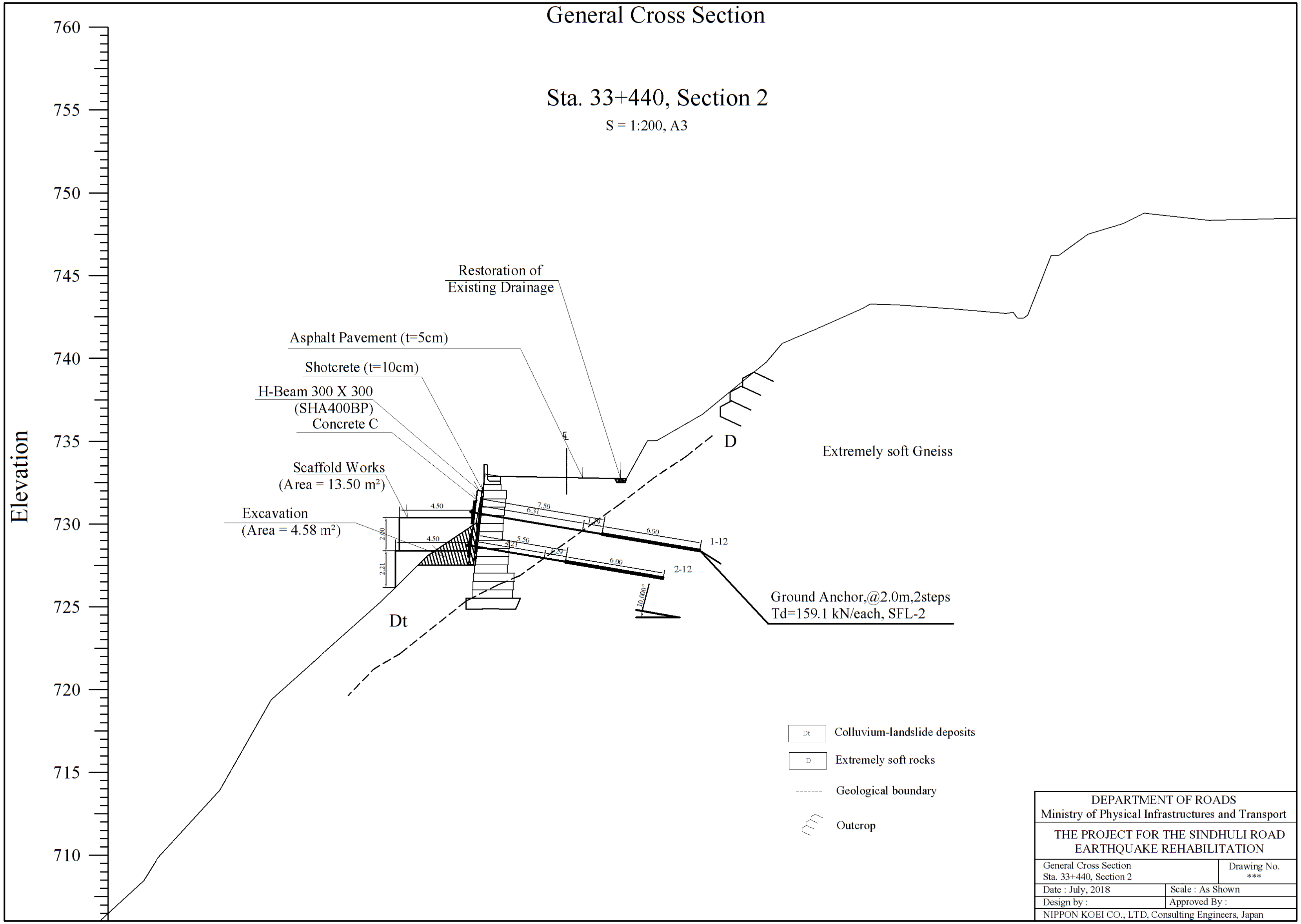
Figure 2.2.19 General Cross Section of Sta.17+400 (Non-Scale)

Source: JICA Study Team



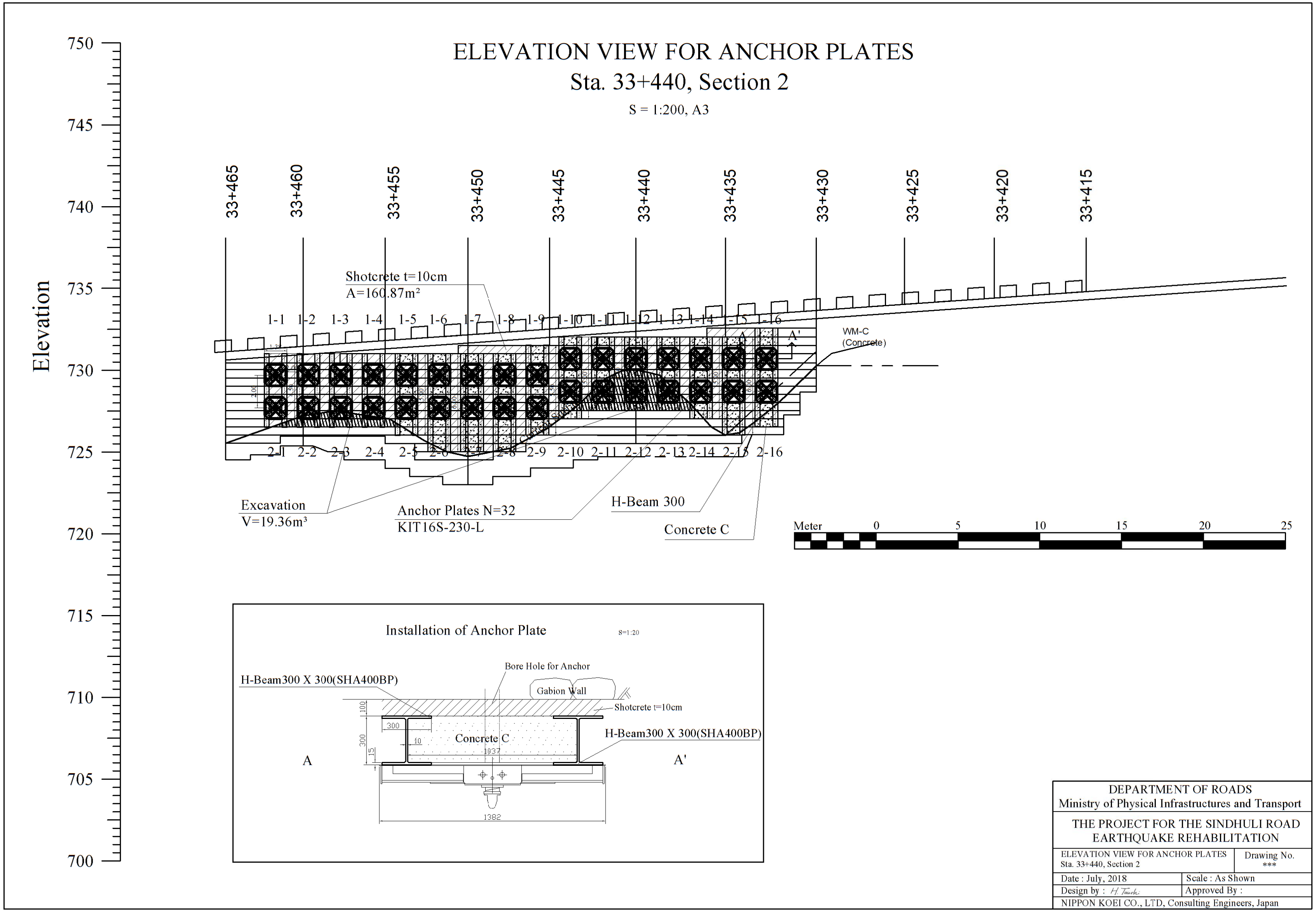
Source: JICA Study Team

Figure 2.2.20 Plan of Slope Protection Works of Sta.33+440 (Non-Scale)



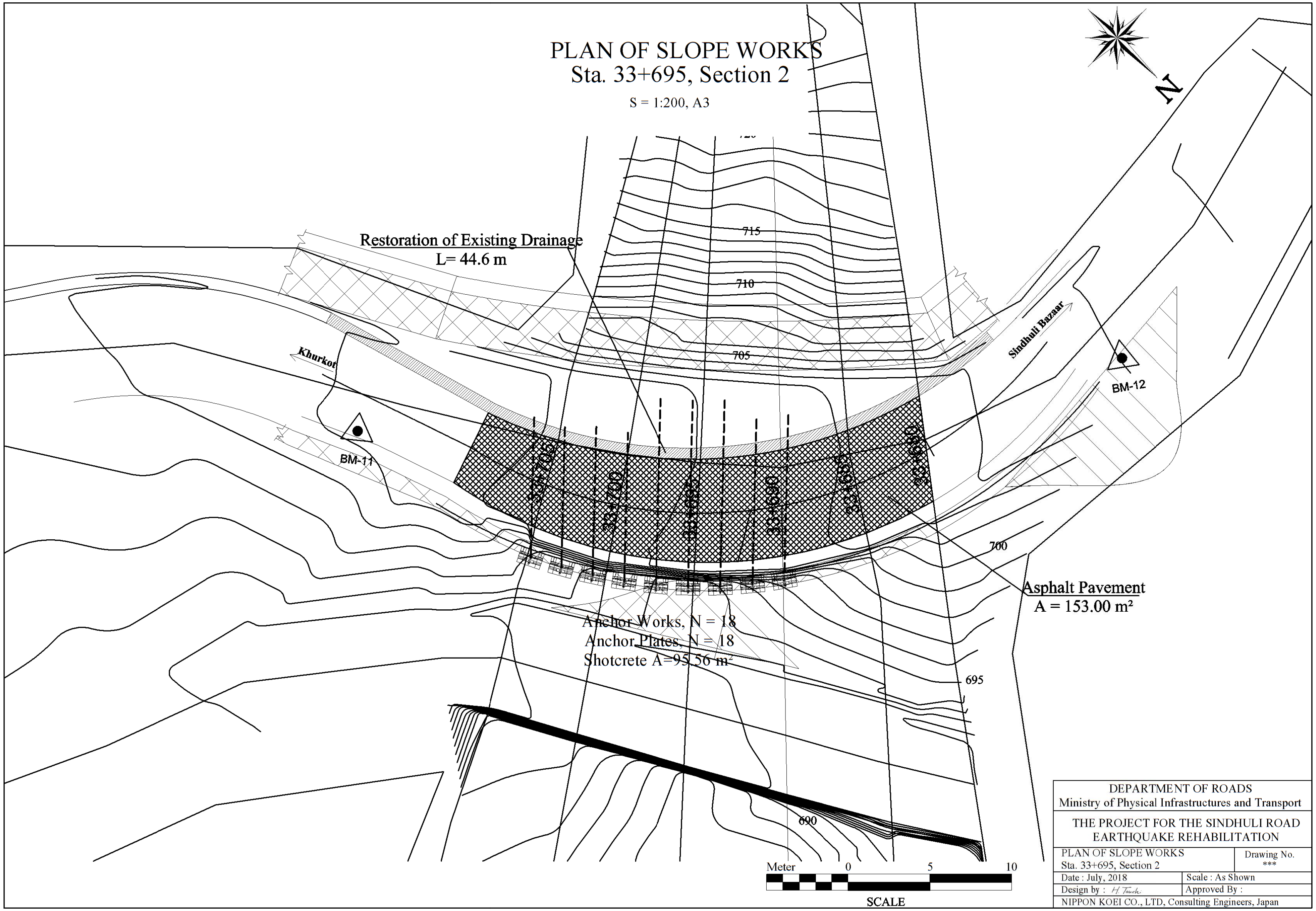
Source: JICA Study Team

Figure 2.2.21 General Cross Section of Sta.33+440 (Non-Scale)



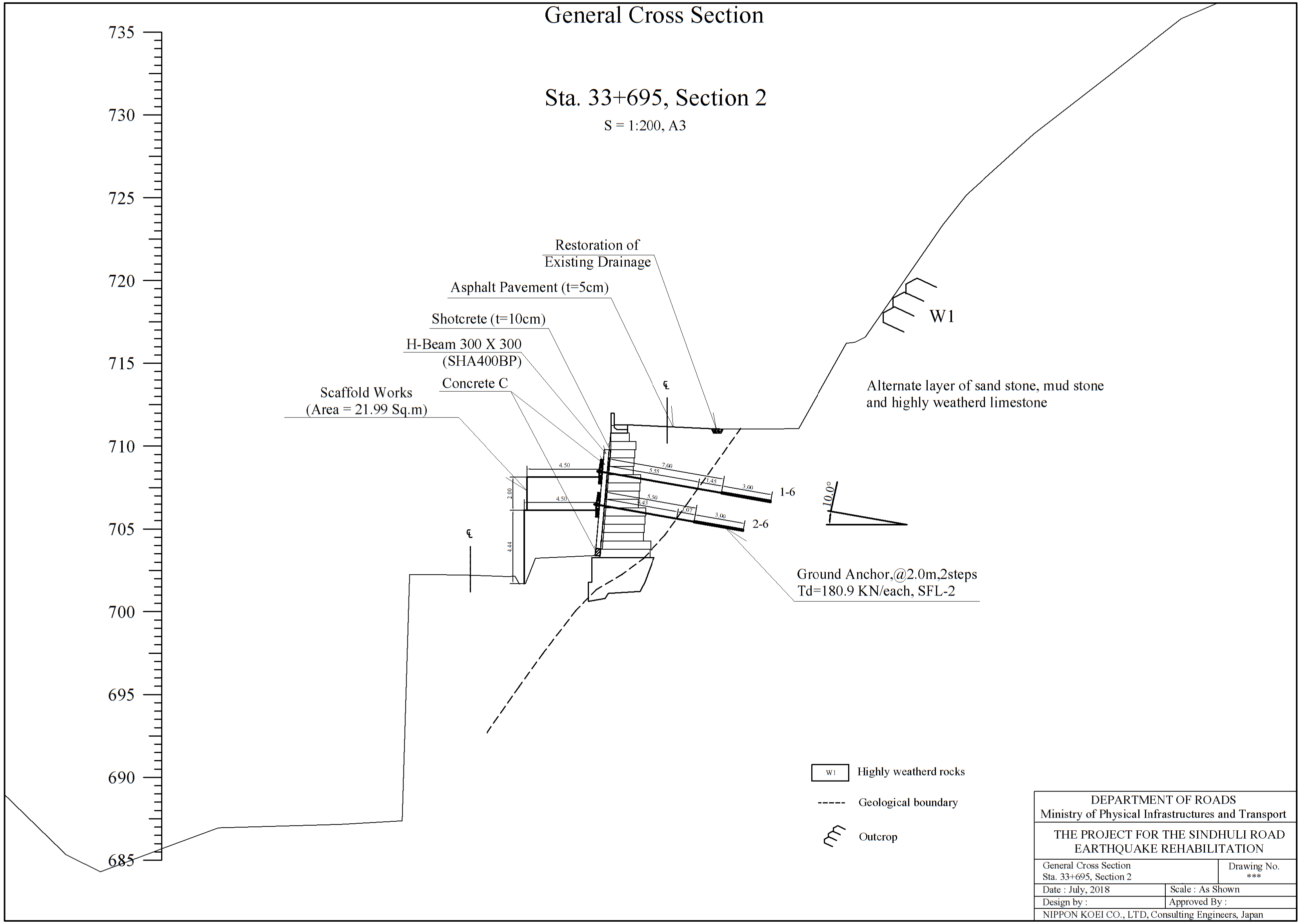
Source: JICA Study Team

Figure 2.2.22 Elevation View for Anchor Plates of Sta.33+440



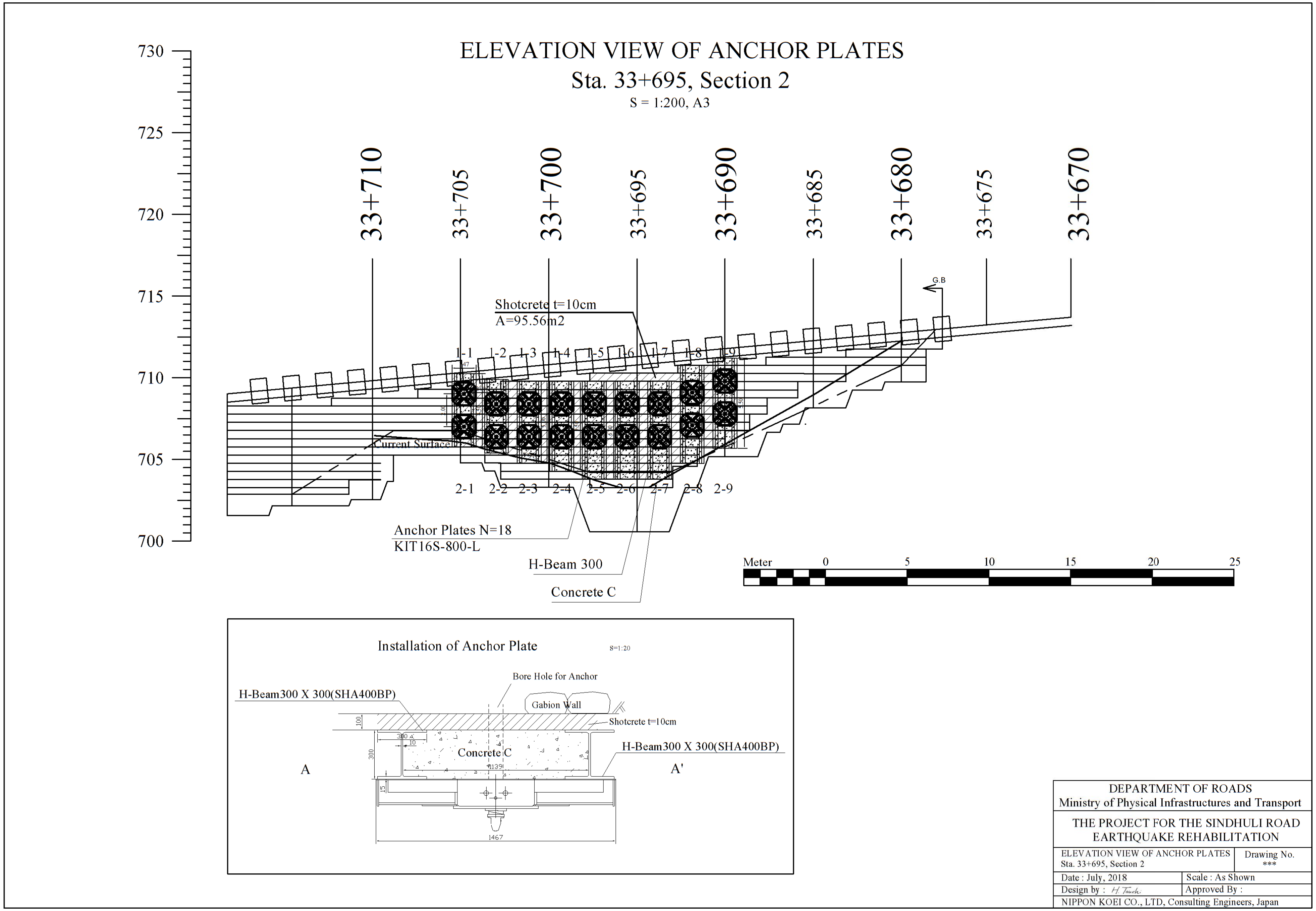
Source: JICA Study Team

Figure 2.2.23 Plan of Slope Protection Works of Sta.33+695 (Non-Scale)



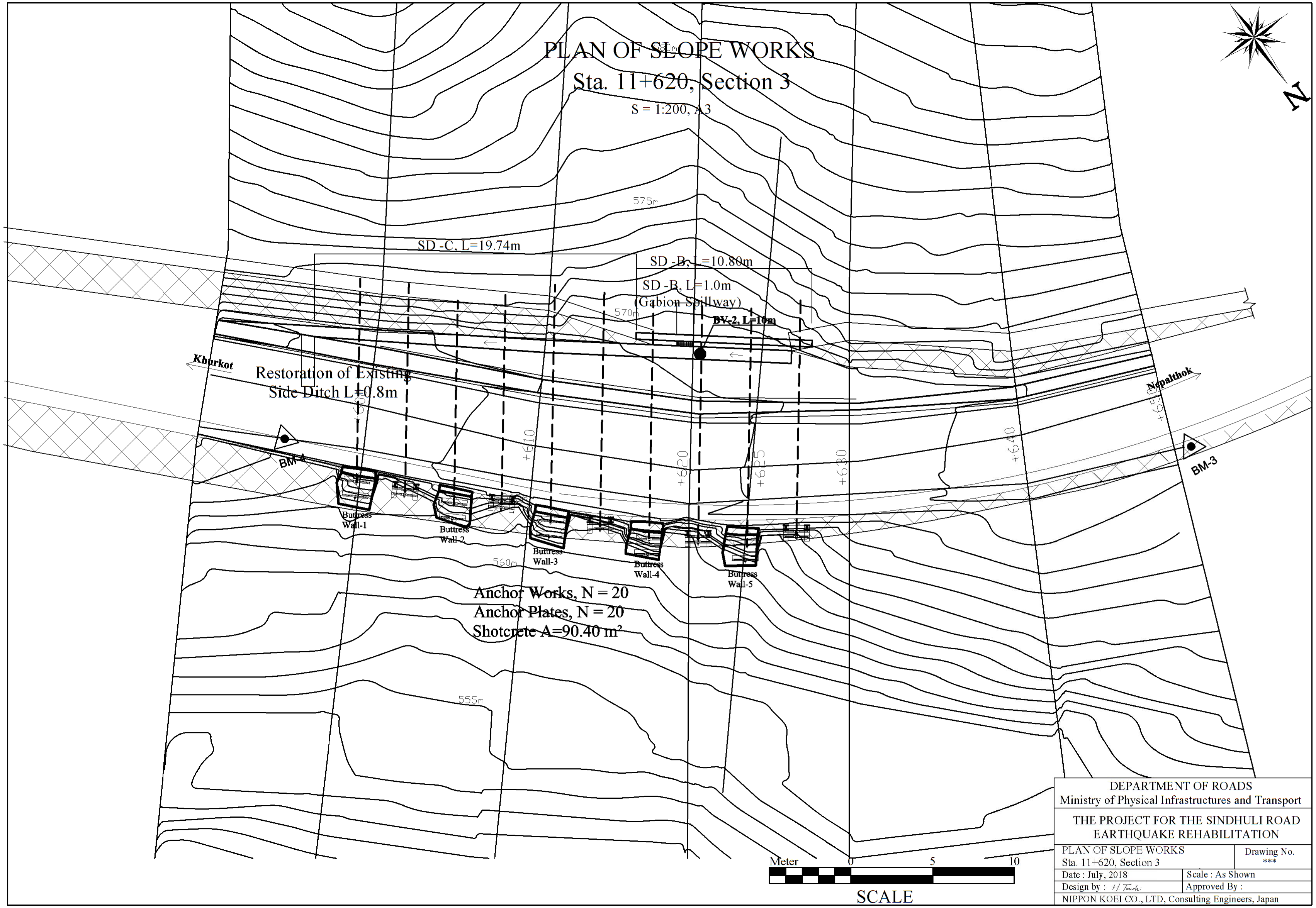
Source: JICA Study Team

Figure 2.2.24 General Cross Section of Sta.33+695 (Non-Scale)



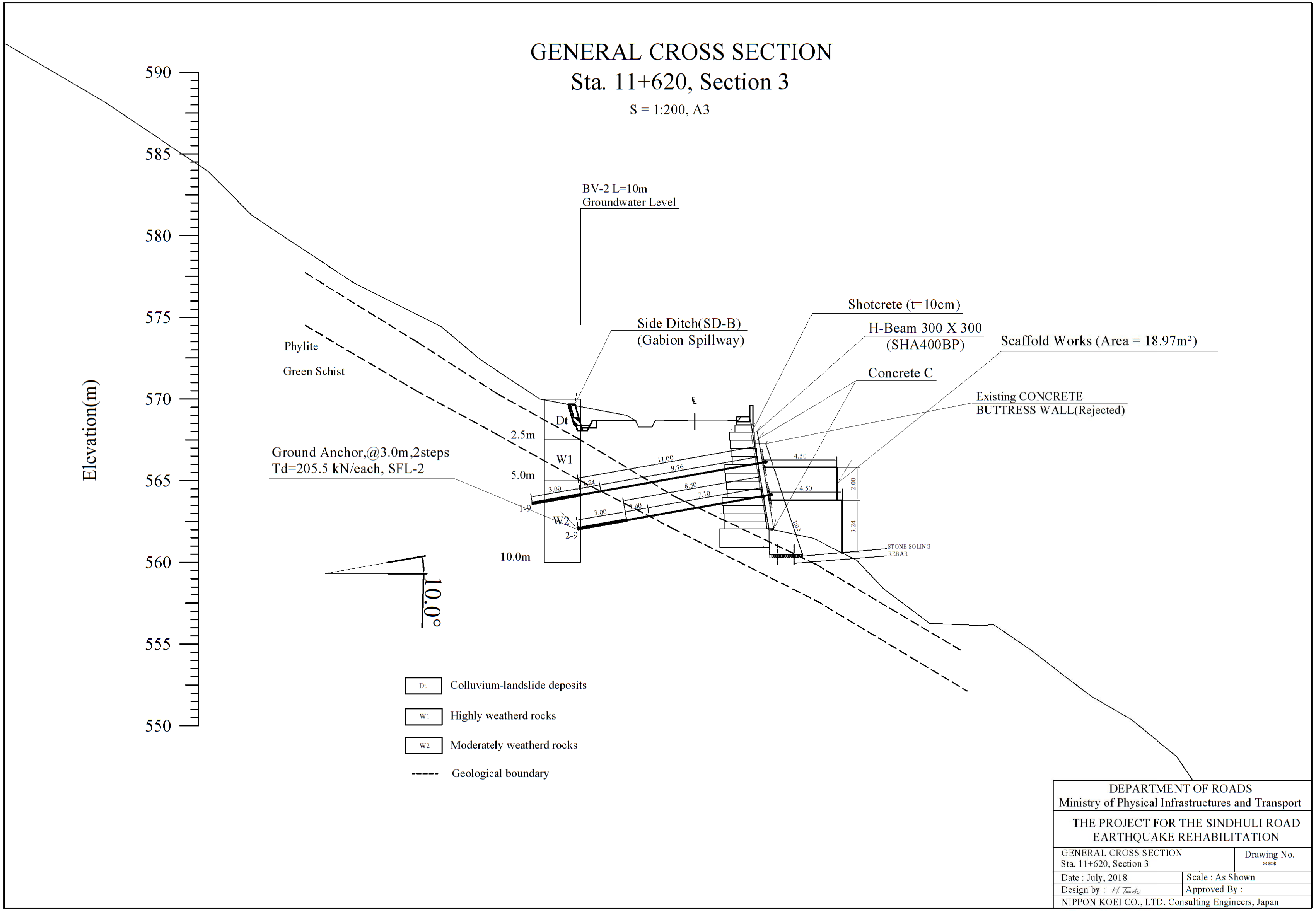
Source: JICA Study Team

Figure 2.2.25 Elevation View for Anchor Plates of Sta.33+695 (Non-Scale)



Source: JICA Study Team

Figure 2.2.26 Plan of Slope Protection Works of Sta.11+620 (Non-Scale)



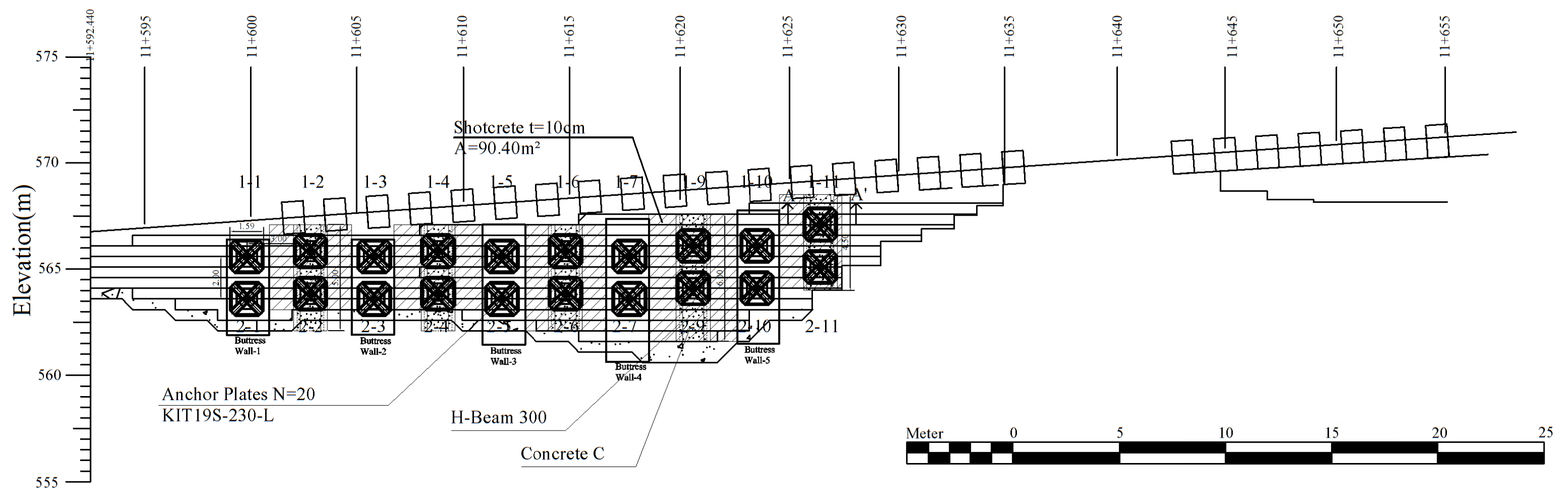
Source: JICA Study Team

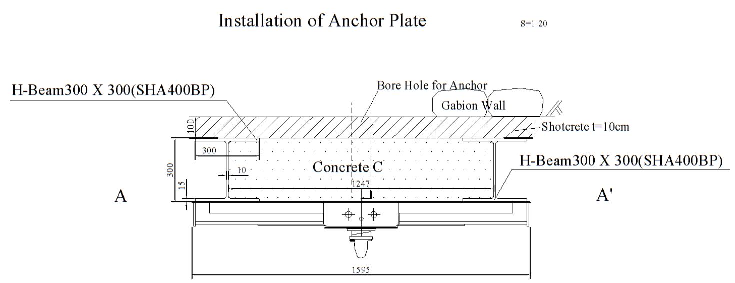
Figure 2.2.27 General Cross Section of Sta.11+620 (Non-Scale)

ELEVATION VIEW FOR ANCHOR PLATE

Sta. 11+620, Section 3

S = 1:200, A3





DEPARTMENT OF ROADS
Ministry of Physical Infrastructures and Transport

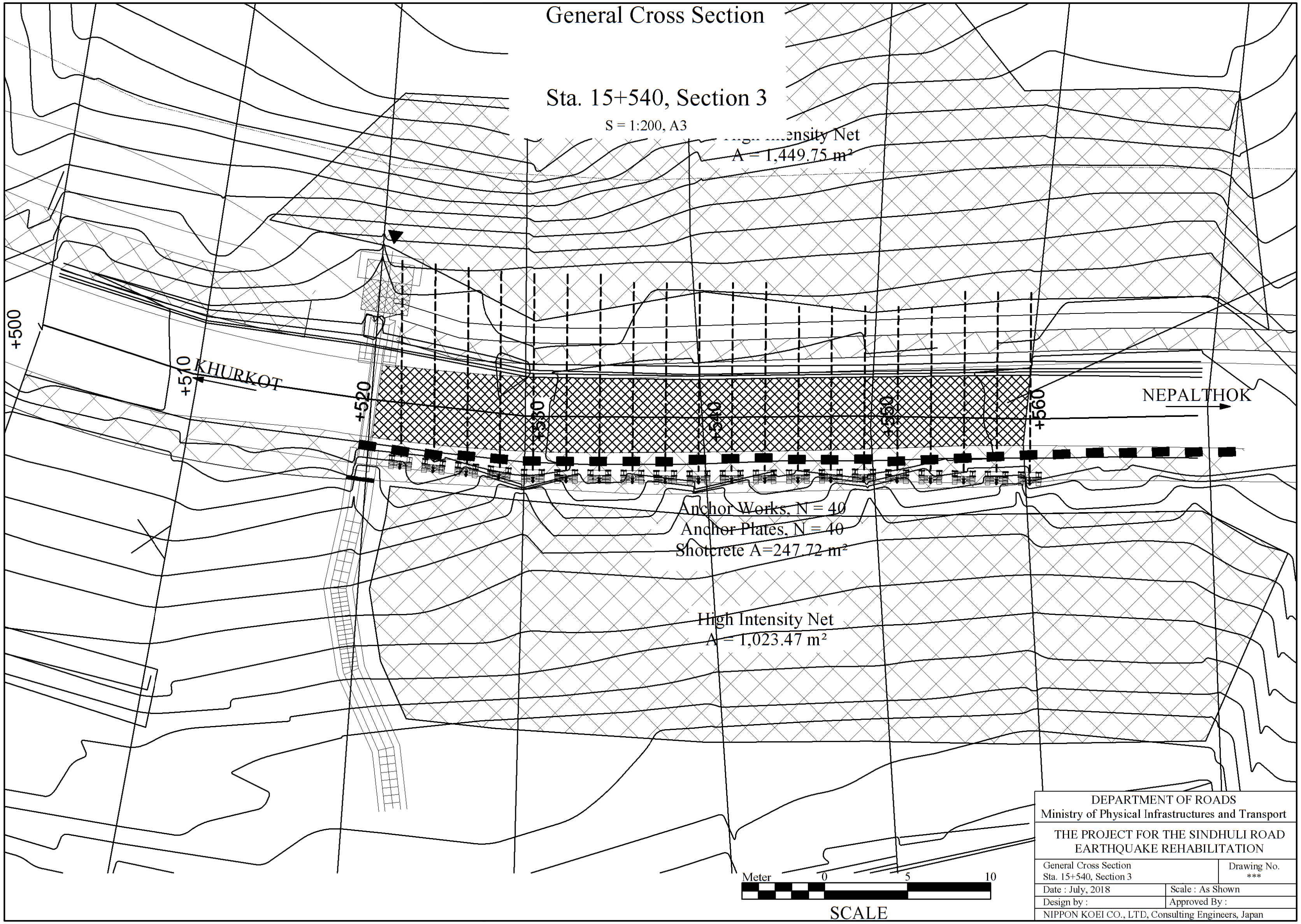
THE PROJECT FOR THE SINDHULI ROAD EARTHQUAKE REHABILITATION

ELEVATION VIEW FOR ANCHOR PLATE Sta. 11+620, Section 3	Drawing No. ***
Date : July, 2018	Scale : As Shown
Design by :	Approved By :

NIPPON KOEI CO., LTD, Consulting Engineers, Japan

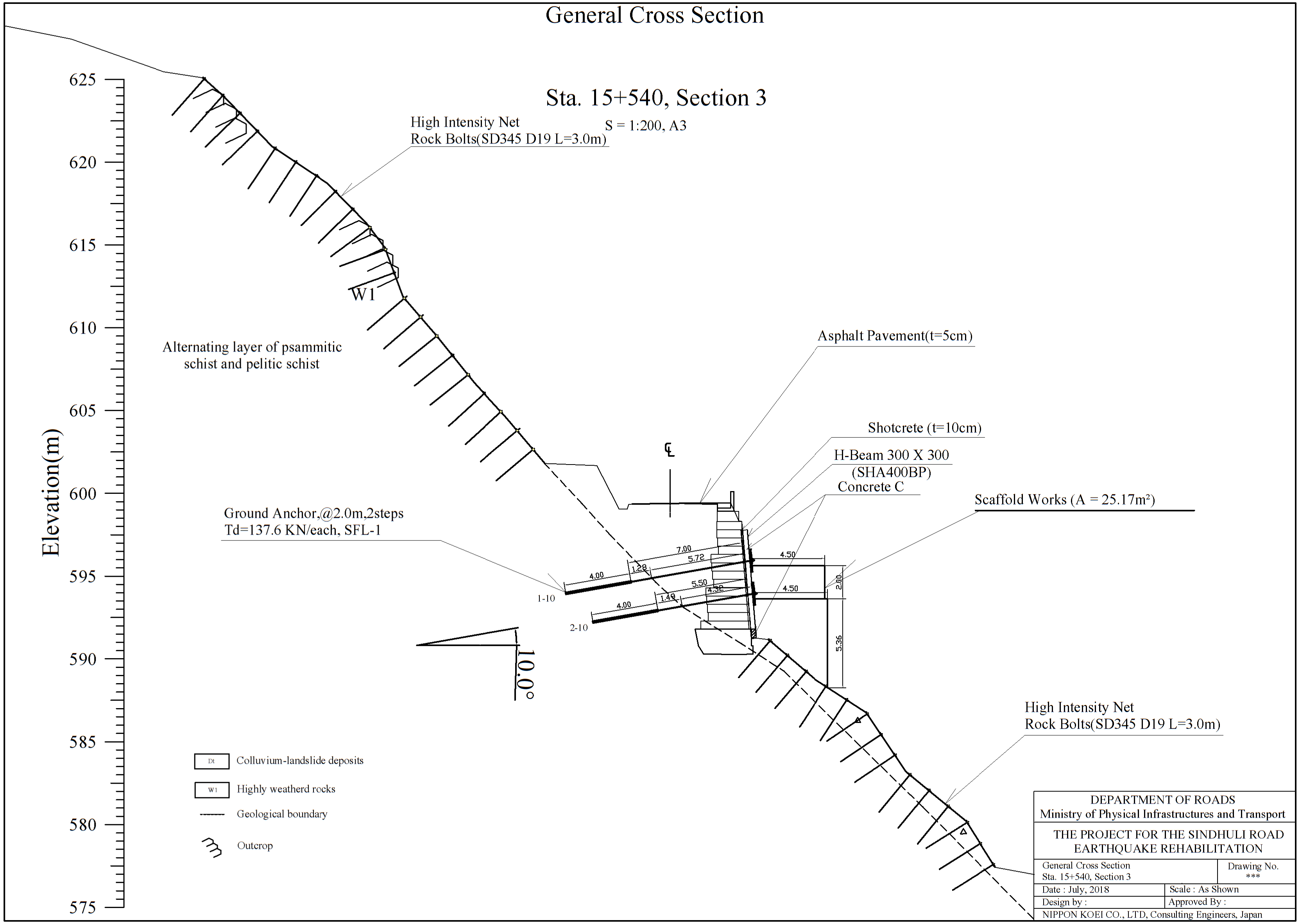
Source: JICA Study Team

Figure 2.2.28 Elevation View for Anchor Plates of Sta.11+620 (Non-Scale)



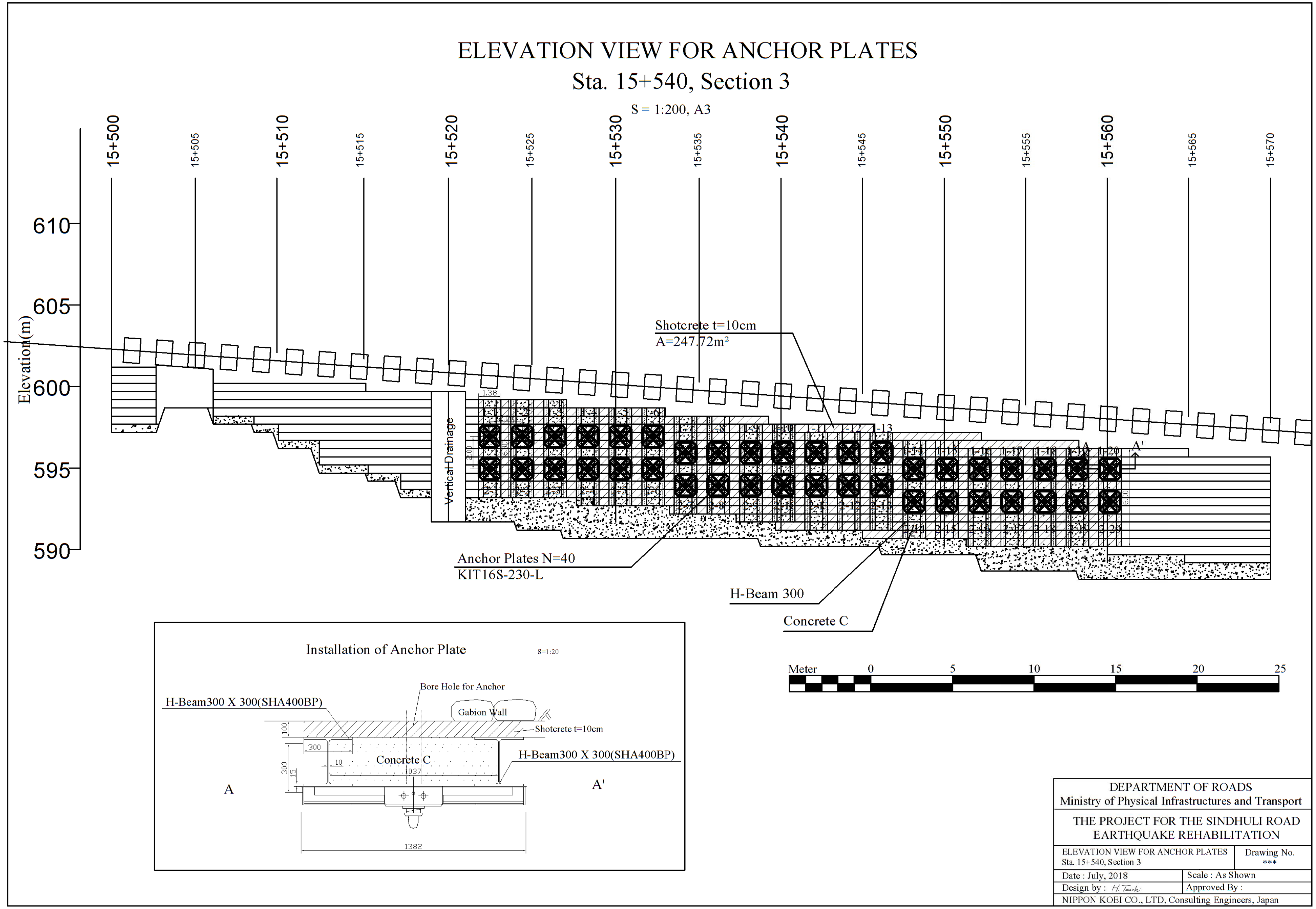
Source: JICA Study Team

Figure 2.2.29 Plan of Slope Protection Works of Sta.15+540 (Non-Scale)



Source: JICA Study Team

Figure 2.2.30 General Cross Section of Sta.15+540 (Non-Scale)



Source: JICA Study Team

Figure 2.2.31 Elevation View for Anchor Plates of Sta.15+540 (Non-Scale)

2.2.4 IMPLEMENTATION PLAN

2.2.4.1 IMPLEMENTATION POLICY

(1) Basic Policy

The implementation plan of the Project was prepared based on the guidelines of the Japanese grant aid with consideration of the site conditions. The policies for implementation are summarized as follows:

- Creation of new employment opportunities and technology transfer promotion, local labor and materials necessary for this project will be utilized form local area as much as possible.
- Since public buses and local transport vehicles currently pass on the road in service, sufficient attention should be given to avoid traffic accidents caused by construction vehicles and minimize negative impacts of the Project against public transportation services.

(2) Construction period

The project program has been drawn up with the following thoughts in mind that the project will be implemented as a single-year bond. As a result, it is scheduled that the construction will be started in April 2019 and should be completed in July 2020 with a 16 months construction period.

(3) construction processes and methods

The flow of construction is shown in **Figure 2.2.32**.

Sta.	Sta.17+400 (Section II)	Sta.33+440 (Section II)	Sta.33+695 (Section II)	Sta. 11+620 (Section III)	Sta.15+520 (Section III)
Construction Process	Preparatory work ▼ Human power earthmoving, side cutting ▼ Slope sweeping ▼ Slope sweeping ▼ Lath tightening method ▼ Crib works F500 ▼ Crib works F300 ▼ Scaffolding works for anchor method ▼ Anchor works (top six stages) (boring, steel processing/assembly/ insertion, grouting and pouring) ▼ Anchor works (5th stage → 4th stage → 3rd stage → 2nd stage → 1st stage) (boring, steel processing/assembly/ insertion, grouting and pouring) ▼ Scaffolding works for rock bolts ▼ Rock bolts ▼ High intensity net + rock bolts ▼ Gabion check dams ▼ Vegetation works ▼ Asphalt pavements ▼ Demobilization	Preparatory work ▼ Earthmoving ▼ Mortar air blast ▼ H beam installation /concrete works ▼ Scaffolding works ▼ Anchor works (upper stages) (boring, steel processing/assembly/ insertion, grouting and pouring, tension anchorage, head treatment) ▼ Anchor works (lower stages) (boring, steel processing/assembly/ insertion, grouting and pouring, tension anchorage, head treatment) ▼ Appurtenant work (Side ditch works) ▼ Asphalt pavements ▼ Demobilization	Preparatory work ▼ Mortar air blast ▼ H beam installation /concrete work ▼ Scaffolding works ▼ Anchor works (upper stages) (boring, steel processing/assembly/ insertion, grouting and pouring, tension anchorage, head treatment) ▼ Anchor works (lower stages) (boring, steel processing/assembly/ insertion, grouting and pouring, tension anchorage, head treatment) ▼ Appurtenant work (Water channel mending) ▼ Asphalt pavements ▼ Demobilization	Preparatory work ▼ Mortar air blast ▼ H beam installation /concrete work ▼ Scaffolding works ▼ Anchor works (upper stages) (boring, steel processing/assembly/ insertion, grouting and pouring, tension anchorage, head treatment) ▼ Anchor works (lower stages) (boring, steel processing/assembly/ insertion, grouting and pouring, tension anchorage, head treatment) ▼ Side ditch works ▼ Asphalt pavements ▼ Demobilization	Preparatory work ▼ Mortar air blast ▼ H beam installation /concrete work ▼ Tube and coupler scaffolding work ▼ Anchor method (upper stages) (boring, steel processing/assembly/ insertion, grouting and pouring, tension anchorage, head treatment) ▼ Anchor works (lower stages) (boring, steel processing/assembly/ insertion, grouting and pouring, tension anchorage, head treatment) ▼ High intensity net ▼ Asphalt pavements ▼ Demobilization

Source: JICA Survey Team

Figure 2.2.32 Construction Process

2.2.4.2 IMPLEMENTATION CONDITIONS

(1) Traffic Regulation and Safety Management during Construction

1) Traffic safety management

The Project involves road construction with maximum utilization of the existing Sindhuli Road. The traffic volume on the road includes a combination of common and construction vehicles. Therefore, flagmen must be designated to control the movement of vehicles and secure smooth and safe traffic.

2) Slope monitoring during construction period

Slope monitoring work is planned to observe the safety management during construction period due to active landslide.

(2) Environmental Protection during Construction Period

The contractor should conduct the environmental monitoring items shown in **Table 1.4.61**, and the related expense has been included in the rate portion of cost estimation.

The following matters will be considered for environmental protection during the construction period.

- Reduce the occurrence of dust induced by construction vehicles during construction period by watering and speed regulation.
- Sound-proof sheet will be used to reduce noise influence generated during construction.
- Working in the morning and evening will be avoided to minimize the influence of construction noise.

(3) Labor Law

The contractor should abide by the "Labor Standards Act" (Rule and Regulation for Workers and Employees to the Private Institution and Factory in Nepal) as well as respect appropriate working conditions and local custom at the time of employment of workers.

(4) Attention Points about Responsibilities of Nepal

Responsibilities of Nepal which may largely impact the construction schedule the most, need to secure the necessary sites (road site, working space, campground, machines and materials storage site) for construction. To complete those responsibilities as early as possible, adjustment with counterpart DOR will be considered.

2.2.4.3 SCOPE OF WORKS

The scope of works to be undertaken by the GOJ and GON is as shown in **Table 2.2.33**.

Table 2.2.33 Responsibilities of Each Countries

Responsibilities of GOJ	Responsibilities of GON
• Consulting services for detailed design, preparation of tender documents, assistance in tender process, and construction supervision. • Construction of countermeasures in the drawings. • Installation and removal of temporary facilities (construction yard). • Protective measures against environmental pollution during the execution of construction works. • Procurement, import and transport of construction equipment and materials shown in the Procurement Plan of Equipment and Materials.	• Free provision of site (land), temporary facilities and other construction activities for the execution of works. • Execution of environmental monitoring. • Remove the communal facilities which may be the hindrance to the project. • Gratis supply of the temporary area used as campground, construction yard and others. • Tax exemption of equipment and materials procured overseas and prompt tax exemption procedure. • Exemption from customs duties and taxes imposed on arrival of Japanese or people from third countries who are assigned to this project. • Free provision of traffic control and management for existing roads. • Proper O&M for all completed facilities. • Continue landslide monitoring after the construction is completed.

Source: JICA Survey Team

2.2.4.4 CONSULTANT SURPERVISION

Once the construction contract is finished, the consultant will issue the start of the construction order to the contractor, and start the construction supervision work. For the contractor, the consultant will supervise the safety, environmental and social considerations, construction progress supervision, technical improvement measures/proposals concerning the construction and payment. Additionally, one year after construction completion a defect inspection will be performed.

One resident construction supervision engineer will be arranged to take charge of the daily construction supervision as well as the coordination and supervision work involved with related organizations. In order to secure reliable quality and process of the anchor work, it has planned to arrange expert technicians familiar with anchor works during the key work period.

The construction supervision work charged by consultants has been planned as follow:

Chief Engineer	In charge of coordination and liaison for all project activities concerning consultant's agreement, tender assistance and supervision in order to ensure the smooth progress and management of all technical aspects.
Resident Engineer	All throughout the construction period, the engineer will reside in the construction site and respond to coordination work and technical support. Besides construction supervision, the engineer will also respond to the daily management of materials, quality, safety, completed work amount and quality, construction schedule control and payment affairs. In addition, the resident engineer will be in charge of coordination work and negotiation with the partner country.

Anchor work Engineer	It has been planned that technical experts who are familiar with anchor works will be dispatched to each important construction process. During the dispatch period, technical experts will respond to review the design condition of anchor method fundamental test, discussion of construction method, grout management necessary for fixing work, instruction of tension management, and discussion of slope stability at the time of such as pressure plate construction, assembly of anchor materials, installation of anchor and anchor tension.

2.2.4.5 QUALITY CONTROL PLAN

The quality control plan of the Project follows the quality control plan in the Sindhuli Road Construction Project due to matching standards on the same road. In addition, quality control is conducted in accordance with project specifications and the quality control plan. The quality control plan needed in the Project is as shown in **Table 2.2.34**.

Table 2.2.34 List of Items for the Quality Control Plan

Item			Test Method	Frequency
Ground Anchors	Drilling	Degree of drilling	Measurement of Degree	Each anchor
		Length of drilling	Measurement of Length	Each anchor
		Hole Cleaning	Density of Cleaning Water	Each anchor
	Assembling of anchors	Material	Certificate of Quality, Inspection Certificate	Each delivery
		Assembling	Measurement of Length	Each anchor
	Insert		Measurement of Length	
	Injection	Material	Certificate of Quality, Result of Physicochemical Test	Each delivery
		Water	Result of Component testing	Each delivery
		Grout density(injection)	Density test（P Float Test）	Each composition
		Injection volume	Measurement of Injection Volume	Each hole
		Grout density(ejection)	Density Test（P Float Test）	Each hole
		Pressure	Measurement of Pressure	Each hole
		Length of head	Measurement of Length	Each hole
		Grout strength	Compressive Strength Test	Each hole
	Tension and settlement	Degree of set	Measurement of Degree	
		Tensioning force	Measurement of Load	
		Load-extension	Load-extension Diagram	
		Confirmation of Settlement	Aptitude test	All anchors × 5%
			Pulling test	5 anchors (5 sites)
			Cycle test	All anchors × 5%
	Treatment of the head	Treatment of the head	Measurement of Anti-corrosion Coating	Each hole
Crib Works	Material		Certificate of Quality	All materials
Re-bar	Material		Mill Sheet, Tensile Strength	Annually or semi-annually
	Tension and settlement	Confirmation of Settlement	Fundamental test	4 sites (each geological condition)
			Confirmation test	Each bolt
Concrete	Placing		Slump	Every batch
			Temperature	Daily
	Test		Compressive Strength (7 days, 28 days)	Daily
Asphalt	Material	Asphalt	Certificate of Quality	Each installation
		Aggregate	Grain size distribution	Each mix work or every month
			water-absorbing ratio	Each installation
			Loss test	
	Composition test		Stability test	Each mix work

Item			Test Method	Frequency
			Flow rate	
			Void ratio	
			Aggregate void ratio	
			Tension strength	
			Residual stability	
			Designed amount	
High Intensity Net	Material		Certificate of Quality, Feature Size	Each lot
	Tension and settlement	Confirmation of Settlement	Confirmation test	All rock bolts ×3%

Source: JICA Survey Team

2.2.4.6 PROCUREMENT PLAN

(1) labor

As to the laborers engaging in this project, workers who do not need special skills such as ordinary workers, security guards will be employed around the site, while engineers and skilled workers will be employed from Kathmandu and other areas. However, as the countermeasure against landslide, anchor works which requires advanced technique and safety considerations as well as construction experience in Nepal are lacking. Therefore, it has been planned that skilled craftsmen related to those work will be sent to the construction site from Japan.

(2) construction materials

Natural materials (sand, stone, banking material, wood, etc.) and general materials such as cement and reinforcing bar (part of standards) including the imported products are generally distributed in the market, and thus can be procured locally. However, the construction materials used in anchor work and other special work are not distributed in Nepal, and thus has been planned to be procured in Japan. **Table 2.2.35** shows the procurement plan for major construction materials.

Table 2.2.35 Procurement Plan of Major Construction Materials

Construction Materials	Nepal	The third country (e.g. India)	Japan	Note
Cement	○			Imported and domestic products are both distributed
Aggregate	○			Local buying
Concrete admixtures	○			Imported products (generally distributed)
Reinforcing bar (D10, D13, D16 equate)	○			Imported and domestic products are both distributed
Bitumen materials	○			Imported products (generally distributed)
Fuel (diesel, gasoline)	○			Imported products (generally distributed)
Anchor work materials			○	Local procurement is impossible
Pipe scaffolding materials (expect the single tube pipe, square pipe and joint)			○	Procurement in Japan for quality assurance
Rock bolt works materials			○	Local procurement is impossible
High-strength network			○	Local procurement is impossible
H-section steel			○	Procurement in Japan for quality assurance
Nameplate			○	

Source: JICA Survey Team

(3) construction equipment

Rental business of construction machines exists in Nepal. Thus, the procurement of general construction machines is available by renting. However, machines like the rough-terrain crane (25 t), boring machine for anchor works, SD drilling machine and air blast machine could not be procured easily in Nepal. To insure the safety, workability and maintenance of the machines in the mountainous region, as well as because of the 14 months long construction period, the construction machines have been planned to be procured in Japan. The expenses have been estimated as losses.

Table 2.2.36 Procurement Plan of Major Construction Equipment

No.	Machine	Specification	Procurement Country		
			Nepal	Third Country	Japan
1	Backhoe	0.8m^3 (heaped)	○		
2	Rough-terrain crane	Lifting capacity 25 ton			○
3	Truck with crane equipment	Load capacity 4.0 ton, lifting capacity 2.9 ton	○		
4	Hand guided vibratory roller	0.8 ~ 1.1 ton	○		
5	Mortar concrete spraying machine	Capacity 6m^3/h			○
6	Grout pump	37~100 L/min	○		
7	Grout Mixer	400×2L	○		
8	Water sand pump	3.7 kW	○		
9	Boring machine	Rotary percussion, skid type, 55kW			○
10	Concrete breaker	20 kg grade	○		
11	Concrete cutter	Vacuum type, 20 cm cut down depth	○		
12	Tamper machine	60~80 kg	○		
13	Air compressor	3.5~3.7 m^3/min	○		
14	Air compressor	10.5~11.0 m^3/min	○		
15	Power Generator	10.5/13kVA	○		
16	SD drilling machine Type 2	Air drifter mode, air feed motor type			○
17	Large breaker	Hydraulic mode, 1,300 kg grade (base machine included)	○		
18	Concrete pump	95~150 m^3/hour	○		

Source: JICA Survey Team

(4) Transportation path

Based on previous Sindhuli Road Construction Plan and experiences of completed construction work, the route of oversea transportation has been planned as below: Yokohama Port (Japan) ~ Kolkata Port

2.2.4.7 IMPLEMENTATION SCHEDULE

After signing the Exchange of Notes (E/N) and Grant Agreement (G/A) between the governments of Japan and Nepal, based on recommendation letter issued by JICA, the consultant will sign a contract of construction supervision including bid tendering support with DOR, the executing agency of the

Nepalese government. After the construction contract is completed, the construction contractor will receive the notice to proceed issued by the consultant and will start the construction work. It has been estimated that 16 months is needed for completing the project (April 2019 to July 2020), and the project implementation schedule is shown in **Table 2.2.37**.

Table 2.2.37 Tentative Implementation Schedule

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Execution drawing	Detailed Design	Site survey																
		Detialed design in Japan																
	Tender Assistance	Preparation of tender documents in Japan																
		Approval of tender documents																
		Report and hand over																
		Tender and contract																
Construction	Preparation & Mobilization																	
	Sta.17+400																	
	Sta.15+520																	
	Sta.11+620																	
	Sta.33+340																	
	Sta.33+695																	
	Pavement																	
	Clean up																	

Source: JICA Survey Team

2.3 OBLIGATIONS OF RECIPIENT COUNTRY

2.3.1 COMMON ITEMS OF JAPAN'S AID SCHEME

For the smooth implementation of the Project, the government of the recipient country should fulfill the following undertakings:

To provide necessary data and information for the implementation of the Project;

To secure land necessary for the Project site (for the camp yard, spoil bank, borrow pit, construction yard, storage of materials and equipment, and the land for construction waste disposal);

To bear the expense of rental land for camp yards;

To get the permission for land use for spoil bank, borrow pit and construction waste disposal including the charge for permission.

To open a bank account under the government's name, in a bank in Japan (B/A), and issue the authorization to pay (A/P);

To ensure all expenses for, and prompt execution of, unloading and customs clearance;

To exempt Japanese nationals from customs duties, local taxes, and other fiscal levies imposed in the recipient country, with respect to the supply of products and services under verified contracts;

To accord Japanese and third nationals, whose services may be required in connection with the supply of products and services under verified contracts, such as facilities necessary for their entry into the recipient country and stay therein for the performance of their works;

To accord Japanese and third nationals engaged in this Project the permission and other competence, if required, for the implementation of the Project;

To ensure proper maintenance, management and preservation of facilities provided under Japan's grant aid;

To bear all expenses, other than those borne under Japan's grant aid, necessary for the construction of facilities as well as for the transportation and installation of equipment;

To prohibit illegal dumping in a construction area; and

To conduct access restriction to the site and to maintain security.

2.3.2 SPECIAL ITEMS OF THE PROJECT

2.3.2.1 BEFORE CONSTRUCTION

The following should be undertaken by the implementing government before the construction of the Project:

To complete all procedures related to tree-cutting works at the site including transportation and management;

To relocate affected public utilities on-site, overhead and underground proposed sites; and

To submit the Project Monitoring Report (with the result of Detailed Design)

2.3.2.2 DURING CONSTRUCTION

The following should be undertaken by the implementing government during construction:

To lend construction equipment granted by GOJ to the Project contractor for free, as long as it does not affect the daily maintenance works of DOR;

To broadcast to the public, through mass media, the traffic regulations during the construction period;

To secure traffic on Sindhuli Road;

To conduct environmental monitoring through DOR;

To submit Project Monitoring Report every month;

To submit Final Project Monitoring Report;

To conduct the afforestation program; and

To arbitrate between residents, existing road users and contractor.

2.3.2.3 AFTER HANDOVER

The following should be undertaken by the implementing government after handover of the Project:

To conduct landslide monitoring and environmental monitoring through DOR;

To offer advice for regional development; and

To submit results of environmental and social monitoring to JICA.

2.3.3 EXPENSES BORNE BY THE RECIPIENT COUNTRY

The estimated initial costs of obligations of the recipient country are as shown in **Table 2.3.1**.

Table 2.3.1 Estimated Initial Costs of Obligations of the Recipient Country

(Unit Price: NPR 1,000)

Item	Content	Quantity	Price (Remarks)
(1) Land Use/Compensation	Land for camps in Section II and Section III	20,000 m^2	960
	Land for stockpiling machines, equipment and materials	12,500m^2	Not required (public land)
(2) Relocation of Public Facilities	*Not Happen*		0
(3) Environmental Monitoring	During detailed design (Update of EMP	1 set	129

	and EMoP, update and submit of PMR)		
(4) Landslide Monitoring	PVC pipe with strain gauge, load meter (once a month) (NPR10,000/month)	24 months	240
(5) Initial Environment Examination	Application fee included	1 set	1,000
(6) Environmental Monitoring	After construction completed (once in three months) (NPR20,000/time)	8 times	160
(7) Bank account opening	Service charge included	1 set	1,500
(8) Afforestation	50 pcs	1 set	25
Total			4,014

Note: This cost is approximate, there is a possibility of change.
Source: JICA Survey Team

The estimated initial cost of obligations of the recipient country is about NPR 3,885,000 including land use and compensation, landslide monitoring, IEE, environmental monitoring and others.

2.4 PROJECT OPERATION PLAN

2.4.1 OPERATION AND MAINTENANCE SYSTEM

It is important to maintain the functions of the countermeasure facilities planned in this project. The maintenance and management system of the DOR was built in Strengthened Maintenance Divisions Program (SMDP) implemented by Swiss in 1993-2006. Currently, this maintenance and management system is the basic system of the DOR maintenance plan. All maintenance offices classify the road maintenance tasks into six items and create an annual road maintenance plan (ARMP) based on this plan. In Sindhuli Road also, maintenance is carried out based on this plan. At present, there are no problems in this maintenance system and this system will continue in the future.

2.4.2 MAINTENANCE METHOD

The maintenance method of anchor work that can be considered at present is as shown in **Table** 2.4.1. The inspection frequency shall be once a year (periodic inspection) and after heavy rains etc. (emergency inspection). The emergency inspection is to be carried out when rain falls at a continuously at 150 mm, but it is desirable to change the continuous rainfall according to the actual result.

Table 2.4.1 Assumed Maintenance Method

Item	Contents of inspection
Anchor works	a. Load measurement with a load meter b. Visual inspection Pop-out of anchor material Deformation of head cap Oil leakage of antirust oil Deformation, settlement of anchor plate Spring Subsidence and displacement

Source: JICA Survey Team

2.5 PROJECT COST ESTIMATION

2.5.1 INITIAL COST ESTIMATION

Initial project cost undertaken by the Japanese government is confidential before tender.

Table 2.5.1 Initial Project Cost Undertaken by the Japanese Government.

ITEMS		ESTIMATION COST (JPY in Million)
Sta.14+700 (Section II)	Earthmoving Slope framework F500, F300 Tube and coupler scaffolding works Anchor works Reinforcing bar insertion works Check dam work, Planting treatment High-strength net	
Sta.15+520 (Section III)	H-section steel foundation works Tube and coupler scaffolding works Anchor works High-strength net	
Sta.11+620 (Section III)	H-section steel foundation works Tube and coupler scaffolding works Anchor works Water channel works	
Sta.33+440 (Section II)	H-section steel foundation works Tube and coupler scaffolding works Anchor works	
Sta.33+695 (Section II)	H-section steel foundation works Tube and coupler scaffolding works Anchor works	
Final design and construction supervision		
TOTAL		

Source: JICA Survey Team

2.5.2 OPERATION AND MAINTENANCE COST

After the construction is completed, the cost of operation and maintenance expected for ten years has been estimated as shown in Table. The cost estimated is less than 1% of NPR 243 million, the DOR maintenance budget for 2016/2017. Therefore, it is assumed that the maintenance budget can be easily secured.

Table 2.5.2 O&M Costs for the Entire Sindhuli Road

Category	Item	Estimated Cost (NPR 1000 / 10 years)
(1) Daily maintenance	Cleaning, reduction of deposit, grass cutting, etc.	5,400
(2) Annual repair	Repair of road surface, side ditch, etc.	400
(3) Repair conducted once in five years (converted to annual cost)	Overlay, reshaping, repair of structures, repainting of traffic signs and steel structures, etc.	200
(4) Urgent rehabilitation works	Removal of collapsed soil, urgent rehabilitation, construction of detour route, etc.	5,000
(5) Preventive works	Preventative works against rock-fall, collapse, scouring and mudflow, etc.	5,000
(6) Monitoring after completion	Monitoring after completion of construction	720
Total		16,720 (NPR 1,672,000/year)

Source: JICA Survey Team

CHAPTER 3 PROJECT EVALUATION

3.1 PRECONDITIONS

Prerequisites for the implementation of the project are described in Chapter 3 OBLIGATION OF THE RECIPIENT COUNTRY.

3.2 NECESSARY INPUTS BY RECIPIENT COUNTY

To derive the benefits from the entire Project and to make it sustainable, the necessary input by recipient country is shown as follows:

- In order to smoothly carry out this project, the budget of GON side mentioned in Chapter 3 is secured in advance.
- In order to secure the permanent function of the countermeasures targeted for this project, GON shall secure the annual budget mentioned in Chapter 4. In addition, GON shall arrange personnel to carry out sustainable maintenance.
- In order to secure acquisition of environmental approval permission, GON shall secure personnel and budget

3.3 IMPORTANT ASSUMPTIONS

The Sindhuli Road is an important logistics route linking the capital city of Kathmandu and the Terai Plain in the south, and the traffic volume is expected to increase further in the future. The external conditions are as follows:

- Continue daily and periodic maintenance to ensure the safety of facilities expected in the design
- Environmental change that exceeds the assumed value such as rainfall exceeding the planned scale does not occur around the site.
- There is no significant change in the relevant policies of GON.
- Continue the improvement of the road and the maintenance management carried out in Nepal to ensure smooth traffic on the Sindhuli Road.

3.4 PROJECT EVALUATION

3.4.1 RELEVANCE

As shown below, the validity of this project is high and it can be judged effective.

3.4.1.1 CONSISTENT WITH LONG-TERM DEVELOPMENT PLAN

The 13th plan (2013/14 - 2015/16) of the national development plan in Nepal has set the goal of developing a safe and reliable transportation network for the social and economic development of the whole country. The 14th plan (2016/17 - 2018/19) is also extension of sustainable and secure road network expansion. In the priority investment plan (2007 - 2016), which is the basic policy of the road development of GON, the following policies are mentioned. The road maintenance management work shall be continuously carried out based on the classification of road maintenance management tasks.

This project aims to reinforce the vulnerable part on Sindhuli Road against earthquakes in order to ensure safe and smooth traffic of Sindhuli Road, which is one of the important arterial roads. This content is consistent with the policy of the road sector of GON.

3.4.1.2 CONSISTENCY WITH THE JAPANESE AID POLICY

In the National Development Cooperation Policy and Business Development Plan of GOJ for Nepal, the following are listed as priority areas:

I. Reconstruction by hard and soft countermeasures against earthquakes and disaster risk reduction; and

II. Improve social and economic infrastructure directly linked to economic growth and improvement of people's lives.

By making Sindhuli Road a strong road to the earthquake, it is possible to secure a stable logistics even in the event of a disaster, contributing to creating a country that is resistant to disasters. It is also expected to make a great contribution to securing stable logistics of the Kathmandu Valley and the Terai region in the south, promoting industry and revitalizing the regional economy, and improving the lives of local people living along the roadside. The purpose of this project is consistent with Japan's aid policy.

3.4.1.3 ADVANTAGE OF JAPANESE TECHNOLOGY

In Japan, torrential rains occur frequently and the geology is weak, therefore, road disaster prevention inspection and conservation technology have been developed to conserve the highly developed road network. Anchor work, which is the main construction method applied to this project, is not Japanese original technology. In applying to road slope countermeasures, it has been improved by Japanese technology as the capacity to realizes reliable disaster prevention, reduction of negative impact on the environment, reduction of life cycle cost including construction cost and maintenance cost.
In this project, Japanese standards are adopted for the design and construction of slope countermeasures. Furthermore, for the purpose of ensuring construction quality and improving workability, anchor material and anchor plate are procured from Japan.

3.4.2 EFFECTIVENESS

The effectiveness of implementation of this plan is considered as follows.

3.4.2.1 QUANTITATIVE EFFECT

This project aims to implement measures to ensure road safety and prevent hindrance to road traffic with respect to vulnerable places along Sindhuli Road due to earthquake. By implementing countermeasures, restoring the driving speed and Vehicle Operation Cost (VOC) to a healthy state and eliminate traffic hindrance losses may occur in the future. In addition, the future elimination of traffic hindrance, caused by road damage and road closure due to road disaster will bring stable traffic volume and growth of passenger number, cargo volume. Base lines and target value are as shown in **Table 3.4.1**

Table 3.4.1 Base lines and Target

Indicators		Original (Yr2017)	Target (Yr2023)
Annual Passenger (Persons/year)	Khurkot	6,006,205	8,048,000
	Singhuli Madi	5,847,170	7,835,000
Annual Cargo volume (ton/Year)	Khurkot	359,896	482,000
	Singhuli Madi	492,042	659,000

*1 Raised the 2017 value at an annual rate of 4%
Source: JICA Survey Team

3.4.2.2 QUALITATIVE EFFECT

In the disaster prevention project like this project, there are few parts that directly contribute to improving transportation services that road users can feel, such as an increase in traffic capacity and speed improvement. On the other hand, the effect of this project is to reduce the risk of loss expansion due to sediment-related disasters such as traffic blockade and road disaster. Qualitative effect indicators are as follows:

- Reduction of road traffic disturbance loss
- Contribution to other development projects
- Role in wide area road network