**Department of Roads**
**Ministry of Physical Planning & Works**
**Federal Democratic Republic of Nepal**

# PREPARATORY SURVEY REPORT
# ON
# THE PROJECT
# FOR COUNTERMEASURE CONSTRUCTION
# FOR THE LANDSLIDES
# ON SINDHULI ROAD(SECTION II)
# IN
# FEDERAL DEMOCRATIC REPUBLIC OF NEPAL

**March 2012**

**JAPAN INTERNATIONAL COOPERATION AGENCY**

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**NIPPON KOEI CO., LTD.**

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# PREFACE

Japan International Cooperation Agency (JICA) decided to conduct the preparatory survey and entrust the survey to Nippon Koei Co., Ltd..

The survey team held a series discussions with the officials concerned of the Government of Federal Democratic Republic of Nepal, and conducted field investigations. As a result of further studies in Japan, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Federal Democratic Republic of Nepal for their close cooperation extended to the survey team.

March 2012

Kiyofumi Konishi
Director General
Economic Infrastructure Department
Japan International Cooperation Agency

## *Summary*

# SUMMARY

## 1 Outline of the Country

The Federal Democratic Republic of Nepal, with an area of approximately 147,000 $km^2$, is a landlocked Himalayan country in Southwest Asia. It is bordered by China in the north and by India on the remaining three directions. The capital of Nepal is Kathmandu located in the Kathmandu Valley, which has a size of about 25 km from east to west and about 20 km from south to north. The total population of Nepal is about 28.58 million as of 2011 according to the Central Bureau of Statistics. Out of this population, the Kathmandu Valley has about 2.51 million. The Terai Plain located along India's border is a major farm production area.

According to the latest data from the Ministry of Finance (MOF), Nepal's nominal gross domestic product (GDP) for the year 2010/2011 is around US$18.5 billion and per-capita nominal GDP is around US$642. Primary industries such as agriculture cover almost 40% of the GDP and sustain about 80% of Nepal's population. Secondary industries such as manufacturing account for about 20% of the GDP, and tertiary industries such as tourism business and services comprise the remaining 40% of the GDP.

The road subsector has the lead role in the national transport system of Nepal. The development of road network started in the 1950s, and the length of the network has expanded up to 10,835 km by 2009/2010. However, road network development in Nepal still has a long way to go since 12 among 75 districts of the entire nation still do not have a motorable roadway at all and 15 district headquarters are not linked to the road network as of December 2005. Furthermore, since there is no all-weather road in Eastern Nepal where Sindhuli Road is located, populations of over one million do not receive the benefits of social and economic development brought about by road development. Moreover, the service level of the road is insufficient since about 70% of the network is unpaved and the road network is weak against sediment-related disasters. Therefore, in order to achieve the National Plan, which primarily aims at poverty reduction, and to reduce traffic cost from the viewpoint of the national economy, the expansion of road networks together with the maintenance and improvement of the existing roads are among the main concerns in Nepal.

## 2 Background and Outline of the Project

The Banepa-Sindhuli-Bardibas Highway (or simply "Sindhuli Road"), with a total length of around 160 km, is currently under construction through grant assistance from the Government of Japan (GOJ) since November 1996. The construction will be completed in 2014. Once fully opened, this road will be an important alternative highway connecting the capital city of Kathmandu with the Eastern Terai Plain. This will contribute to the development of the eastern region of Nepal.

Many road sections in Nepal are cut off due to heavy rains during the rainy season. The sections along Sindhuli Road are also situated on adverse topographic geological conditions. Therefore, road construction has been managed carefully to cope with sediment-related disasters. However, during and after construction, the road remains affected by sediment-related disasters in completed Sections I, II and VI. Most of the damaged sections have been appropriately rehabilitated. Nevertheless, as some sections have not yet been repaired, full traffic operations will not be sustained even after the full opening of the road.

In order to improve the current traffic situation and strengthen the road maintenance system of Sindhuli Road, the Government of Nepal (GON) has requested GOJ for a grant aid technical assistance project. In August 2009, the Japan International Corporation Agency (JICA) implemented a brief study on the strengthening of the maintenance system for Sindhuli Road. During the study, the present conditions of the completed Sections I, II, and IV of Sindhuli Road were inspected. Among the slope failures along the road, Sta. 17+400, Sta. 17+600 and Sta. 18+200 in Section II were found to be most serious where such failures could cause major impacts to road traffic in the future. Successively, JICA carried out Phase 1 of the “Preparatory Survey on the Project for Countermeasure Construction for Landslides on Sindhuli Road Section II” to identify the necessity and validity of the implementation of permanent countermeasures in 2010. As a result of the survey, it was found out that permanent countermeasures for the three sites were required to ensure traffic safety, and the corresponding basic design was planned. Among the three sites mentioned, it was decided that countermeasures for Sta. 17+400 can be implemented by applying Nepalese construction technology. As for Sta. 17+600 and Sta. 18+200, advanced technologies should be introduced to maintain sustainable and safe road traffic conditions.

Considering the above situation, GOJ decided to conduct Phase 2 of the “Preparatory Survey on the Project for Countermeasure Construction for the Landslides on Sindhuli Road Section II”. GOJ dispatched the JICA Survey Team to Nepal from September 1 to 30, 2011 to design permanent countermeasures on the construction project to mitigate landslides at Sta. 17+600 and Sta. 18+200.

## 3 Outline of Preparatory Survey and Main Features of Project Facilities

Countermeasures for Sta. 17+400 among the three points mentioned above have already been implemented by GON. Hence, studies for countermeasure planning for Sta. 17+600 and Sta. 18+200 were carried out in this preparatory survey. Considering the result of the survey, countermeasures for the two sites have been planned. The policies for the selection of countermeasures are listed below.

- Policy for Selection of Countermeasures at Sta. 17+600

Quartzite and sandy schist is distributed around Sta. 17+600. As a whole, it is hard and dense, but the schistosity dips at a high angle oblique to the slope, and the sheeting joints parallel to the slope have developed (landslide A area) (See location map II of in the beginning of this project). This type of schistosity and joint has caused the occurrence of cracks on the road surface. Ground anchors are the best method to prevent landslides that have such geology and failure mechanism. In addition to the A area, loosened zone (landslide B area) is distributed on the lower side at Sta. 17+620. The loosened zone of the schist has been creeping due to toppling phenomenon, which moves towards valley direction. It was judged that a mass landslide would occur in the area without a suitable countermeasure. The embankment to stabilize the B area was selected to prevent landslide occurrence in the future.

The road traffic in the site would be secured by implementation of two major countermeasures mentioned above.

- Policy for Selection of Countermeasures at Sta. 18+200

Slope failures at Sta. 18+200 have occurred on the steep slope that consists of quartzite schist, which is deforming and creeping due to toppling. Cracks appeared on the slope just below the road in 2003, as well as on the road that was first constructed in 2005. In 2006, the road was realigned about 6 m toward the mountain side to avoid the landslide area. As a result of observation during the rainy season in 2010, it was found that the dimensions of loosened zone at Sta. 18+200 having width of -about 50 m (width) and length of about -50 m (length) including the existing road, and have been deforming actively during rainy season. The realignment for safety zone was selected at Sta. 18+200.

- Outline of the Countermeasures

The facilities designed in the survey are summarized below.

**Table 1 Outline of the Countermeasures**

| Area | Item | Contents and Scale | Purpose |
|---|---|---|---|
| Landslide countermeasure （Landslide A and Landslide B） | Ground anchors | Length of construction: 50 m<br>Pieces:120<br>Length: 9.5-14.0 m, ΣL=1,400 m | To deter the occurrence of landslide A which can reach up to 50 m (Sta. 17+555 - Sta. 17+605) and cause cracks on the road. |
| | Crib works F500 | A=1,300 $m^2$,<br>Shotcrete within crib works | |
| | Crib works F300 | A=300 $m^2$, Shotcrete within crib works | |
| | Shotcrete | A=2,200 $m^2$ | To prevent infiltration of surface water. |
| | Embankment | Embankment volume: V=76,000 $m^3$<br>Vegetation: A=7,600 $m^2$<br>Drainage<br>Closed conduit: L=350 m<br>Open ditch (ground): L=350 m<br>Open ditch (embankment): L=650 m<br>Catch basin: Q=12 | Countermeasure against landslide B includes environment improvement such as revegetation around the slope under the road. Excavation at Sta. 18+200 will be used as embankment material. |
| Realignment (Landslide C) | Road length | L=170 m | Countermeasure against landslide C:<br>The road is realigned to avoid landslide C.<br>Road will be realigned in the stability zone. Road alignment and travel performance are improved.<br>Excavation at Sta. 18+200 will be used as embankment material in landslide C. |
| | Width of Road | W=4.75 m | |
| | Design speed | 20 km/hr（without hairpin curve） | |
| | Earthworks | V=76,000 $m^3$（diversion to embankment） | |
| | Pavement | Pavement: A=500 $m^2$, DBST: 500 $m^2$ | |
| | Crib works F300 | A=2,300 $m^2$ | |
| | | Sandbags within the crib works: 7,400 bags | |
| | Rock bolt | 560 lods, ΣL=1,700 m | |
| | Retaining wall | A=1,000 $m^2$ | |
| | Drainage | Drainage on the road: 200 m<br>Drainage on the cat walk: 350 m<br>Vertical drainage: 50 m<br>Pipe culvert: 10 m<br>Catch basin: Q=3 | |
| | Guard fence | Q=30 | |
| Erosion prevention works | High intensity net | High intensity net: A=5,500 $m^2$<br>Rock bolt: 1,700 lods, ΣL=5,100 m | To protect the unstable slope, the road will be installed with high intensity nets and rock bolts. |

## 4 Environmental and Social Consideration for the Project

Countermeasures for landslide-prone areas will be made after completion. And, there will be no Project Affected Persons (PAPs) who is needed to remove due to implementation of the project. Hence, the Project will contribute to the improvement of the natural condition of the Project area. However, some natural and social problems will come up during the construction stage, and, therefore, adequate environmental considerations should be paid for implementing the Project along with JICA and DOR regulations.

# 5 Construction Period and Estimated Project Cost

The estimated duration for the entire project including the detailed design and tendering processes will be 31 months. After issuance of notice to proceed (N/P), construction will commence. The estimated duration for construction stage of the project would be 25 months in total.

The cost to be shouldered by the Nepalese side, separate from Japan's grant aid, is estimated at about NRs 9.3 million, which includes compensation of using private lands, relocation of water supply facilities, landslides monitoring, environmental monitoring including initial environmental examination, etc.

# 6 Project Evaluation

## 6.1 Quantitative Effect

Running distance of traffic from Kathmandu to Bardibas in Terai Plain will be reduced about 140 km after the entire Sindhuli Road is constructed. And, roundtrip between Kathmandu-Central Terai Area that requires eight hours of travel time can eventually be done in just five hours.

In addition, project evaluation is carried out through the benefit-cost ratio (B/C), economic net present value (ENPV) and economic internal rate of return (EIRR) analysis, all of which are generally employed in the evaluation of public works. Their indexes are evaluated as shown in the table below. In Sta. 17+600, B/C is 3.18 and in Sta.18+200, B/C is 6.01. It is clear that this project has a high investment effect. A prompt countermeasure implementation generates higher investment effect.

**Table: Examination of Cost Benefits**

| Site | BCR | ENPV (NRs) | EIRR |
|---|---|---|---|
| Sta. 17＋600 | 3.18 | 677,531,956 | 35% |
| Sta. 18＋200 | 6.01 | 2,296,729,117 | 60% |

Source: JICA Study Team

## 6.2 Qualitative Effect

By the implementation of this project, as the damages induced by road closure to capital could be avoided, life of 2.51 million citizens of Kathmandu will become stable as well as the physical stability of road user and life of peripheral people will be stepped up.

And, by the opening of all-weather road in the area that has been less developed due to the commerce, fabrication and housing industries will be developed steadily and investment effects improved will contribute to regional development and poverty reduction to 1.54 million citizens living along the road.

**THE PREPARATORY SURVEY**

**ON**

**THE PROJECT FOR COUNTERMEASURE CONSTRUCTION**

**FOR**

**THE LANDSLIDES ON SINDHULI ROAD(SECTION II)**

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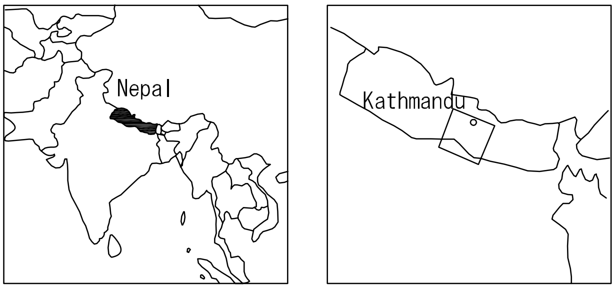
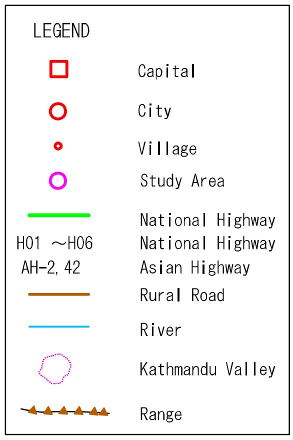
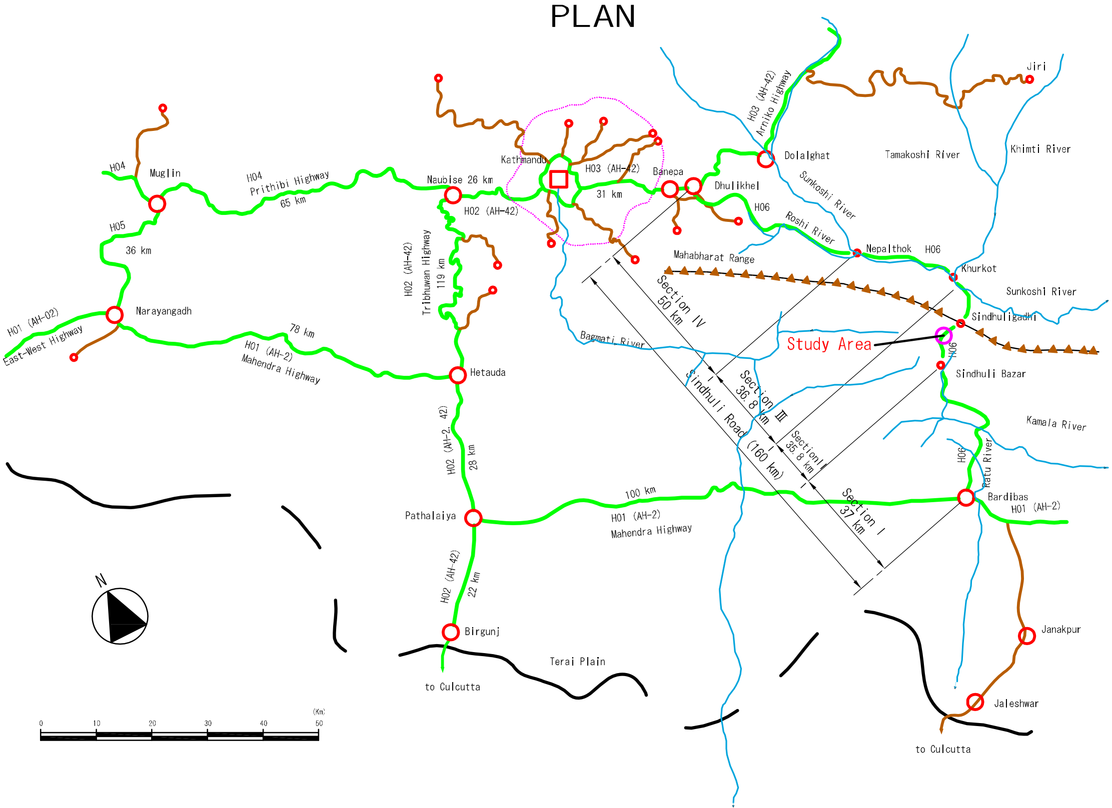


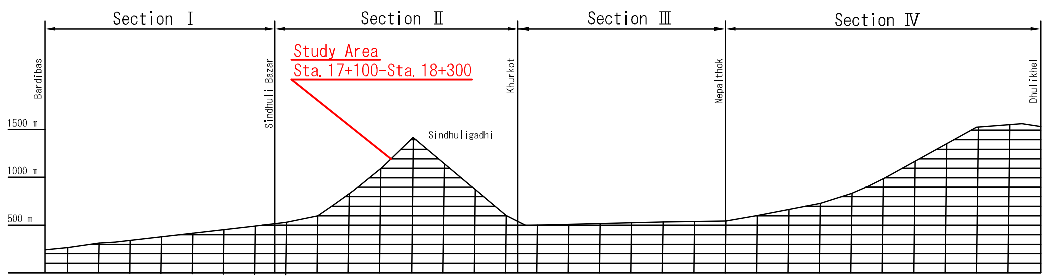

KEY PLAN



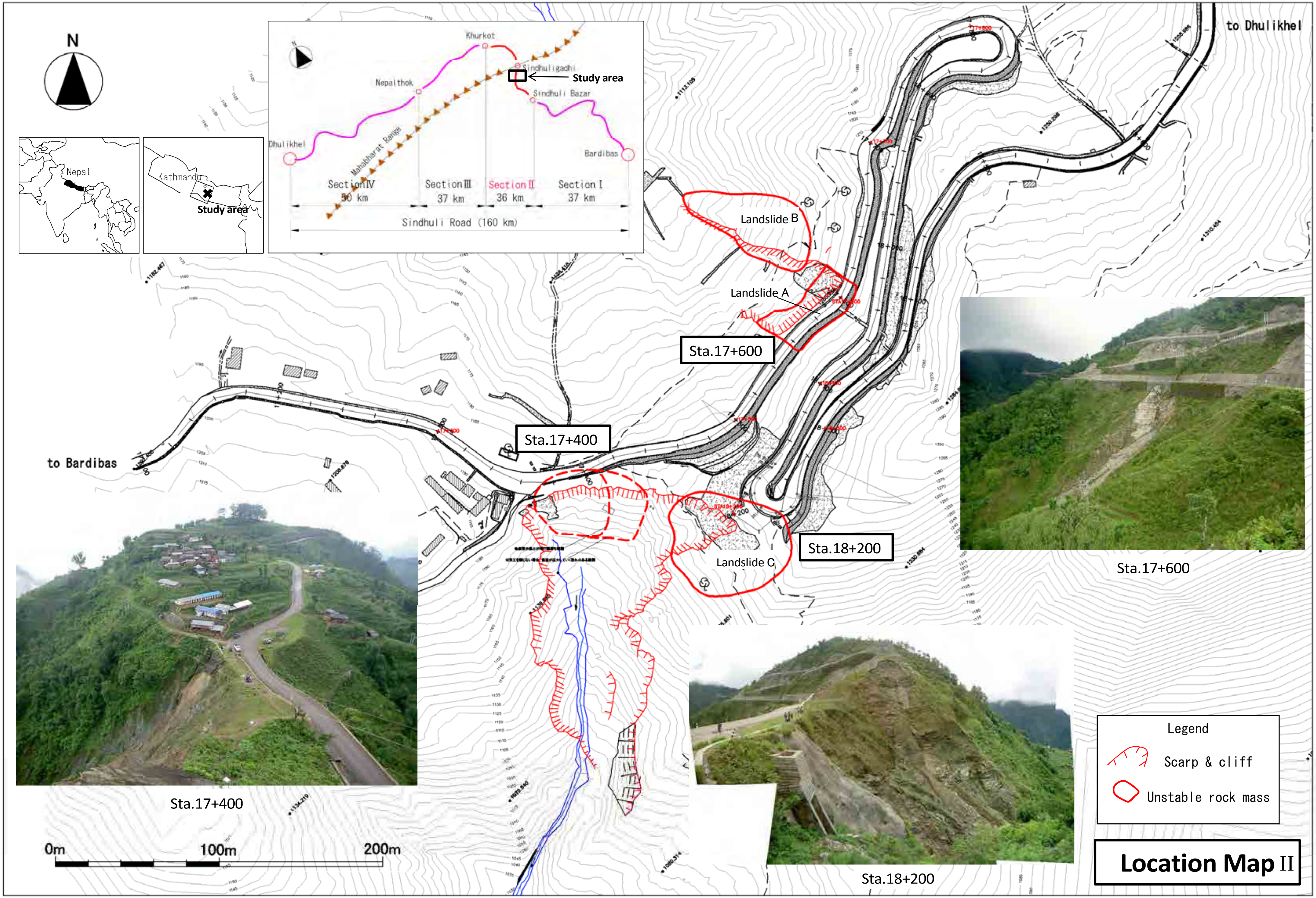

PLAN




PROFILE




# LOCATION MAP I




**Location Map II**

Perspective View of the Sindhuli Road　(Sta. 17+600-18+360)

# List of the Figures

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# Abbreviation

| | |
|---|---|
| AADT | Average Annual Daily Traffic |
| ADB | Asian Development Bank |
| ALp | Potential Annual Loss |
| A/P | Authorization to Pay |
| ARMP | Annual Road Maintenance Plan |
| B/C | Benefit-Cost ratio |
| DBST | Double Bituminous Surface Treatment |
| DCC | District Coordination Committee |
| DDC | District Development Committee |
| DL | Detour Loss |
| DOR | Department of Roads |
| EA | Environmental Assessment |
| EIA | Environmental Impact Assessment |
| EIRR | Economic Internal Rate of Return |
| E/N | Exchange of Notes |
| ENPV | Economic Net Present Value |
| EMU | Environmental Management Unit |
| EPA | Environmental Protection Act |
| ERP | Environmental Protection Rules |
| FRCDp | Potential Frequency of Road Closure Disaster |
| G/A | Grant Agreement |
| GOJ | Government of Japan |
| GON | Government of Nepal |
| GESU | Geo-Environment and Social Unit |
| H01～H06 | National Highway 01-06 |
| IDF | Rainfall Intensity-Duration-Frequency Curves |
| IEE | Initial Environmental Examination |
| JICA | Japan International Cooperation Agency |
| Lp | Potential Loss of a site |
| MBT | Main Boundary Thrust |
| MoE | Ministry of Environment |
| MoPPW | Ministry of Physical Planning & Works |
| NEXCO | Nippon Expressway Company |
| N/P | Notice to Proceed |
| NRs | Nepal Rupee |
| O&M | Operation and Maintenance |
| PAPs | Project Affected Persons |
| PFs | Proposed Factor of Safety |
| RCC | Road Coordination Committee |
| RCD | Road Closure Disaster |
| ROW | Right of Way |
| RTO | Road Transportation Organization |
| Rs | India Rupee |
| SPAP | Severely Project Affected People |
| STA. | Station |
| SRN | Strategic Road Network |
| TCC | Track Construction Committee |
| ToR | Terms of Reference |
| US$ | US Dollar |
| UVOC | Unit Vehicle Operation Cost |
| VDC | Village Development Committee |
| WB | World Bank |

# *Chapter 1*
# *Background of the Project*

# CHAPTER 1 BACKGROUND OF THE PROJECT

## 1.1 BACKGROUND OF THE PROJECT

The Banepa-Sindhuli-Bardibas Highway (or simply "Sindhuli Road"), with a total length of around 160 km, is currently under construction through grant assistance from the Government of Japan since November 1996. The construction will be completed in 2014. Once fully opened, this road will be an important alternative highway connecting the capital city of Kathmandu with the Eastern Terai plains. This will contribute to the development of the eastern region of Nepal.

Many sections of road traffic in Nepal are cut off due to heavy rains during the rainy season. The sections along Sindhuli Road are also situated on adverse topographic geological conditions. Therefore, road construction has been managed carefully to cope with sediment-related disasters. However, during and after construction, the road remains affected by sediment-related disasters in completed Sections I, II and VI. Most of the damaged sections have been appropriately rehabilitated. Nevertheless, as some sections have not yet been repaired, full traffic operations will not be sustained even after the full opening of the road.

In order to improve the current traffic situation and strengthen the road maintenance system of Sindhuli Road, the Government of Nepal (GON) has requested the Government of Japan (GOJ) for a grant aid technical assistance project. In August 2009, the Japan International Corporation Agency (JICA) implemented a brief study on the strengthening of the maintenance system for Sindhuli Road. During the study, the present condition of the completed Sections I, II, and IV of Sindhuli Road were inspected. Among the slope failures along the road, Sta. 17+400, Sta. 17+600 and Sta. 18+200 in Section II were found to be most serious where such failures could cause major impacts to road traffic in the future. Successively, JICA carried out Phase 1 of the "Preparatory Survey on the Project for Countermeasure Construction for Landslides on Sindhuli Road Section II" to identify the necessity and validity of the implementation of permanent countermeasures in 2010. As a result of the survey, it was found out that permanent countermeasures for the three sites were required to ensure traffic safety, and the corresponding basic design was planned. Among the three sites mentioned, it was judged that countermeasures for Sta. 17+400 can be implemented by applying Nepalese construction technology. As for Sta. 17+600 and Sta. 18+200, advanced technologies should be introduced to maintain sustainable and safe road traffic conditions.

Considering the above situation, GOJ decided to conduct Phase 2 of the "Preparatory Survey on the Project for Countermeasure Construction for the Landslides on Sindhuli Road Section II". GOJ dispatched the JICA Survey Team to Nepal from September 1 to 30, 2011 to design permanent countermeasures on the construction project to mitigate landslides at Sta. 17+600 and Sta. 18+200.

## 1.2 OUTLINE OF THE PROJECT

### 1.2.1 PURPOSE OF THE SURVEY AND OVERALL GOAL

The general objective of the Survey on the Project for Countermeasure Construction for the Landslides on Sindhuli Road Section II (hereinafter referred to as "the Project") is to prepare a plan for the construction of countermeasures against landslides occurring between Sta. 17+600 and Sta. 18+200 along Section II of Sindhuli Road. The following studies were carried out:

1. Verification on the technical effectiveness and economical validity of implementing the countermeasures.
2. Design of reasonable permanent countermeasures to prevent disaster occurrences which will

affect sustainable and safe traffic at target sites.

3. Planning of the countermeasure construction project introducing advanced construction technology considering the socio-environmental aspects, technical capacity of the construction industry in Nepal, and the implementation capability of the Nepalese government.

4. Estimation of project costs.

5. Preliminary environmental and social consideration studies on project implementation.

6. Recommendations on key considerations on project implementation and road maintenance.

7. Proposal of the undertaking of the Nepalese government in the Project

The overall goal of the survey is to secure sustainable and safe traffic along Sindhuli Road through the construction of countermeasures which is formulated in the preparatory study.

### 1.2.2 OUTLINE OF PROPOSED COUNTERMEASURES FOR LANDSLIDES

The results of risk evaluation on slope disasters occurring at Sta. 17+400, Sta. 17+600 and Sta. 18+200 indicate that road traffic would be damaged seriously if these sections were left unprotected with adequate preventive countermeasures. As mentioned above, among these three sites, it has been found that current Nepalese construction methods are sufficient to mitigate landslides occurring at Sta. 17+400. Preventive works for the said site is already being implemented by the Department of Roads (DOR).

On the other hand, advanced construction methods are required to stabilize the landslides at Sta. 17+600 and Sta. 18+200 considering steep slope and failure mechanisms. The outline of the proposed countermeasures for the said two sites is as shown in Table 1.2.1.

**Table 1.2.1 General Outline of Countermeasures**

| Section | Major Countermeasure | Purpose/Remarks |
|---|---|---|
| Sta. 17+600 (Landslide A and B) | a) Anchoring | Prevention work for rock block slide occurring between Sta. 17+555 and Sta. 17+605. |
| | b) Crib Work | Protection of fragile lower rock slope at Sta. 17+600. |
| | c) Embankment | ● Stabilization by counterweight filling (76,000 $m^3$) for unstable block developing under Sta. 17+620.<br>● Fill material is provided by slope cut work at Sta. 18+200. |
| | d) Shotcrete | Protection from rockfalls from steep and fragile slopes along the site and prevention from surface water infiltration to lower slopes. |
| Sta. 18+200 (Landslide C) | a) Realignment of road to mountain side | ● Shifting roads out of landslide-prone areas.<br>● 76,000 $m^3$ slope cutting is necessary.<br>● Cut materials are utilized as fill at Sta. 17+600.<br>● Cut slope is protected with grass planting and crib works. |
| | b) Slope protection by high-strength net | Protection from landslides occurring on the slope. |

Source: JICA Study Team

Considering topographical and geological conditions, failure mechanisms, and road alignment situations of each site, permanent countermeasures were planned and designed through the introduction of advanced technology, which can sufficiently protect the target sections for a long period. Detailed description on the design of countermeasures and plan of the Project are described in Chapter 2.

## 1.3 RESULT OF FIELD SURVEY

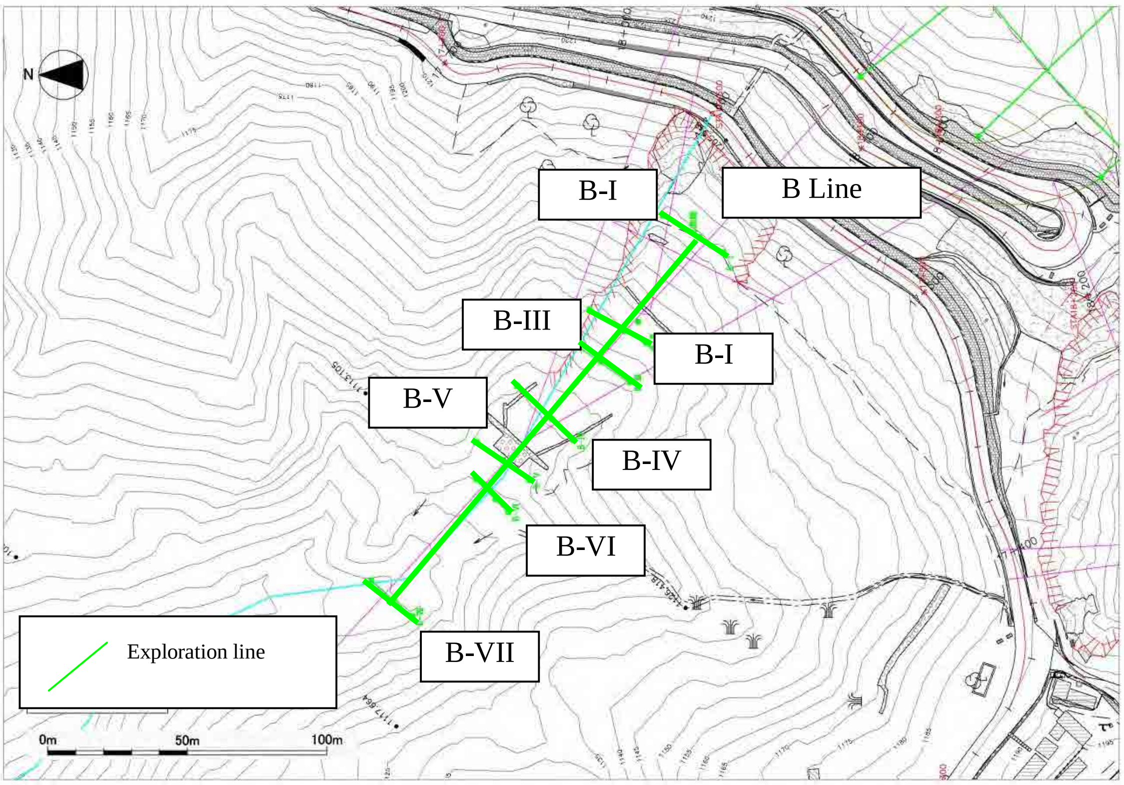
### 1.3.1 GEOPHYSICAL EXPLORATION

Geophysical exploration was conducted using surface wave exploration and seismic refraction method to figure out the soil layers in the lower slope of Sta. 17+600. Seismic exploration was conducted to judge the ripper ability at Sta. 18+200 where the cutting is planned.

#### 1.3.1.1 GEOPHYSICAL EXPLORATION TO FIGURE OUT THE SOIL LAYERS AT STA. 17+600

**(1) Exploration Line and Quantity**

The exploration line that was conducted around the lower slope of Sta. 17+600 is as shown in Figure 1.3.1. The exploration was conducted in eight lines having a total length of 229 m.




Source: JICA Study Team

**Figure 1.3.1 Exploration Line at the B Area**
**(Surface Wave Exploration Refraction Method)**

At the lower slope of Sta. 17+600, talus deposits were formed caused by previous slope failure and are now deposited. To plan the embankment, it is necessary to figure out the geological condition of the slope. At first, surface wave exploration was initially conducted, although sufficient measurement data was not obtained. This is because big boulders in the slope disturbed the diffusion of the surface wave. Therefore, the seismic exploration by refraction method was conducted.
The two methods of measurement are attached at the end of this report.

**(2) Exploration Result**

The seismic exploration results of B and B-II lines are as shown in Figures 1.3.2 and 1.3.3, respectively, while the seismic exploration results of the other four lines and time-distance curve are attached at the end of this report. The seismic velocity layers that were detected at the B lines consist of four layers as shown in Table 1.3.1.

**Table 1.3.1 Seismic Velocity Layers at Sta. 17+600**

| Velocity Layer | Seismic Velocity (km/s) | Geologic Stratum on Seismic Velocity |
|---|---|---|
| I | 0.3-0.5 | Loose talus deposits of ground surface by recent slope failure. |
| II | 0.9-1.1 | Consolidated talus deposits composing of gravel, sand and clay. |
| III | 1.9-2.1 | Weathered psammitic schist: This is stable base rock. |
| IV | 3.8-4.0 | Fresh psammitic schist: This is stable base rock. |

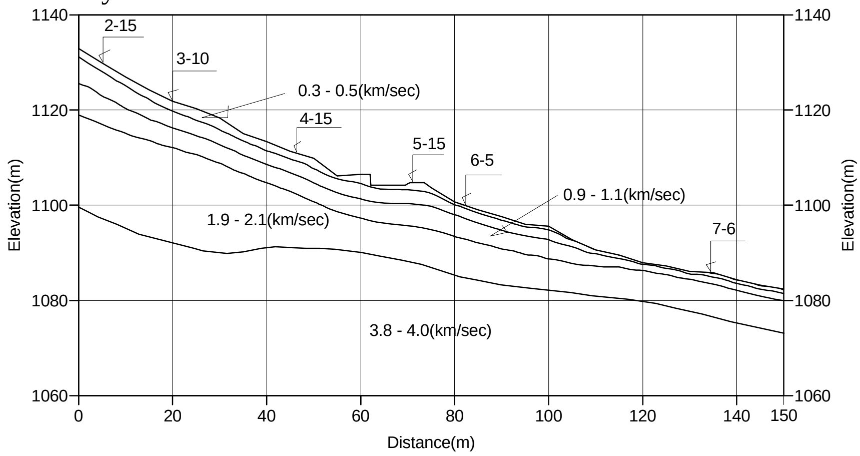
Source: JICA Study Team

The thickness of each velocity layer at the B-II line is as follows:

- ✓ Velocity layer I (0.3-0.5 km/s): The thickness is about 2 m at higher elevation area and less than 1 m at lower elevation.
- ✓ Velocity layer II (0.9-1.1 km/s): The thickness is about 2-4 m at higher elevation area and less than 2 m at the lower elevation.
- ✓ Velocity layer III (1.9-2.1 km/s): The thickness of the upper deposits is about 10 m at higher elevation area and less than 5 m at the bottom of B-II line.
- ✓ .Velocity layer IV (3.8-4.0 km/s): The depth of velocity layer IV is about 30 m at higher elevation area, then it decreases downward with depth of about 10 m at the bottom of the B-II line.

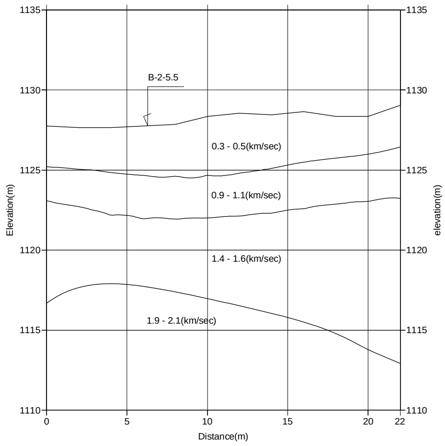
The conclusion below is taken from the exploration result.

- ✓ The loose surface layer with thickness of about 1-2 m needs to be treated carefully as the foundation of embankment.
- ✓ Layer III and layer IV are stable foundations for embankment.




Source: JICA Study Team

**Figure 1.3.2 Seismic Exploration Result (B Line)**



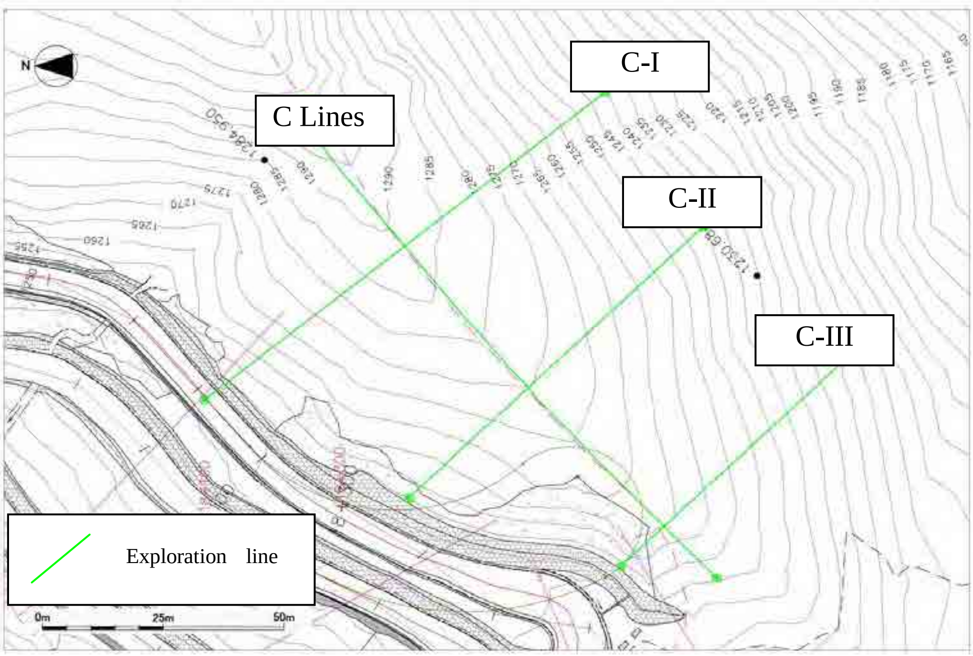

Source: JICA Study Team

**Figure 1.3.3 Seismic Exploration Result (B-II Line)**

### 1.3.1.2 SURVEY ON THE RIPPER ABILITY OF THE SLOPE AT STA. 18+200

#### (1) Survey Items and Location of Survey

At Sta. 18+200 where slope cutting is planned to realign the road, seismic exploration by refraction method and rock tests are prepared to judge the ripper ability of the slope. In this section, the seismic exploration results are described while the results of rock tests are described in the next section. The locations of the survey are shown in Figure 1.3.4. The survey was conducted in four lines, with total length of 373 m.




Source: JICA Study Team

**Figure 1.3.4 Seismic Exploration Line at Sta. 18+200**

#### (2) Seismic Exploration Result

Seismic exploration result of the C line is shown in Figure 1.3.5. Seismic exploration result of the other lines is attached at the end of this report. The seismic velocity layers that were detected at the B lines are four layers below.

**Table 1.3.2 Seismic Velocity Layers at Sta. 18+200**

| Velocity Layer | Seismic Velocity (km/s) | Geologic Stratum on Seismic Velocity |
|---|---|---|
| I | 0.3-0.5 | Soils generated by weathering of schistose rocks |
| II | 0.9-1.1 | Strongly weathered schistose rocks, mostly weathered to soil |
| III | 1.4-1.6 | Strongly weathered schist, partly weathered to soil |
| IV | 1.9-2.1 | Slightly weathered schist. Weathered along schistosity and joints. |

Source: JICA Study Team

The bedrock that composes this slope is mainly psammitic schist. The fresh part of this rock is sound that seismic wave velocity is determined at 4 km/s (this is the highest seismic velocity at Sta. 17+600). But 4 km/s seismic velocity was not detected in this slope because the slim ridge formed from successive erosion is weathered totally. It is supposed that the base layer is distributed under the level of the road.

The relation of each velocity layer detected in the site and excavation method is shown in Table 1.3.5, which is judged referring to Japanese manuals on excavation methods shown in Tables 1.3.3 and 1.3.4.

**Table 1.3.3 Relation of Velocity Layer/Rock/Soil Type and Excavation Method**

| Seismic Velocity | Rock/Soil Type | Excavation Method |
|---|---|---|
| 1st Layer（0.3-0.5 km/s） | Gravels | Wheel-type or track-type tractor (loosened) power shovel, bulldozer (fixed), manpower excavation |
| 2nd Layer（0.9-1.1 km/s） | Soft Rocks | Bulldozer with ripper (21 t class) |
| 3rd Layer (1.4−1.6 km/s) | | Bulldozer with ripper (more than 21−32 t class) |
| 4th Layer (1.9−2.1 km/s) | | Bulldozer with ripper (32−43 t class), dynamite |

Source: JICA Study Team

The 1st layer (gravels) could be excavated by power shovel and bulldozer without ripper. But to excavate soft rocks from 2nd to 4th layer, it is necessary to use power shovel and bulldozer with ripper. It is estimated that hard rocks that include soft rocks and part of soft rocks in the 4th layer require the use of dynamite and static fracture dynamite for excavation.

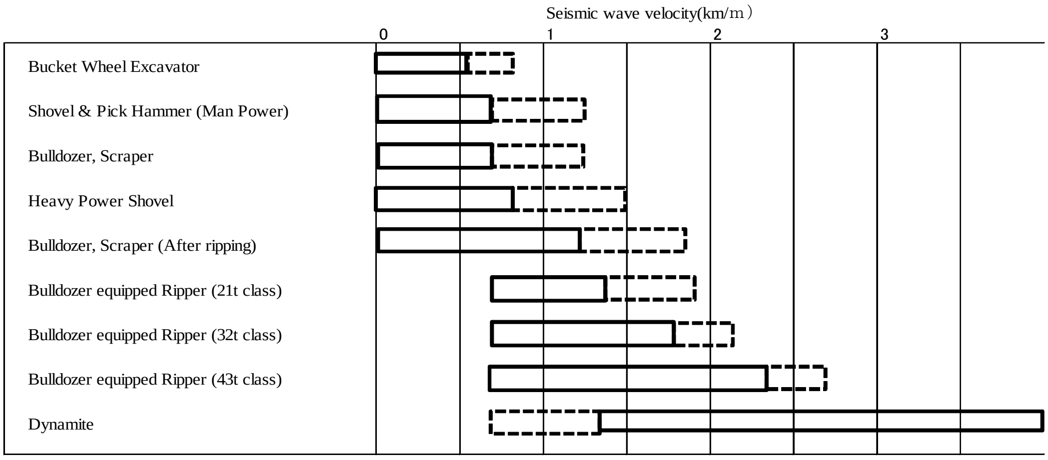
**Table 1.3.4 Classification of Rocks and Soils for Earthworks**

| Name | | Clarification | Applicability | Soil Classification |
|---|---|---|---|---|
| Rock or Stone | Hard Rock | Rock with no crack or few hair cracks | Seismic velocity 3,000 m/s or more | |
| | Semi-hard Rock | Slightly weathered rock, Crack interval about 30-50 cm | Seismic velocity 2,000-4,000 m/s | |
| | Soft Rock | Dense layers of quaternary, weathered rocks older than tertiary, can be excavated by ripper. | Seismic velocity 700-2,800 m/s | |
| | Boulder Stone Group | Dense deposit of boulders, difficult to excavate | | |
| | Mass of Rock Cobblestone | Mixture of mass rocks and cobblestones, very difficult to excavate | Soil with cobblestone, mass of rock, crushed stone, riverbed stone | |
| Soil | Gravel | Digging ability is getting lower due to mixture of gravel | Sand with much gravel, Sandy soil with much gravel, cohesive soil with much gravel | {G}<br>{GS} |
| | Sand | Difficult to dig by heaped capacity (full bucket) | Desert hill sand, decomposed granite soil | {S} |
| | Sandy Soil | Digging is easy, digging by heaped capacity | Sandy soil, decomposed granite soil, well-graded sand, good condition | {S}<br>〔S〕<br>{M} |

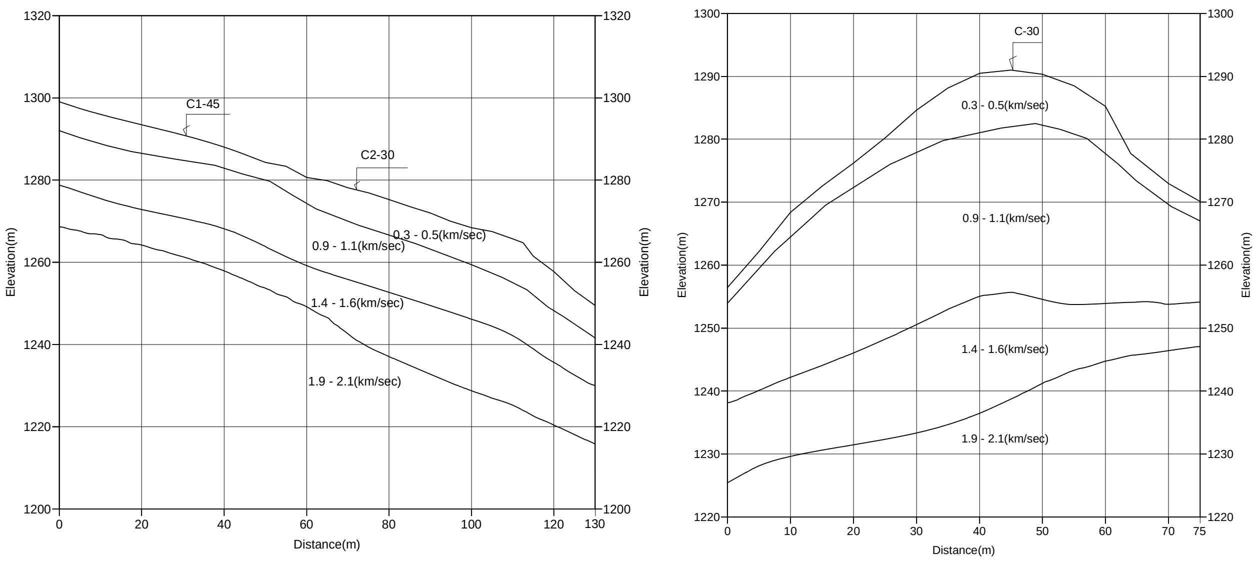
| | | | | |
|---|---|---|---|---|
| | | | loam | |
| | Cohesive Soil | Soil adheres to bucket easily, issues on trafficability | Fine-grained soil<br>Loam | {M}<br>{C} |
| | Wet Cohesive Soil | Soil adheres to bucket easily and difficult in terms of trafficability | Bad condition loam,<br>Bad condition fine-grained soil<br>Volcanic cohesive Soil | {M}<br>{C}<br>{V}<br>{O} |
| | Organic Soil | | | {Pt} |

Source: The Manual for Road Construction (Japan Road Association)

**Table 1.3.5 Relation of Seismic Wave Velocity and Excavation Method**




Source: The Manual for Road Construction (Japan Road Association)




Source: JICA Study Team

**Figure 1.3.5 Seismic Exploration Result (C Line) at Sta. 18+200**

## 1.3.2 RESULT OF GEOLOGICAL SURVEY

### 1.3.2.1 METHOD OF GEOTECHNICAL SOIL TEST

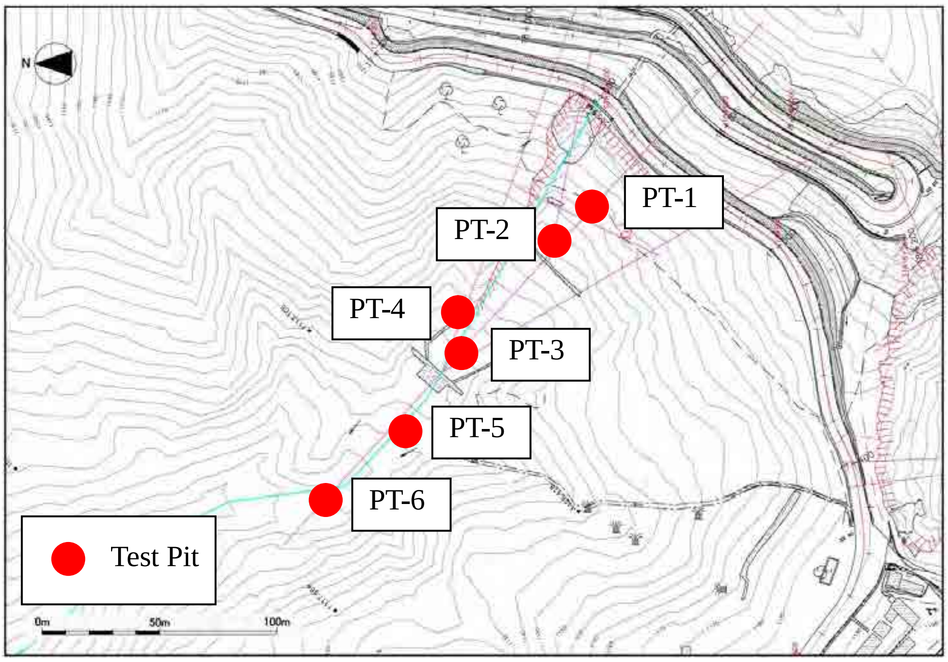
Test pit digging, soil sampling, and field and laboratory soil tests were carried out at Sta. 17+600 slopes for planning the counterweight embankment and at three alternative borrow pits where riverbed materials are deposited. These locations are shown in Figure 1.3.6 and Figure 1.3.7. The investigation contents are shown in Table 1.3.6.

Result of these tests are described in Clauses (1) Condition Of Foundation Embankment, (2) Characteristics of Embankment Material, and (3) Borrow pits comparison.

**Table 1.3.6 Soil Investigation List**

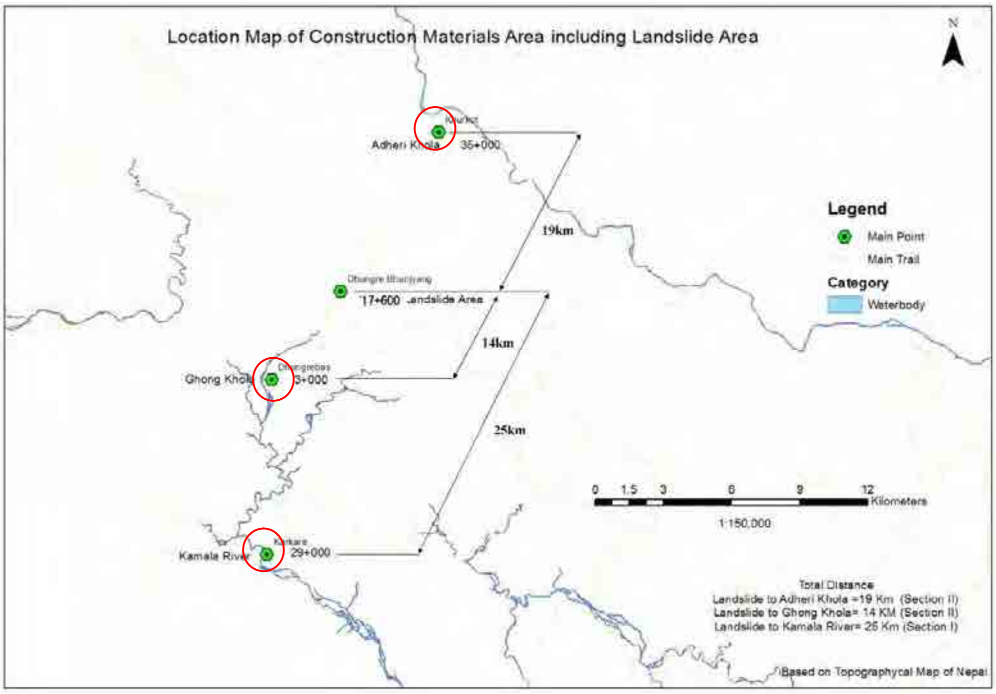
| Item | Unit | Quantity | | |
|---|---|---|---|---|
| | | Counterweight bank area | Three borrow pits of riverbed materials | Sum |
| 1. Test Pit | | | | |
| Pitting (Digging) | pit | 6 | 9 | 15 |
| Pit Observation | pit | 6 | 9 | 15 |
| Field Density Test | place | 6 | 9 | 15 |
| Field Sieve Test | sample | 6 | 9 | 15 |
| Sampling | sample | 6 | 9 | 15 |
| 2. Soil Test | | | | |
| Specific Gravity Test | sample | 6 | 9 | 15 |
| Specific Gravity & Water Absorption Tests | sample | 18 | 9 | 27 |
| Water Content Test | sample | 6 | 9 | 15 |
| Grain Size Analysis | sample | 6 | 9 | 25 |
| Minimum and Maximum Index Density Tests | sample | 6 | 9 | 15 |
| 4.Rock Test | | | | |
| Specific Gravity & Water Absorption Tests of Rock | sample | 4 | - | 4 |
| Ultrasonic Wave Velocity Test of Rock | sample | 4 | - | 4 |
| Point Load Strength Test | sample | 4 | - | 4 |

Source: JICA Study Team




Source: JICA Study Team

**Figure 1.3.6 Sta.17+600 Location of Investigation**




Source: JICA Study Team

**Figure 1.3.7 Location of Investigation for Riverbed Material**

### (1) Conditions of Foundation of Embankment

Observation of the layer until 2 m depth and ground density test at 1 m depth were conducted to figure out the conditions of foundation of embankment. The composition of the layers and soil characteristics that were found out are listed below.

1） Layer Composition

- The slope surface of Sta. 17+600 is covered by cobbles with particle size of 75-300 mm and boulders with particle size greater than 300 mm. The thickness of this surface layer is 0.1-0.3 m.

- Under this layer, the sandy gravel layer with cobbles has diameter of 4.75-150 mm, and is evenly distributed. The voids of the gravel layer are filled with sand and silt.

- The gravel layer has 0.3-0.5 km/s seismic velocity. The thickness of this layer is 1 m at the bottom of the slope and 5 m at the upper slope.

- Under the gravel layer, consolidated talus or soft rock, weathered rocks, fresh rock deposits, which correspond to seismic velocities of 0.9-1.1 km/s, 1.9-1.2 km/s, and 3.8-4.0 km/s, respectively, are distributed.

2） Soil Characteristics

- Soil of the gravel layer is distributed 1-5 m from the surface and is composed of loose gravel or sand with gravel that has wet density of 19-20 kN/m$^3$ and relative density of 33-77% (average is 50%). This characteristic corresponds to “natural ground – sand with gravel – not stiff” as shown in Table 1.3.8. According to this survey result, 20 kN/m$^3$ is adopted for the design wet density, 35° is adopted for the design of internal friction angle and soil is assumed to be cohesionless.

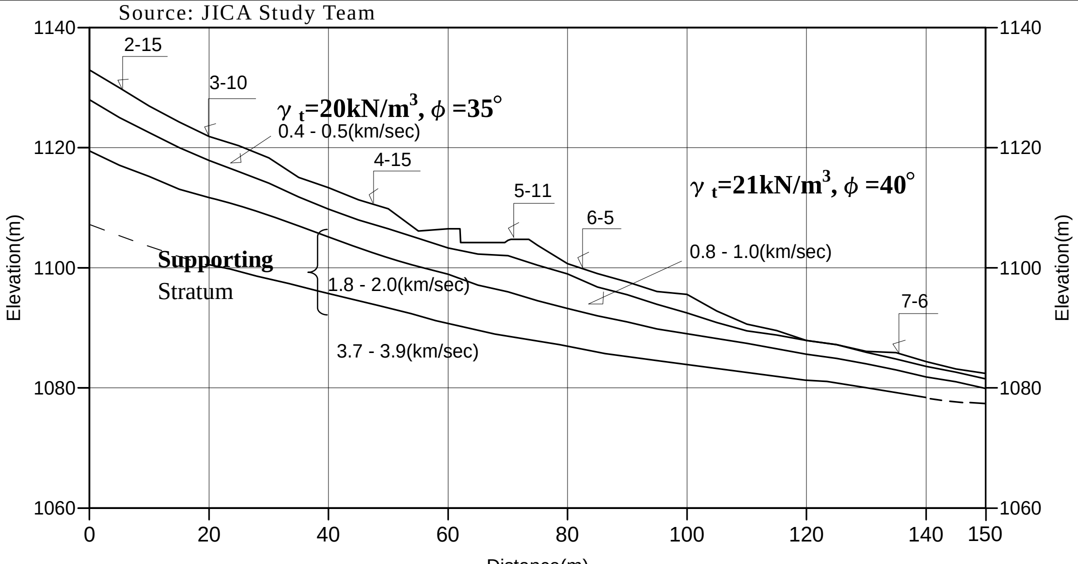
- It is assumed that the 2nd layer consists of tight deposits and soft rocks. It has 0.9-1.1 km/s of seismic velocity and is in the boundary of ripper excavation and bearing ground. The layer is equivalent to “natural ground - gravel - stiff or well-graded” in Table 1.3.8. For this reason, 21 km/m$^3$ is adopted for its design wet density, 40° is adopted for the design of internal friction angle and soil is assumed to be cohesionless.

- It was concluded that seismic 3rd and 4th layers are bearing ground that requires ripper excavation or dynamite excavation.

**Table 1.3.7 Soil Constants of Foundation Ground**

| Classification of Layers | | Density Test Result | | | Soil Constants | | |
|---|---|---|---|---|---|---|---|
| | | | | | Weight | Shear Strength | |
| Velocity Layer | Layer | Wet Density $\gamma$ (kN/m$^3$) | Void Ratio $e_b$ | Relative Density Dr (%) | Wet Density $\gamma$ (kN/m$^3$) | Cohesion C (kN/m$^2$) | Internal Friction Angle $\phi$ (°) |
| 1st Layer 0.4-0.5 km/s | Gravelly Soil | 19-21 | 0.3-0.4 | 33-71 | 20 | 0 | 35 |
| 2nd Layer 0.8-1.0 km/s | Talus or Soft Rock | - | - | - | 21 | 0 | 40 |
| 3rd Layer 1.8-2.0 km/s | Soft Rock | Supporting Stratum | | | | | |
| 4th Layer 3.7-3.9 km/s | Hard Rock | | | | | | |

Source: JICA Study Team




Sourse: JICA Study Team

**Figure 1.3.8 Soil Constants of Each Foundation Ground**

**Table 1.3.8 Reference Soil Constants for Design**

| Kind | | Condition | | Unit Weight (kN/m$^3$) | Internal Friction Angle $\phi$ (° ) | Cohesion C (kN/m$^2$) | Soil Classification | |
|---|---|---|---|---|---|---|---|---|
| Embankment | Gravel or Sand with gravel | Compacted | | 20 | 40 | 0 | {G} | |
| | Sand | Compacted | Well-graded | 20 | 35 | 0 | {S} | |
| | | | Poorly-graded | 19 | 30 | 0 | | |
| | Sandy soil | Compacted | | 19 | 25 | 30 or less | {SF} | |
| | Cohesion Soil | | | 18 | 15 | 50 or less | {M}, {C} | |
| | Kanto loam | | | 14 | 20 | 10 or less | {V} | |
| Natural Ground | Gravel | Stiff or Well-graded | | 20 | 40 | 0 | {G} | 2st Layer |
| | | Not Stiff or Poorly-graded | | 18 | 35 | 0 | | |
| | Sand with gravel | Stiff | | 21 | 40 | 0 | {G} | 1st Layer |
| | | Not Stiff | | 19 | 35 | 0 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Sand | Stiff or Well-graded | 20 | 35 | 0 | {S} |
| | | Not Stiff or Poorly-graded | 18 | 30 | 0 | |
| | Sandy soil | Stiff | 19 | 30 | 30 or less | {SF} |
| | | Not Stiff | 17 | 25 | 0 | |
| | Cohesion soil | Stiff | 18 | 25 | 50 or less | {M}, {C} |
| | | Softish | 17 | 20 | 30 or less | |
| | | Soft | 16 | 15 | 15 or less | |
| | Clay or silt | Stiff | 17 | 20 | 50 or less | {M}, {C} |
| | | Softish | 16 | 15 | 30 or less | |
| | | Soft | 14 | 10 | 15 or less | |
| | Kanto loam | | 14 | 5 | 30 or less | {V} |

Source: Manual for Embankment (Japan Road Association)

### (2) Characteristics of Embankment Material

Earth excavated at Sta. 18+200 would be used as embankment material. It is assumed that the characteristic of embankment material can be evaluated by soil test of talus deposit at Sta. 16+600 which has similar characteristic of the excavated materials at Sta. 18+200.

The mixed gravel is quartz schist that has water absorption of less than 2%. It is weathering-proofed and has strong shear strength.

1） Granularity Characteristic

The soil is composed mainly of sand and gravel with grain diameter less than 300 mm which contains boulders with 500 mm maximum diameter.

The uniformity coefficient (Uc) indicates that the material has a wide range grain size distribution and that it is good to compact as seen in the graph below. The materials are judged to have high permeability with fine content (silt and clay) rate of less than 7% (Table 1.3.9).

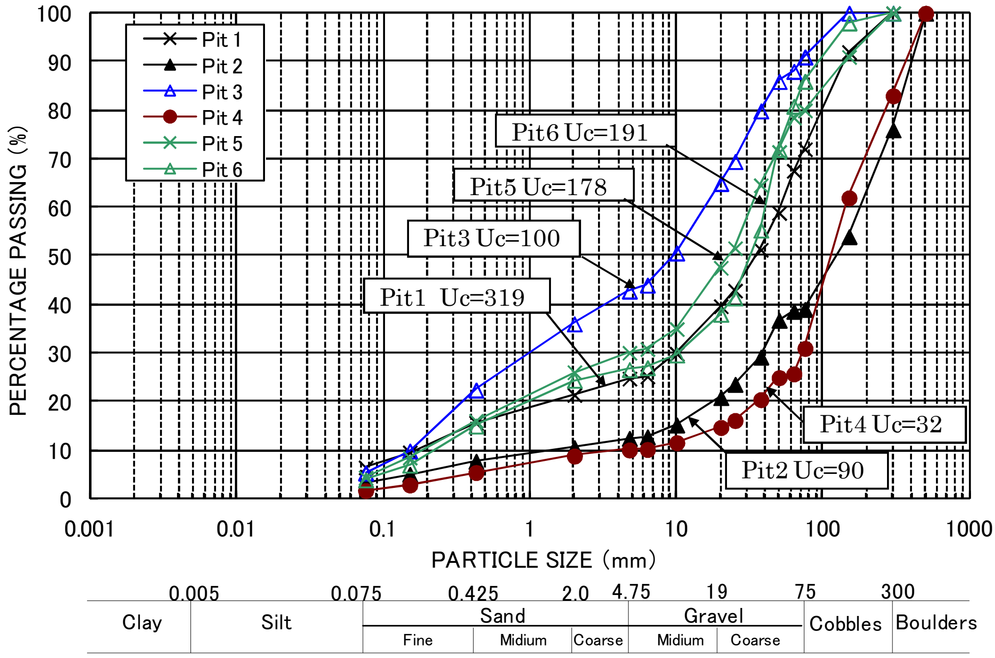
[Quality evaluation of particle size distribution]

$Uc \geqq 10$ : Well-graded, $Uc < 10$ : Poorly-graded

Where, Uc : Uniformity Coefficient $Uc = D_{60}/D_{10}$

$D_{60}$, $D_{10}$ : are the particle diameters corresponding to 60% and 10% finer on the cumulative particle-size distribution curve, respectively.

Source: Japanese Geotechnical Society standard "Method of Classification of Geomaterials for Engineering Purpose"




Source: JICA Study Team

**Figure 1.3.9 Grain Size Frequency Curve**

**Table 1.3.9 Fine Contents and Permeability**

| Material | Fine content (Fc) |
|---|---|
| Material with relatively high permeability | Fc ≦ 3 |
| Material with relatively low permeability | 3 < Fc ≦ 15 |
| Material with low permeability | 15 < Fc ≦ 25 |

Source: Japanese Geotechnical Society Standard

2） Specific Gravity and Water Absorption

Specific gravity of the grain is 2.59-2.62 g/cm$^3$ and its water absorption is 0.9-1.2%. Also, the composed particle has low porosity and hard. Hence, the materials are suited for embankment from viewpoints of durability and shear strength.

3） Compaction Characteristic

Because the material has the above characteristics and its grain size distribution has wide range, it is assumed that the density after the compaction is 90-95% of the maximum dry density and wet density is 2.0-2.2 t/m$^3$.

4） Shear Strength

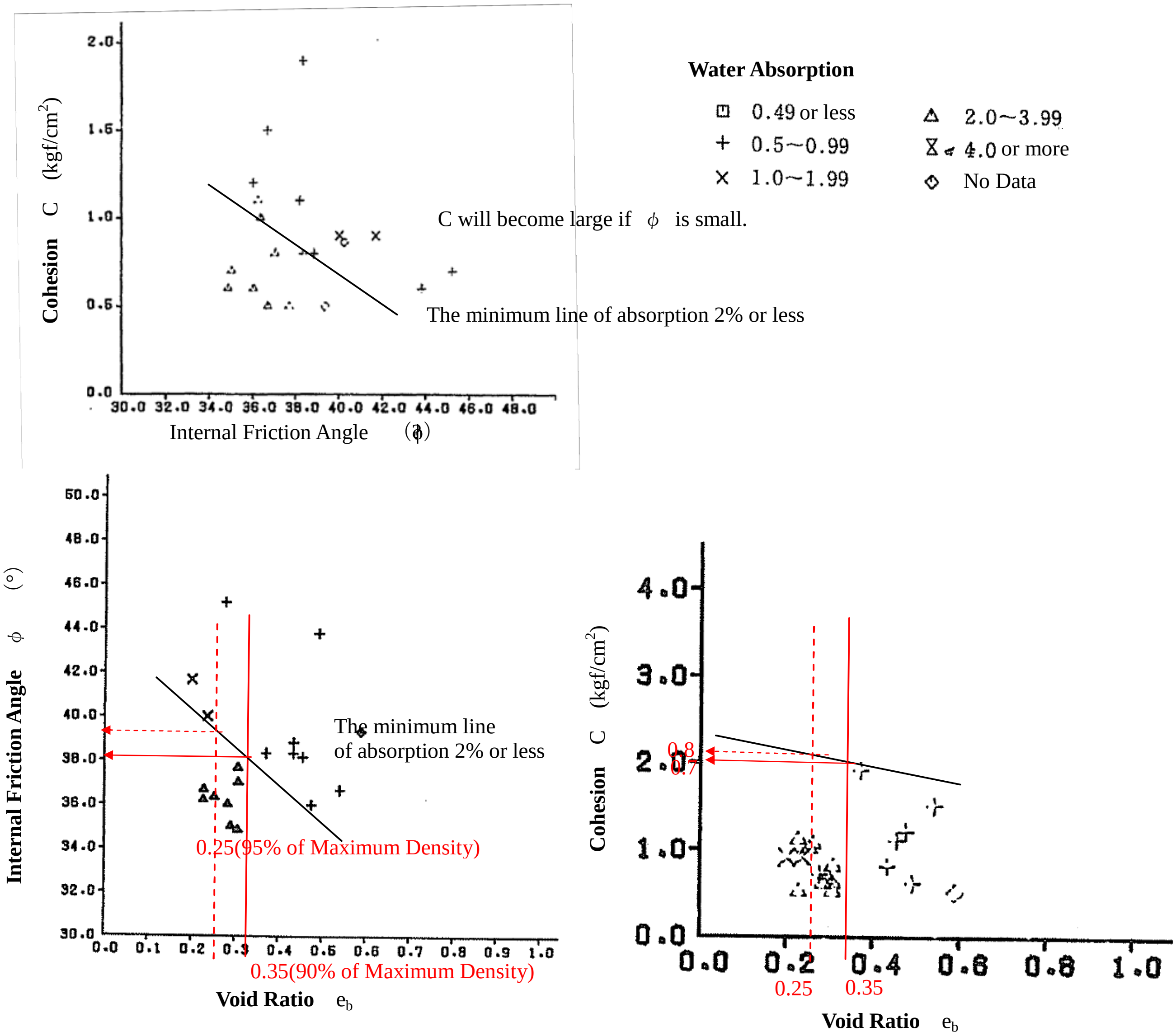
Shear strength of the embankment materials that contain much gravel has 40° internal friction angle and has no cohesion (refer to Table 1.3.10). Also, the shear strength has the correlation with void ratio and water absorption as shown in Figure 2.2.31. From the results of the tri-axial compression test, the shear strength of the material that has 90-95% void ratio to maximum dry density consists of an internal friction angle of 38° and cohesion of 0 kN/m$^2$. Thus, 38° is adopted for the internal friction angle and material is said to be cohesionless for the design value to be on the safe side.

**Table 1.3.10 Test Result and Density After Compaction**

| | | Test Result | | | | Density after compaction (Calculated value as 90% and 95% of Maximum Density) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Pit No. | | Specific Gravity Gb (g/cm$^3$) | Water Absorption Q (%) | Minimum Dry Density (t/m$^3$) | Maximum Dry Density (t/m$^3$) | Degree of compaction | Wet Density $\rho_t$ (t/m$^3$) | Dry Density $\rho_d$ (t/m$^3$) | Void Ratio $e_b$ | Relative density Dr (%) |
| 1-6 | 2.56-2.62 | 0.7-1.1 | 1.74-1.83 | 2.19-2.27 | 90% | 2.06-2.19 | 1.97-2.05 | 0.28-0.32 | 52-65 | |
| | | | | | 95% | 2.17-2.29 | 2.08-2.16 | 0.22-0.25 | 77-83 | |

Remarks: Minimum dry, maximum dry and construction density are based on the soil test without Pit 2, 3 that are accounted with more than 30% of rock having diameter of more than 75 mm.

Source: JICA Study Team




### (3) Borrow Pits Comparison

The selection of the borrow site was conducted by comparing the quality of materials, location condition, environmental condition and cost of three sites, namely: Adheri Khola, Ghong Khola and Kamala River (refer to Figure 1.3.7).

Comparison results are shown in Table 1.3.11. Among the three choices, Kamala River was selected because the site is a public land that has superiority in terms of cost, quantity and environment conditions such as riverbed lowering, which is best for borrow pits.

**Table 1.3.11 Borrow Pits Comparison**

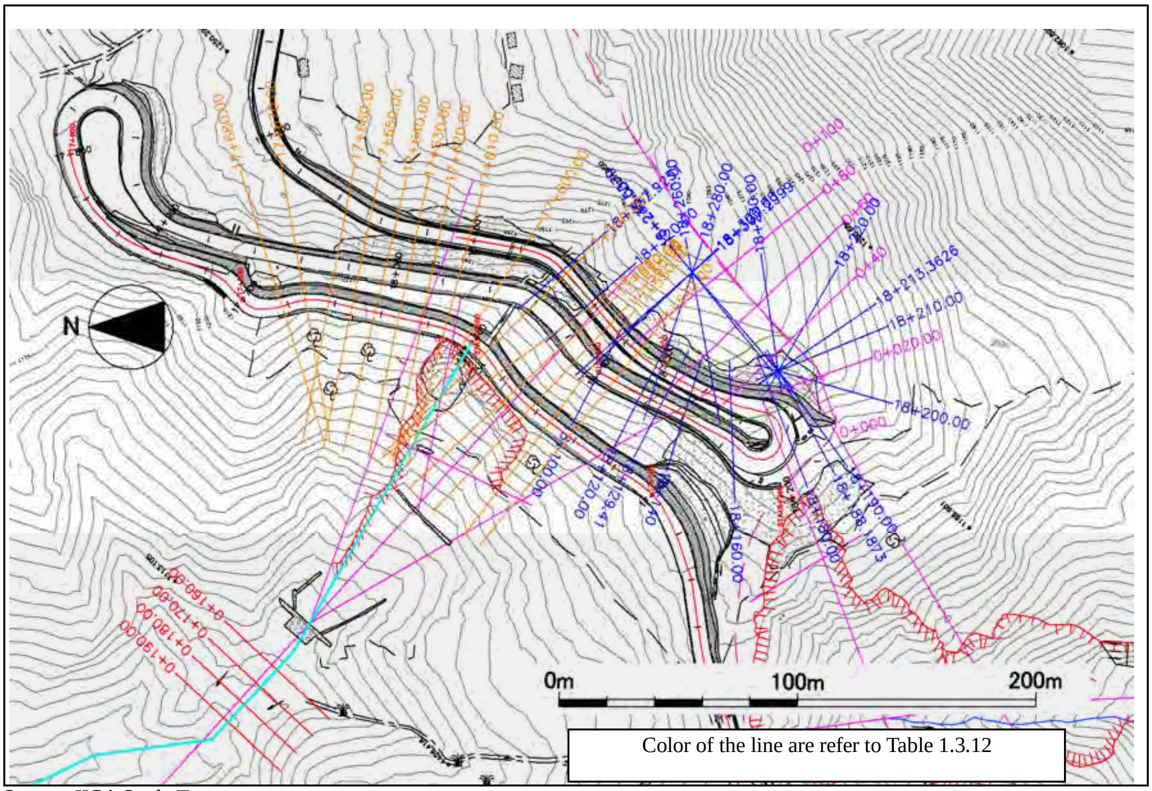
| Borrow Pit Name/ Comparison Item | | I Adheri Khola | II Ghong Khola | III Kamala River | Notes (basis, etc.) |
|---|---|---|---|---|---|
| Conditions of Location and | Distance from Embankment Area | 19 km | 14 km | 25 km | The distance from Sta. 17+600 is computed by road distance post |
| | Landowners | **Private Land**<br>**1 point** | **Public Land**<br>Private land if not enough<br>**2 points** | **Public Land**<br>**3 points** | By field inspection |
| | Approach Road | Existing road | Existing road | Existing road | |
| | Influence on Farm Facility | There is uncultivated land. | nothing | nothing | |

| | | | | | |
|---|---|---|---|---|---|
| | Influence on Riverbed Lowering | Since the riverbed (public land) is lower than the surrounding land by not less than 2 m, excavation is difficult. **1 point** | Since the riverbed (public land) is narrow (about 20 m wide) and sandbank is not large and thin, the digging of large area is necessary to avoid riverbed lowering **2 points** | Since sandbank accumulates large area and is thick, the influence on riverbed lowering is low. **3 points** | |
| | Others | Being collected from private land by Hazama | Being collected from public land by local company | Being collected from public land by public works, etc. | |
| Quality of Riverbed Material | | Sand and gravel contain cobbles (particle size of 75~300 mm) and boulders (particle size of 300 mm or more) **2 points** | Sand and gravel contain cobbles **3 points** | Sand and gravel contain cobbles **3 points** | By soil investigation |
| Quantity | | Medium **2 points** | Small **1 point** | Large **3 points** | |
| Cost | Material Cost (DOR) | Several times more than NRs 167 **1 point** | Several times more than NRs 167 **1 point** | About NRs 167 **3 points** | By field inspection |
| Cost | Transport Cost (JAPAN) | Middle **2 points** | Short **3 points** | Long **1 point** | |
| | Sum | A little high | Low | Low | |
| Comprehensive Evaluation | | **9 Points** | **12 points** | **16 points** | |

Source: JICA Study Team

### 1.3.3 SURVEY

The longitudinal section survey and cross section survey are conducted. Location of the survey is as shown in Figure 1.3.11. The purpose and quantity of the survey are as shown in Table 1.3.12. Electronic output of the survey is stored in the electronic output of this report.




Source: JICA Study Team

**Figure 1.3.11 Location of the Survey**

**Table 1.3.12 Purpose of the Survey and Implementation Quantity**

| Location | Purpose | Quantity |
|---|---|---|
| Around Sta. 17+600<br>Color：Orange | Outline design for landslide A | Longitudinal section：200 m<br>Cross section：15*120 m ΣL=1,800 m |
| Sta. 17+600 Lower<br>Color: Red | Outline design for landslide B | Longitudinal section：40m<br>Cross section：4*60 m ΣL=160 m |
| Sta. 18+200 Mountain side<br>Color: Blue | Outline design for road realignment | Longitudinal section：170m<br>Cross section：19*60 m ΣL=1,340 m |
| Sta. 18+200 Mountain side<br>Color: Pink | Outline design for cutting area | Longitudinal section:140 m<br>Cross section: 5*100 m ΣL=500 m |

Source: JICA Study Team

## 1.4 PRELIMINARY PLAN OF ENVIRONMENTAL AND SOCIAL CONSIDERATIONS AND MONITORING

The Project involves rehabilitation works for target sections which are affected by landslides. Countermeasures for landslide-prone areas will be made after completion. And, there will be no Project Affected Persons (PAPs) who is needed to remove due to implementation of the project. Hence, the Project will contribute to the improvement of the natural condition of the Project area. However, some natural and social problems will come up during the construction stage, and, therefore, adequate environmental considerations should be paid for implementing the Project along with JICA and DOR regulations.

Preliminary environmental and social studies carried in the study, which are shown in Appendix 5.1, are summarized below.

### 1.4.1 ENVIRONMENTAL CATEGORY OF THE PROJECT

The Project was determined to be under environmental Category B according to the JICA Guidelines for Environmental and Social Considerations (April 2010), on the basis of the following reasons:

- The Project is to construct countermeasures for landslides within Sindhuli Bazar – Khurkot Road (Section II), and the rehabilitation of national highways. Accordingly, no significant negative impacts are expected in the construction activities of the Project.
- The locations to be implemented for countermeasure construction involve two sites, with a total road section length of about 130 m. In addition, the proposed countermeasures are planned to be completed within two years.
- The proposed countermeasures against landslides are permanent works with high stability, such as anchors and reinforced earth walls.

> Definition and Regulation of *Category B*:
> Proposed projects are classified as Category B if their potential adverse impacts on the environment and society are less adverse than those of Category A projects. These impacts are generally site-specific; few if any are irreversible; and in most cases, normal mitigation measures can be designed more readily. The project proponent is in principle required to submit an initial environment examination (IEE) report for JICA environmental review.

### 1.4.2 ENVIRONMENTAL ORGANIZATIONS AND THEIR TASKS IN NEPAL

In Nepal, the Ministry of Environment (MoE) is in-charge of environmental control and management for the project requiring an environmental impact assessment (EIA) for all sector agencies. MoE is responsible for providing adequate environmental and social safeguards in the design and implementation of the Strategic Road Network (SRN). In the case of EIA study, the approval of the terms of reference (ToR) for the EIA and the corresponding report lies with the MoE.

On the other hand, the concerned ministry has overall responsibility for environmental monitoring of the projects implemented. For projects requiring an initial environmental examination (IEE), the proponent will prepare the ToR for the IEE study and submit to the concerned ministry through the concerned department. the concerned ministry will be responsible for environmental monitoring and final approval of the ToR and IEE report.

Submission Body and Days until Approval of EIA/IEE report is below.

**Table 1.4.1 Responsible Body for EIA/IEE Report on this Project**

| Categorization | Responsible Body | Submission to | Examination period |
|---|---|---|---|
| EIA | MoE | MoE | Within 60 |
| IEE | MoPPW | MoPPW | Within 21 |

The proponent of the Project is DOR under the Ministry of Physical Planning and Works (MoPPW). Accordingly, the DOR has been preparing the ToR for the IEE study, which will be completed on May 2012. The IEE report will be submitted to MoPPW through the Geo-Environment and Social Unit (GESU), and MoPPW will be responsible for the approval of IEE reports for the Project.

### 1.4.3 PRELIMINARY STUDY ON ENVIRONMENTAL AND SOCIAL IMPACT

The final environmental and social consideration plan will be decided along with the results of the IEE for the project as mentioned above. However, preliminary study on environmental and social impact was checked through the review of the EIA Report for Section II by DOR (1999) and site survey. Results of the study are listed as shown in Appendix II and as summarized in Table 1.4.2.

**Table 1.4.2 Potential Environmental Adverse Impacts during Planning and Construction**

| No. | Potential Impact | Rating | Description of Impact |
|---|---|---|---|
| **Pollution** | | | |
| 1 | Air pollution | B- | Dust and gas emissions are anticipated to occur during construction. |
| 2 | Water pollution | B- | Petroleum and hydraulic fluid spills from heavy equipment may occur and pollute water ways. |
| 3 | Spoils and waste | B- | Excavation material will be used as fill material and other wastes will be disposed off at a designated place. |
| 4 | Soil contamination | C- | Petroleum and hydraulic fluid spills and leaks from heavy equipment might cause soil contamination especially on farm lands. |
| 5 | Noise and vibration | B- | Noise and vibration are expected to occur due to the use of machines and equipment for construction activities. |
| 6 | Ground subsidence | D | No ground subsidence is expected at the project area. |
| 7 | Offensive odor | D | No offensive odor is expected at the project area. |
| 8 | Bottom sediment | D | No sedimentation is expected at the project area. |
| **Natural Environment** | | | |
| 9 | Topography and geology | B- | Small-scale topographical reformation or alteration will be required due to realignment and subsequent excavation. |
| 10 | Slope stability | A+ | Landslides will be stabilized, and all excavated slopes will be protected with appropriate structures. |
| 11 | Soil erosion | C- | Excavation and embankment works might cause soil erosion. |
| 12 | Hydrological situation | D | No adverse hydrological effects are anticipated at the proposed construction site (material source from riverbed) |
| 13 | Groundwater | D | Adverse impacts will be minimized due to anchor installation. |
| 14 | Nature preserve | D | No natural preserves exist within the project area. |
| 15 | Ecosystem | D | No ecosystems exist within the project area. |
| **Socioeconomic Environment** | | | |

| No. | Potential Impact | Rating | Description of Impact |
|---|---|---|---|
| 16 | Involuntary resettlement | D | No involuntary resettlements are expected. |
| 17 | Poor people | D | No poor people exist in the project area. |
| 18 | Ethnic minorities and indigenous people | D | Ethnic people exist in the project area but the adverse impacts to these groups are expected to be very small. |
| 19 | Local economy such as employment and livelihood | C- | Construction activity might create some temporary traffic blockage and affect economic activities. |
| 20 | Land use and utilization of local resources | B- | Private lands will be temporarily used for access roads, stockpiles, and staff houses. |
| 21 | Use and access to water | C- | Some natural springs in the project area serve as the major source of drinking water for the local people. No water rights exist in the project area. |
| 22 | Existing social infrastructure and services | C- | The removal of existing water supply pipes will be required. Temporary restriction and control of existing traffic are anticipated. |
| 23 | Maldistribution of benefit and damage | D | Adverse impacts would be very small. |
| 24 | Local conflict of interest | D | No local conflict of interest exists in the project area. |
| 25 | Cultural heritage | D | Bhadrakali temple at Sta. 17+00 is close to the project area, but the adverse impacts to the temple are expected to be very small. |
| 26 | Landscape | D | Adverse impacts may be small due to small-scale earthworks |
| 27 | Labor environment | C- | Defective management of safety and health for worker is expected during construction activities. |
| 28 | Sanitation | D | No sanitation exists in the project area. |
| 29 | Hazards (Risks) | C- | Rock falls are expected to occur around the upper slope. |
| **Others** | | | |
| 30 | Accidents | B- | Construction activity and temporary traffic blockage may cause traffic accidents. |
| 31 | Global warming | D | Adverse impacts would be small. |
| **Overall Rating** | | **B-** | It is necessary for landowners to give compensation and recovery prior to construction. Moreover, mitigation measures against traffic safety, noise, dust and vibration should be provided. |

Rating: A+/- = Significant positive/negative impact is expected, B+/- = Positive/negative impact is expected to some extent, C+/- = Extent of positive/negative impact is unknown or may be small at this stage, and D = No impact is expected

As a result, one item is categorized as A+, seven items as B-, seven items as C-, while the rest are categorized as D. Accordingly, the implementation of the Project is expected to contribute positive environmental effects and, to some extent, cause negative environmental impacts.

### 1.4.4 MITIGATION MEASURES

Mitigation measures, as listed in Table 1.4.3, were recommended and discussed.

**Table 1.4.3 Mitigation Measures**

| No. | Potential Impact | Rating | Conceivable Mitigation Measures |
|---|---|---|---|
| **Pollution** | | | |
| 1 | Air pollution | B- | A. Construction Stage: a) Periodical watering around the implementation area will be carried out to prevent airborne dust. |
| 2 | Water pollution | B- | A. Construction Stage: a) Provision by proper construction plan and management. |
| 3 | Spoils and waste | B- | A. Plan and Design Stage: a) Excavated material is planned to be reused as fill material.<br>B. Construction Stage: a) The wastes will be disposed off at dedicated places. |
| 4 | Soil contamination | C- | A. Construction Stage: a) Provision by suitable planning and management of project implementation. |
| 5 | Noise and vibration | B- | A. Plan and Design Stage: a) Machines and equipment of adequate capacity with low noise and vibration will be planned to be used for each activity.<br>B. Construction Stage: a) Installation of soundproof wall; b) Limiting the operation time during holidays, such as local festivities. |
| **Natural Environment** | | | |
| 6 | Topography and geology | B- | A. Plan and Design Stage: a) Cut and fill slopes are planned and designed to minimize the changes in topography; b) Only approved |

| No. | Potential Impact | Rating | Conceivable Mitigation Measures |
|---|---|---|---|
| | | | materials and sources will be used for embankment and as crushed aggregates. |
| 7 | Soil erosion | C- | A. Plan and Design Stage: a) Proper slope protection works are provided.<br>B. Construction Stage: a) Limiting and controlling progress of earthworks during rains. |
| **Socio-economic environment** | | | |
| 8 | Local economy as such employment and livelihood | C- | A. Construction Stage: a) At the beginning of the project implementation, provide adequate information to bus companies and relevant local organizations; b) Provide adequate compensation for landowners; c) Give local residents preference to have join in the construction works. |
| 9 | Land use and utilization of local resources | B- | A. Plan and Design Stage: a) Prepare construction plan to limit the use of private lands.<br>B. Construction Stage: a) Provide adequate compensation for landowners; b) Restore to the original status after construction. |
| 10 | Use and access to water | C- | A. Construction Stage: a) Periodical check for the amount of water use, b) Proper compensation to local communities. |
| 11 | Existing social infrastructure and services | C- | A. Construction Stage: a) Move affected water supply pipes at the beginning of project implementation. |
| 12 | Labor environment | C- | A. Construction Stage: a) Provide proper construction plan and management to consider the health, safety, security of the workers for the implementation of the project. |
| 13 | Hazards (Risks) | C- | A. Construction Stage: a) Periodical inspection of upper slopes; b) Use of safety helmets: c) Installation of rock fall protection nets, if necessary. |
| **Others** | | | |
| 14 | Accidents | B- | A. Construction Stage: a) Construction work signs and traffic controller will be provided accordingly; b) Consideration to a primary school located near the project site. |

Rating: B- = Negative impact is expected to some extent, C- = Extent of negative impact is unknown or may be small at this stage.

### 1.4.5 ENVIRONMENTAL MONITORING (CONSTRUCTION PHASE)

Environmental monitoring will be implemented to provide a basis for logical comparison of the predicted and actual impacts due to the project implementation, to further identify any unpredicted impacts, and to implement necessary measures to minimize the environmental impacts of the Project.

Under DOR, GESU has integrated environmental aspects in road development and maintenance projects. GESU will be responsible for the implementation of the environmental monitoring of the Project. The monitoring plan is proposed as presented in Table 1.4.4.

**Table 1.4.4 Monitoring Plan**

| No. | Potential Impact | Rating | Monitoring | | | |
|---|---|---|---|---|---|---|
| | | | Parameter | Frequency | Method | Responsibility |
| **Pollution** | | | | | | |
| 1 | Air pollution | B- | Dust, odors | Monthly | Observation | GESU |
| 2 | Water pollution | B- | pH, turbidity | Monthly | Measurement, Inspection | GESU |
| 3 | Spoils and waste | B- | Construction spoil, waste, etc. | Monthly | Drawings, Inspection | GESU/Project |
| 4 | Soil contamination | C- | Dust, hazardous materials, oils | Monthly | Inspection, Hearing | GESU |
| 5 | Noise and vibration | B- | Sound source | Monthly | Observation, Hearing | GESU/Project |
| **Natural Environment** | | | | | | |
| 6 | Topography and geology | B- | Land alteration | Monthly | Drawings, Observation | GESU |
| 7 | Soil erosion | C- | Collapse, soil loss | Monthly | Drawings, Observation | GESU |
| **Socio-economic environment** | | | | | | |

| No. | Potential Impact | Rating | Monitoring | | | |
|---|---|---|---|---|---|---|
| | | | Parameter | Frequency | Method | Responsibility |
| 8 | Local economy as such employment and livelihood | C- | Compensation, traffic blockage | Semi-annually | Hearing | GESU |
| 9 | Land use and utilization of local resources | B- | Land use area | Monthly | Drawings, Observation | GESU |
| 10 | Use and access to water | C- | Natural springs | Monthly | Hearing | GESU |
| 11 | Existing social infrastructure and services | C- | Shifting of water supply pipe | Monthly | Hearing, Inspection | GESU |
| 12 | Labor environment | C- | Holidays, insurance | Monthly | Hearing | GESU |
| 13 | Hazards (Risks) | C- | Rock fall, slope collapse | Monthly | Inspection | GESU/Project |
| **Others** | | | | | | |
| 14 | Accidents | B- | Accidents by vehicle and due to construction | Monthly | Hearing, Inspection | GESU/Project |

Rating: B- = Negative impact is expected to some extent, C- = Extent of negative impact is unknown or may be small at this stage.

# *Chapter 2*
# *Contents of the Project*

# CHAPTER 2 CONTENTS OF PROJECT

## 2.1 DESIGN POLICY

### 2.1.1 REQUESTED SECTION

Three landslide-prone areas from Sta. 17+550 to Sta. 18+300 of Section II are requested to be implemented with countermeasures through the Project.

### 2.1.2 DESIGN CONCEPT AND PLANNING POLICY FOR COUNTERMEASURES AGAINST LANDSLIDES

Risk evaluation of the slope disasters from Sta. 17+600 and Sta. 18+200 indicated that road traffic functions would be seriously affected if these were left uncontrolled or unprotected with adequate preventive measures. Countermeasure alternatives have been examined to maintain sustainable road traffic function with the following policies:

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

B) Slope failure mechanism for landslides should be clarified, and the countermeasures adopted for slope failure mechanism should be planned accordingly.

C) Countermeasures should be planned considering traffic safety because Sections I and II must be placed in service.

D) The planned countermeasures will be implemented to improve the road slope hazards. However, the construction of these countermeasures may also have impacts on the natural and social environment especially during construction. Mitigation of these impacts should be considered in planning and selecting the countermeasures.

E) Maintenance of the countermeasures after completion should be minimal.

### 2.1.3 PARTICIPATION IN ROAD MAINTENANCE OF NEPAL SIDE

Road maintenance in Nepal is conducted based on the Annual Road Maintenance Plan (ARMP). Road maintenance in Section II and Section IV have already been handed over to DOR. In the Project, Sindhuli Road will be used for material transport and aggregate transport. This road is prone to sediment disasters such as slope failures, large-scale landslides and scouring that could wash away the roads. If this road is closed for traffic, the schedule of the Project would be affected. The maintenance of Sindhuli Road should be conducted by DOR. The particular methods such as ground anchors are planned for the Project. If additional maintenance is necessary, the consultants should suggest maintenance methods.

### 2.1.4 POLICY ON NATURAL CONDITION

#### 2.1.4.1 CLIMATE CONDITION

Climate data observed at Sindhuli Gadhi in Section II for the past 13 years was used for the study. In Sindhuli Gadhi, the highest average temperature is at 31.7ºC in April while the lowest average is at 7.2ºC in January, as shown in Figure 2.1.1. The Project site is in a continental climate, mainly warm with large temperature differences between day and night. As shown in Figure 2.1.2, the station at Sta. 17+400 in Section II has an average annual rainfall of 1,710 mm. The maximum average monthly rainfall is 462 mm in July, while the minimum monthly average is

0 mm in November and December. The recorded annual rainfall in 2007 was 2,814.5 mm.(Refer to Figure 2.1.3) The period between late May and early October falls under the monsoon season. Pavement works such as double bituminous surface treatment (DBST) and asphalt concrete pavement 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.

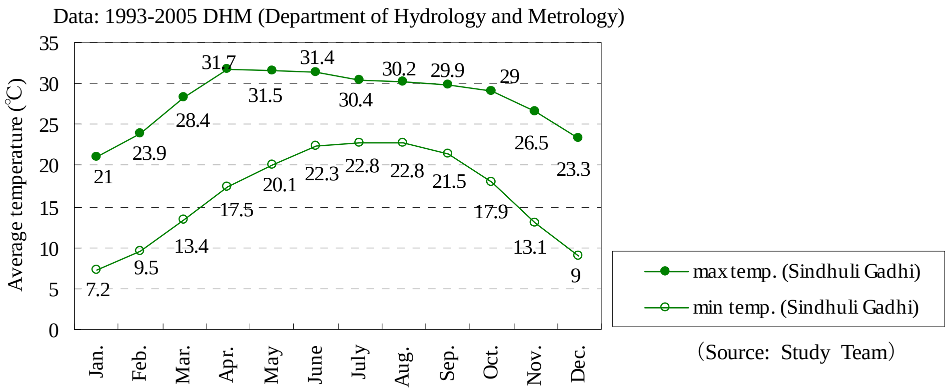



**Figure 2.1.1 Average Temperature at the Sindhuli Gadhi**

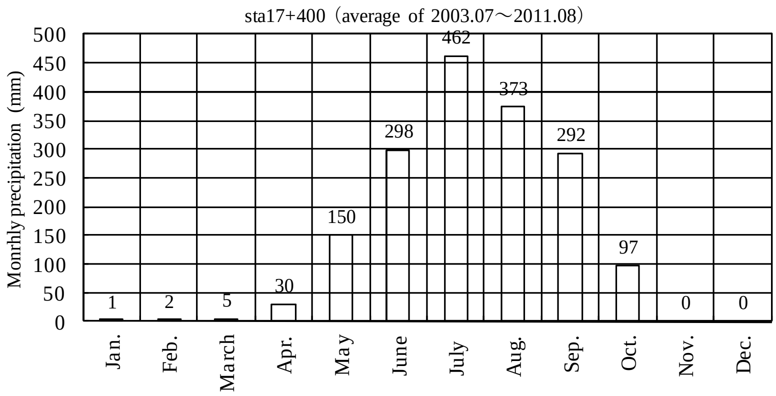



**Figure 2.1.2 Average Monthly Rainfall (Station: Sta. 17+400)**

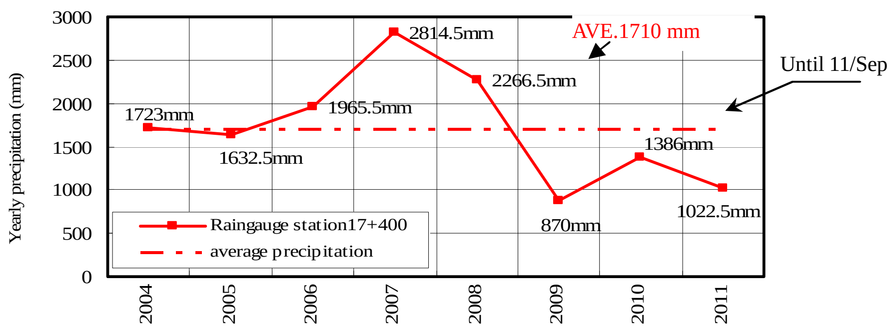



**Figure 2.1.3 Annual Rainfall**

(Source: Study Team)

### 2.1.4.2 BASIN

Design discharges for ditches and cross drainages were calculated according to the design policy for Section II. For the calculation of rainfall intensity, rainfall data observed at Sindhuli Gadhi Station was used.

#### 2.1.4.3 TOPOGRAPHY AND GEOLOGY

The site is at the northern section of the Main Boundary Thrust (MBT) that divides Nepal into the north and south. The ground of the site is constituted by slate and phyllite affected by the metamorphism of the Paleozoic layer. Strike inclinations vary throughout the site. Moreover, talus and colluvial deposits are widely distributed. In order to reduce the risks of slope disasters, slopes should have minimal and stable gradient. If the slope does not have a stable gradient, it should be protected by crib works and rock bolts.

#### 2.1.4.4 FOREST AND TREES

Only few well-developed forests have trees of varying heights. There are also many slopes with little vegetation. From the viewpoint of conservation of natural environment, cut and embankment slopes should be minimized while artificial slopes for cute and fill works should be revegetated. In addition, tree cutting should be limited during the construction.

#### 2.1.4.5 EARTHQUAKES

As the Project site was designated with the highest-risk seismic zone V according to the Indian Standard Criteria for Earthquake-Resistant Design of Structure, Third Revision, 1989, earthquakes were considered in the design of fill works.

#### 2.1.4.6 CONSIDERATION OF NATURAL ENVIRONMENT

Since the Project area is rich in natural environment, vegetation works should be adopted in areas where possible.

### 2.1.5 POLICY ON SOCIAL CONDITION

#### 2.1.5.1 CONSIDERATION OF SOCIAL ENVIRONMENT

In selecting the countermeasures, impacts including loss of lands, vibration, noise, exhaust gas, dust, and traffic safety should be considered. If these impacts cannot be avoided, mitigation measures should be planned accordingly. There are many cultivated areas in the temporary road, so compensation for harvested products should be planned, and cultivated areas should be restored to their original state.

### 2.1.6 POLICY ON CONSTRUCTION AND PROCUREMENT

#### 2.1.6.1 PROCUREMENT CONDITION OF LABORS

It is relatively easy to procure common labor services in the Project area. On the other hand, many skilled laborers and heavy equipment operators in Nepal are working in neighboring countries like India and the Middle East, where construction is rapidly progressing. Therefore, the number of skilled laborers for road construction has become limited in recent years.

It should be noted that labor wages as well as the prices of commodities in Nepal are rising.

#### 2.1.6.2 PROCUREMENT CONDITION OF MATERIALS AND EQUIPMENT

Natural materials including sand, stone and timber, reinforcing bars and gabion wires are available in the local markets of Nepal. Materials and goods that are unavailable in local markets, such as ground anchors, high intensity nets and crib works would be procured from Japan.

#### 2.1.6.3 LABOR LAWS AND CONSTRUCTION REGULATION

The “Rules and Regulations for Workers and Employees to the Private Institution and Factory in Nepal” of 1991 and 1993 should be followed for labor employment.

#### 2.1.6.4 PROCUREMENT CONDITION OF GOODS FOR DAILY LIFE

Considering the safety of local residents and natural environment, the living quarters of migrant workers will be provided with potable water and liquefied petroleum gas for cooking.

### 2.1.7 POLICY ON APPLICATION OF LOCAL CONTRACTOR

#### 2.1.7.1 APPLICATION OF LOCAL CONTRACTOR

Appropriate periods for negotiations between the main contractor and subcontractor should be considered in the preparation of the implementation schedule in this study.

#### 2.1.7.2 USE OF ITEMS POSSIBLY PRODUCED AND FABRICATED IN NEPAL

Some small and medium-sized enterprises in Nepal can produce and fabricate items such as gabion wires and steel poles. Items other than these would be procured from other countries.

#### 2.1.7.3 PROCUREMENT OF EQUIPMENT

Construction machineries other than machineries available in Nepal would be procured from Japan.

### 2.1.8 POLICY ON IMPLEMENTATION AGENCY FOR MANAGEMENT AND MAINTENANCE

DOR, the executing agency of the Project, has experienced implementing Japanese grant-aid projects. The capacity of DOR on management and operation and maintenance (O&M) has been proven in past Sindhuli Road projects since 1986. However, particular construction methods such as installation of ground anchors would be planned for countermeasures, therefore, a well-coordinated O&M and secured budget are expected.

### 2.1.9 POLICY ON LEVELS OF SERVICE

#### 2.1.9.1 DESIGN STANDARDS TO BE ADOPTED

For the design of countermeasures against landslides, Nepalese standards should be adopted. However, 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 IV would also be followed for road alignment and structures. Table 2.1.1 lists the standards that will be adopted for the Project.

**Table 2.1.1 List of Adopted Standards**

| Site | Main Countermeasure | Adopted Standards |
|---|---|---|
| Sta. 17+600 | a) Ground anchors | -Manual for Slope Protection, Japan Road Association<br>-Standard for Design and Construction of Anchor Works, Japanese Geotechnical Society |
| | b) Embankment | -Manual for Road Construction, Japan Road Association<br>-Manual for Fill Works, Japan Road Association<br>-Manual for Drainage Works, Japan Road Association |
| | c) Crib works | -Manual for Design and Construction of Crib works, Japan Slope Protection Association |

| | | |
|---|---|---|
| | d) Shotcrete | -Standard Specification for Concrete Structures, Japan Society of Civil Engineers |
| Sta. 18+200 | e) Realignment of road | -Japanese Roads Structure Ordinance, Japan Road Association<br>-Road Earthwork Drainage Guidelines, Japan Road Association |
| | f) High-intensity net and Rock bolt | -Standard for Design and Construction of Reinforced Earth Method, Nippon Expressway Company |

Source: Study Team

### 2.1.9.2 PROPOSED FACTOR OF SAFETY FOR LANDSLIDES

The proposed factor of safety (PFs) is the target value for enhancing the degree of safety of the slope and achieving the conservation of the slope through landslide countermeasure works. Considerations in determining the PFs include the landslide and its scale, and the degree of importance of the object to be protected.

Table 2.1.2 shows the different PFs for different objects to be protected from landslides. Sindhuli Road, which is the object to be conserved in the Project, is a significant road in Nepal. Therefore, the PFs that should be adopted is 1.2.

**Table 2.1.2 Determination of Proposed Factor of Safety**

| Object to be Protected from Landslides | | Proposed Factor of Safety |
|---|---|---|
| Significant road, rivers, and houses | | 1.2 |
| Other than those above | Local and prefectural roads | 1.15 |
| | Municipal road | 1.12 |
| Emergency construction | | 1.05 |

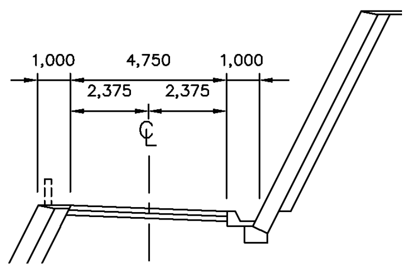
Source: Manual for Disaster

## 2.1.10 STANDARDS OF THE REALIGNMENT DESIGN

The design of the realignment road is based on design standards of Sindhuli Road to secure the traffic function for a series of the route.

As shown in Table 2.1.3 the design speed in this section is 20 km/h, which is the same as with Sindhuli Road Section II because the target section is a hairpin curve passing through steep mountainous areas. In addition, the road design is considered for road safety, with a road structure that is easy to repair.

**Table 2.1.3 Standard of Road Design**

| Item | Standard of Design | Standard Width of Road Configuration |
|---|---|---|
| Design speed | 20 km/h |  |
| Standard width | 4.75 m | |
| The design condition follows the standards of the Project for Sindhuli Road Section II. | | |

## 2.1.11 POLICY ON CONSTRUCTION METHODS AND CONSTRUCTION PERIOD

### 2.1.11.1 CONSTRUCTION PERIOD

Considering a construction period of 25 months, the Project would be implemented in three years through grant aid assistance.

### 2.1.12 POLICY ON SOCIO-ECONOMY

#### 2.1.12.1 SECURING ROAD FUNCTION IN NATIONAL ROAD NETWORK

One of the objectives of the Sindhuli Road Construction Project, which constitutes the SRN as Highway No.6 (H06) and East-West Highway, is to achieve economic growth and industrial promotion through stimulating socioeconomic activities. The Project covers disaster prevention works in areas that are highly prone to sediment disaster. In order to secure traffic safety, permanent countermeasures will be introduced for long-term stability of the target road sections and slopes.

## 2.2 BASIC PLAN

### 2.2.1 SLOPE FAILURE MECHANISM

#### 2.2.1.1 AREAS FOR COUNTERMEASURE WORKS

The areas allotted for countermeasure works are located at Landslides A, B and C as shown in Figure 2.2.1.

Countermeasure works at Sta. 17+400 will be made by DOR, because the speed of failure is slow and influence of traffic is not that heavy.

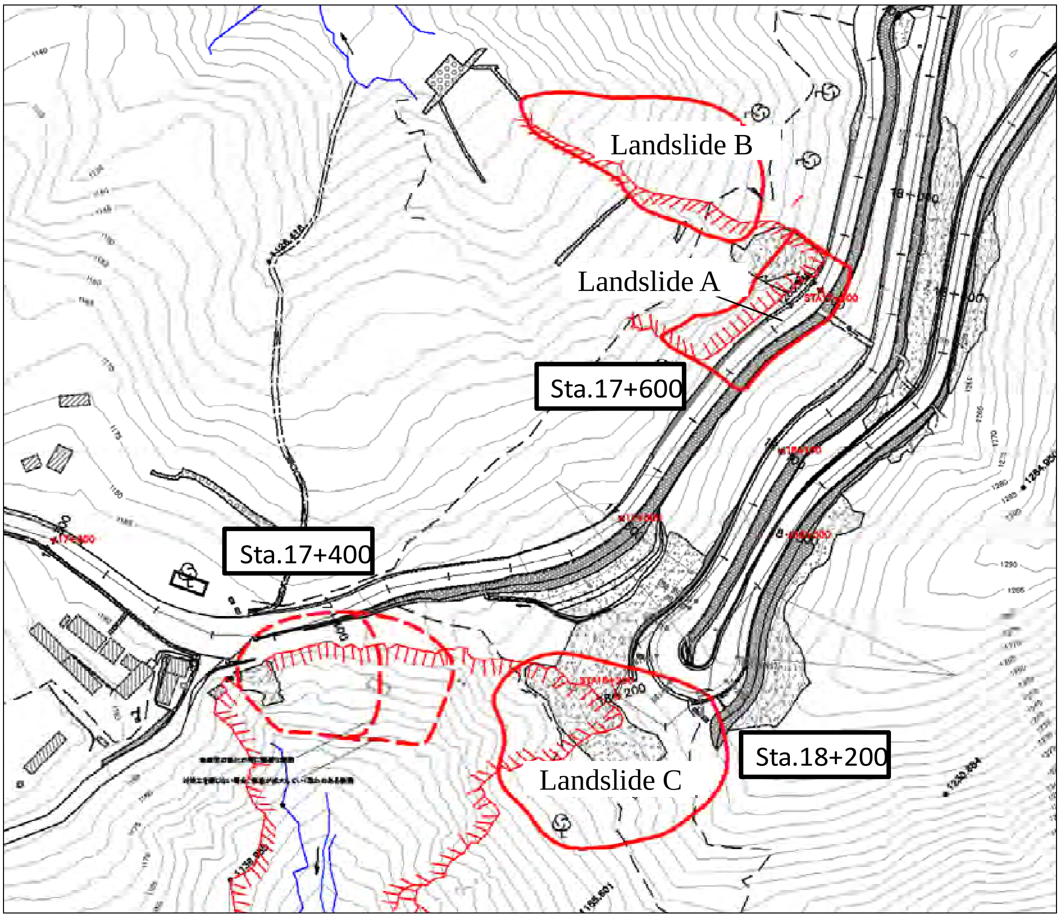



**Figure 2.2.1 Areas for Countermeasure Works**

The Study Team reviewed the slope failure mechanism, stability of slope by checking the monitoring data prepared by DOR.

### 2.2.1.2 CONDITION OF EACH LANDSLIDES

#### (1) Landslide B (Sta. 17+620)

1） Scale of Landslide A

The scale of Landslide A is much smaller compared to the area of collapse in July 2009, the location of crack and shape of topography. Its dimensions are as follows: width - 50 m, length - 22 m, and depth - 12 m (without road embankment).

2） History of Disaster Occurrences

A failure, approximately 50 m wide and 90 m long, has first occurred on the said area of the road in August 2007. Other failures also affected the road in September of the same year, when cracks appeared on the road surface and retaining wall built on the mountainside. Thereafter, hair cracks were observed in July 2009 on the same section.

3） Failure Mechanism

High-angle schistosity oblique to the slope and sheeting joints parallel to the slope have developed. For this reason, the slope is characterized by a structure where planar and wedge failures are likely to occur. The collapse in July 2009 occurred by this geological structure.

Between July and August 2007, when the continuous total rainfall reached 607 mm, the first large collapse has occurred. Subsequently, small collapses occurred with continuous rainfall of approximately 150 to 300 mm. Although an hourly rainfall of around 50 mm took place eight times, no collapse has occurred. It is also noted that there were no incidents of collapse during this study period.

4） Slope Monitoring

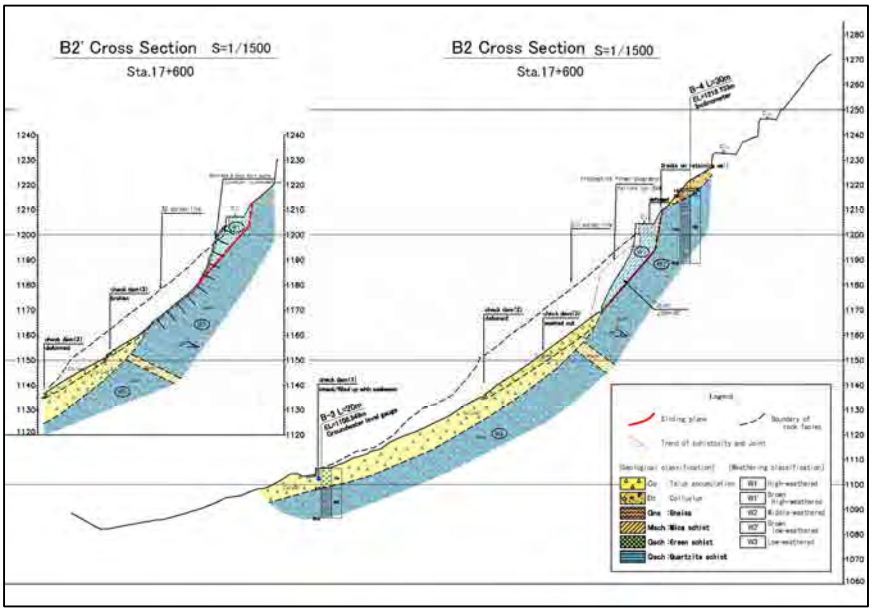
A small tendency of expansion in the rainy season was confirmed based on the measurements of the cracks on the road and retaining wall above the scarp. A small accumulative tendency was also confirmed during the monitoring with tiltmeter. Considering these observations, signs of instability of the road and its structure are confirmed to be influenced by the collapse under the said road.

5） Probability of Disaster Occurrence

Slope is just balanced temporarily from the observation of monitoring data. However, it has the possibility of suddenly collapsing due to heavy rains and earthquake within the area 50 m wide along the crack of parallel structure to the slope.

6） Necessity of Countermeasure Works

In case that the slope, including the road in the vicinity of Sta. 17+600, would collapse, realignment of the road to the mountainside will not be possible since its other section runs through a slope above Sta. 17+600. In effect, excavation of the slope for such realignment will reach the other section of the road above. Therefore, stabilization of the landslide itself is necessary without realigning the road at this section.




Source: JICA Study Team

**Figure 2.2.2 Geological Section of Landslide A**

### (2) Landslide B (Sta. 17+620)

1） Scale of Landslide

The scale of Landslide B is not enough considering the open crack on the top, collapse by the side, shape of valley, and geological survey. Its dimensions are as follows: width – 40 m, length – 85 m, and depth - 18 m.

2） History of Disaster Occurrences

(Situation is the same as in Landslide A)

Landslide B is a ridge located in the neighborhood of this collapse, and no collapse has happened before.

3） Failure Mechanism

The loosened zone of the schist has been creeping due to toppling phenomenon, moving towards the Terai Plain's side and valley direction. It resulted in progressive weakening and therefore has become unstable. On the other hand, this part serves as a counterweight against the possible landslide of the rock slope overlying this loosened zone.

In case the slope collapses, a cliff will appear just below the road, similar to the case of the failure that occurred in September 2007. This will result in an unstable condition of the road due to further loosening of the newly formed cliff.

4） Slope Monitoring

No significant displacements were observed using all the monitoring devices. On the other hand, a significant tendency of expansion was confirmed based on the measurements of the cracks on the road and retaining wall above the scarp. A fractional significant accumulative tendency was also confirmed during the monitoring with tiltmeter. Considering these observations, signs of instability are confirmed.

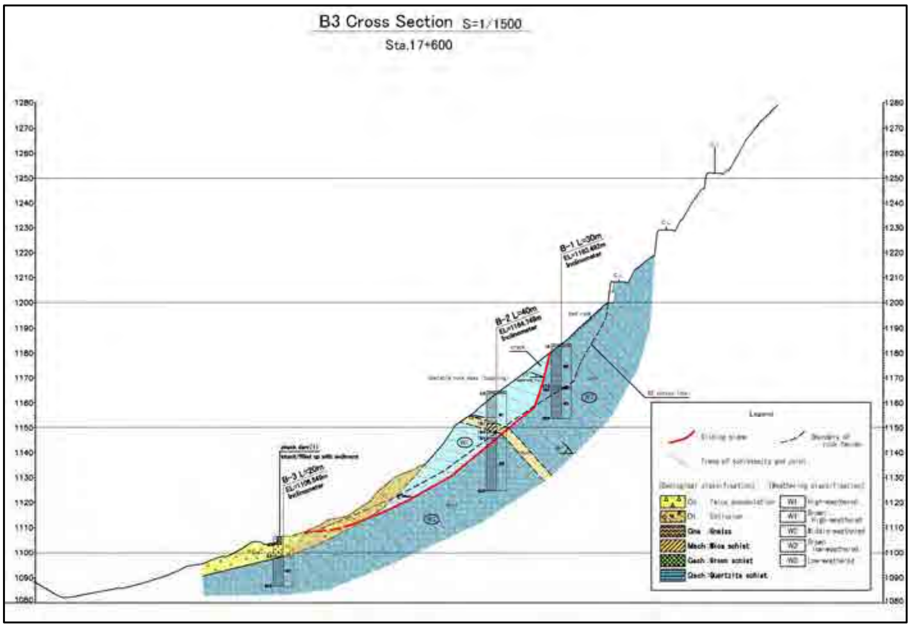
5） Probability of Disaster Occurrence

The failure type is considered to be that of a slide of loosed soil and weathered rock failure, where micro-deformation by gravity will continue and accumulate. Consequently, this may result in sudden occurrences of slope failures, particularly triggered by heavy rainfalls or large-scale earthquakes.

In case the slope collapses, a cliff will appear just below the road, similar to the case of the failure that occurred in Landslide A. This will result in an unstable condition of the road due to further loosening of the newly formed cliff.

6) Necessity of Countermeasure Works

If the entire area of Landslide B becomes unstable and it falls down, it is possible that the upper slope where the road is located will become secondarily unstable. In that case, the road on the entire area of the upper slope of Landslide B will be destroyed and it will be difficult to recover the traffic on the steep slope. Therefore, stabilization of the loosened zone itself will be necessary in the future.




Source: JICA Study Team

**Figure 2.2.3 Geological Section of Landslide B**

### (3) Landslide C (Sta. 18+200)

1) Scale of Landslide

The scale of Landslide C is not enough considering the open crack on the top, collapse by the side, shape of valley, monitoring data, and geological survey. Its dimensions are as follows: width - 70 m, length - 70 m, and depth - 22 m.

2) History of Disaster Occurrences

Landslide C is located in the steep slope on the tip of the ridge. Cracks appeared on the slope just below the road in 2003, as well as on the road in 2005. In 2006, the road was realigned by about 10 m toward the mountainside. Loss of rock slope and appearance of cracks on the retaining wall have occurred after such realignment.

3) Failure Mechanism

The site is located on the toe of the ridge, which has creep deformation due to toppling. This could possibly cause slope failure triggered by heavy rainfalls or large-scale earthquakes.

After the collapse in July 2004 and July 2007, the collapsed surface becomes steep and unstable and thus an unstable slope exists. The unstable part easily falls down when subjected to a substantial amount of rain. Small collapses often occurred during heavy rains as observed by the JICA Study Team. The collapse is still continuing, and mudflow and expansion of the collapse can be observed.

4） Slope Monitoring

Monitoring of crack widths on the retaining wall was conducted using a manual measuring device. Displacement/movement of the slope was measured using tiltmeters and inclinometers. The result of crack monitoring showed a tendency for crack expansions. The peeling off of the shotcrete surface and the continuing of the collapse can also be observed. The monitoring results based on the usage of tiltmeter and inclinometer showed significant accumulated displacements of the landslide.

5） Probability of Disaster Occurrence

The toppling failure of Landslide C has become evident. Displacements measured using monitoring devices (tiltmeter and inclinometer) were not confirmed during the dry season while expansion of cracks after rainfall was confirmed during the rainy season. If countermeasure works are not done, collapse would expand and traffic would terribly be affected.

6） Necessity of Countermeasure Works

It is therefore concluded that the slope has become unstable and countermeasures against the entire slope failure of Landslide C should be constructed immediately. Otherwise, shifting the road to the area of stable zone (outside of Landslide C) is needed. With regards to road shift, countermeasure works on the edge of shotcrete, where small collapses often occur during rainy season, are needed to ensure the stability of the entire landslide area. There were no cracks outside the upper zone of Landslide C. In addition, a space of around 5 m was allotted between Landslide C and the new road.

### (4) Sta. 17+400

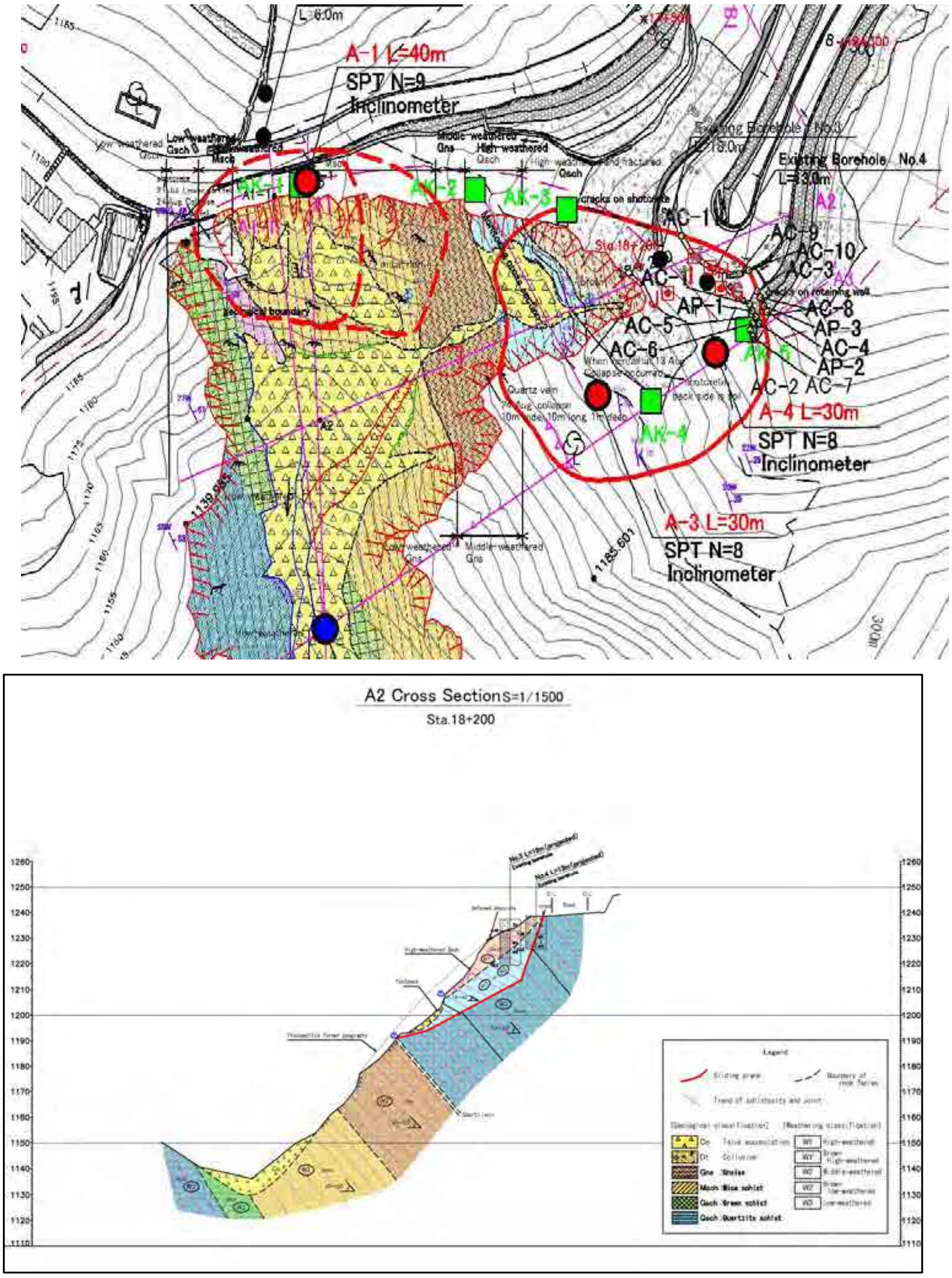
Countermeasure work is now under construction by DOR at this Landslide. The result of investigation before has been reviewed for reference.

1） Scale of Landslide

The scale of this Landslide is not enough considering the area of collapse zone, topography, and geological survey. Its dimensions are as follows: width - 70 m, length - 40 m, and depth - 8 m.

2） History of Disaster Occurrences

After the first failure in June 2003, subsequent failures occurred in July 2004 and August 2005 at the south-facing slope on narrow ridge where Sta. 17+400 of the road is located. The ridge width has narrowed from around 15 m due to these intermittent collapses. Moreover, the road shoulder is likely to be further damaged by future failures. Therefore, the road section was realigned to the west side (mountainside) in 2006. Small collapses occur every rainy season. The shotcrete and wall of the old road structure fell down completely during the rainy season of August 2010.




Source: JICA Study Team

**Figure 2.2.4 Geological Map and Section of Landslide C**

3） Failure Mechanism

Talus deposit with a maximum depth of 10 m is distributed in the lower part of the slope while weathered schist rocks are exposed in its upper part just below the road. Talus deposit was accumulated due to several past failures and surface denudation of highly weathered rocks of the upper part of the slope.

It was observed that: (a) continuous rainfall of approximately 300 mm was recorded every year; (b) when the hourly and continuous rainfalls exceeded 30 mm and 150 mm, respectively, collapses seem to occur; and (c) large-scale collapses occur only when continuous rainfall exceeded 500 mm.

4) Slope Monitoring

The monitoring of slope movement was conducted using two tiltmeters and one borehole inclinometer. Significant displacements were not clearly observed with the devices. However, surface failures have often occurred during rainy seasons. It is judged that the failure mechanism is an intermittent surface failure triggered by rainfall.

5) Probability of Disaster Occurrence

The expansion pace of the slope failure is considered to be sluggish and will not totally block the transportation system of the road in the immediate future. However, the failures will eventually reach the road in the future if no countermeasures are implemented.

6) Necessity of Countermeasure Works

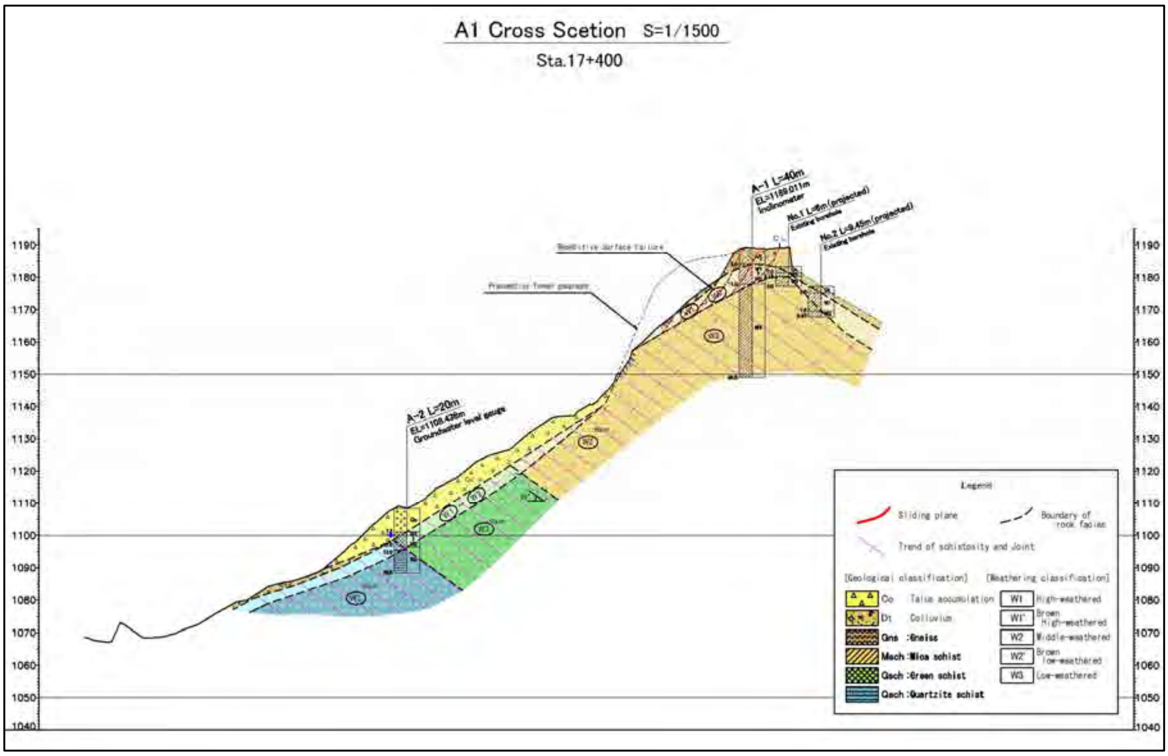
Countermeasures against slope failures are expected to be constructed in a step by step process in order not to damage the road in the future. The following countermeasures were considered:

Upper slope：retaining wall and gabion wall

Lower slope：check dam, drainage channel from road, and green method in collapsed area

Implementation of countermeasures is also preferable for the purpose of environmental improvement because the slope has been totally deforested and deserted, which has lessened its durability against erosions.

Check dam is constructed by DOR near the borehole A-2 site in 2011. Thus, erosion control is increased.




Source: JICA Study Team

**Figure 2.2.5 Geological Map and Section of Sta. 17+400**

### 2.2.1.3 CONCLUSION

**Table 2.2.1 Slope Failure Mechanism**

| Location | | Landslide A<br>Sta. 17+600 | Landslide B<br>Sta. 17+600 | Landslide C<br>Sta. 18+200 | Sta. 17+400 |
|---|---|---|---|---|---|
| Failure Mechanism | Topography | Scarp on head of catch basin | Creeping-deformed slope (flank is steep) | Toe of ridge | Col on narrow ridge |
| | Geology | Quartzite schist with dip joints | Quartzite schist with schistosity of opposite dip | Mica and quartzite schist with schistosity of opposite dip | Highly weathered mica schist/green schist /gneiss |
| | Disaster type | Planar failure and wedge failure /Deformation of the road embankment | Toppling failure | Toppling failure (including partial surface failures) | Intermissive surface collapse |
| History of the disaster that has occurred | | July 2009 | September 2007 | After November 2003 | Since June 2003<br>Shotcrete fell down<br>Aug 2010 |
| Result of Monitoring | Tiltmeter | Slightly significant accumulated displacement (Rank B～C) | Small accumulated displacement (Rank C～) | Significant accumulated displacement (Rank B) | No displacement |
| | Inclinometer | - | No significant displacement | Accumulated displacement | No displacement |
| | Crack | Tendency for a small expansion | - | Tendency for a significant expansion | - |
| Slope Stability | | Deformation of the road structure gives signs of destabilization. | Creep is in progress. The failure is likely to occur on the road part. | Expansion of failure and cracks due to rainfall are confirmed. | When it rains, small-scale surface collapses occur intermittently. |
| Predicted failure in the future | | It is difficult to predict the timing of the failure occurrence because accumulated rainfall of over 500 mm or earthquake can lead the sudden occurrence of failure. | Accumulated rainfall of over 500 mm or earthquake might lead the failure as large as that in September 2007 to occur. It is difficult to predict the timing of the occurrence of failure. | Cracks expanded about 10 mm/month during the rainy season. Therefore, the failure is expected to worsen within a few years. | If velocity of surface failures is 10 cm under one-year probable rainfall and 60 cm under a five-year probable rainfall, the failure will erode 6 m of the slope and damage the road shoulder in 30 years. |
| Impact on traffic | | The progress of deformation affects the road and its structure directly. The road would be closed for around two months. | In case the landslide occurrence forms scarps under the road, then the road would become unstable due to loosening. | The failure will Landslide the passage for around one month. | The impact on the road will not start in recent years. The progress of the surface collapse will cause the disaster which would Landslide the road for around one month in the future. |

Source: JICA Survey Team

## 2.2.2 SELECTION OF COUNTERMEASURES

### 2.2.2.1 CLASSIFICATION OF COUNTERMEASURES

The selection of countermeasures was conducted due to the results of review on Phase I and the geological surveys. Countermeasures against landslides include control works and restraint works. Control works involve modifications of natural conditions related to landslides, such as topography and groundwater, which indirectly control portions of landslide movements. Meanwhile, restraint works are the implementation of structures that mitigate landslide movement. Generally, these two countermeasures are combined. The classification of countermeasures are as shown in .

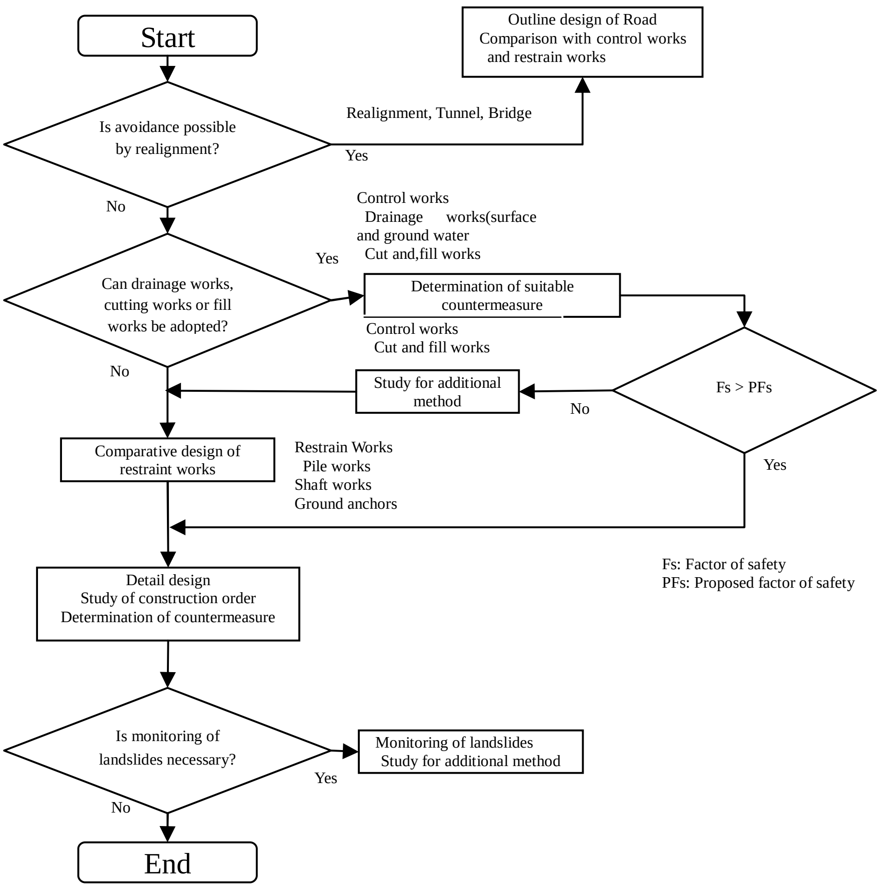
Restraint works cannot be implemented while landslides are occurring. Hence, control works are implemented first, and after landslides have stopped, restraint works will then be implemented.

Figure 2.2.6 shows the process of selecting countermeasures against landslides are selected.

**Table 2.2.2 Classification of Countermeasures Against Landslides**

| | |
|---|---|
| Control Works | |
| Surface water drainage works | Surface water drainage works are channel works constructed with corrugated wave tube and seepage water prevention works consisted by water proof sheets. |
| Shallow groundwater drainage works | Shallow groundwater drainage works are designed to pare down shallow groundwater. These are horizontal drainages, closed and opened conduit. |
| Deep groundwater drainage works | Deep groundwater drainage works are designed for the landslides which slip surface is deep. These are horizontal drainages, deep wells and the drainage tunnels. |
| Groundwater interception works | These works are intercept and drain groundwater out of landslide |
| Cut works | These works cut the upper half portion of landslide |
| Fill works | These works stabilize the landslide by filling the foot of the landslides with soil. |
| Erosion control works | These works prevent erosion at the end of landslides by constructing revetments, etc. |
| Restraint works | |
| Pile works | These works deter landslides by constructing piles that penetrate through the landslide mass. |
| Shaft works | These works deter landslides by concrete piles (shaft) in the ground. This method is adopted in cases where usual piles are difficult to apply. |
| Ground anchors | Ground anchors are intended to prevent landslides using high-tensile strength steel wires or bars installed across the slip surface. |

Source: JICA Survey Team




Source: JICA Survey Team based on Manual for slope prtection

**Figure 2.2.6 Selection of Landslide Countermeasure**

### 2.2.2.2 SELECTION OF COUNTERMEASURES

#### (1) Landslide A (Sta. 17+600)

Dimensions of the landslide: 50 m wide, 25 m long and 10 m deep

Initial factor of safety: Fso=1.00. Proposed factor of safety: PFs=1.20

The adaptabilities of countermeasure for Landslide A are carried out (refer to Table 2.2.3 ). The results of inquest suggest that only ground anchors are possible to be adapted for this site, because the geography is precarious. Also, bridge works are adapted to avoid landslides on roads.

**Table 2.2.3 List of the Adaptabilities of Countermeasure for Landslides A**

| Countermeasure | | Adaptabilities of Landslide A | Determination |
|---|---|---|---|
| Avoidance of landslide | | Realignment is impossible due to zigzag roads. Bridge can be constructed to avoid landslides but the roads must be closed for traffic due to bridge works. | OK with conditions |
| Control works | Surface-water drainage works | Roadside ditches have already been constructed. Shotcrete will be implemented on upper slopes to prevent stormwater infiltration. | OK |
| | Groundwater drainage works | These works are not effective because the slope is steep and large increase of groundwater levels cannot be confirmed. | NG |
| | Groundwater interception works | It is estimated that ground water supply from outside of the landslide is low. Shotcrete will be implemented on upper slopes to prevent stormwater infiltration. | NG |
| | Cutting works | These works cannot be constructed due to upper road. | NG |
| | Fill works | These works cannot be constructed due to the height of the slope under the road | NG |
| | Erosion control works | Exclusion | NG |
| Restraint works | Pile works | These works cannot be constructed due to steep slope. | NG |
| | Ground anchors | These works are adaptable for steep slope. | OK |

Source: JICA Survey Team

The approximate construction costs are as listed in Table 2.2.4. Also in the table are the unit prices that were collected in Phase I of the preparatory survey. Based on the costs, the design of ground anchors is less expensive than that of bridge.

**Table 2.2.4 List of the Approximate Construction Costs for Countermeasures for Landslide A**

Ground anchors design

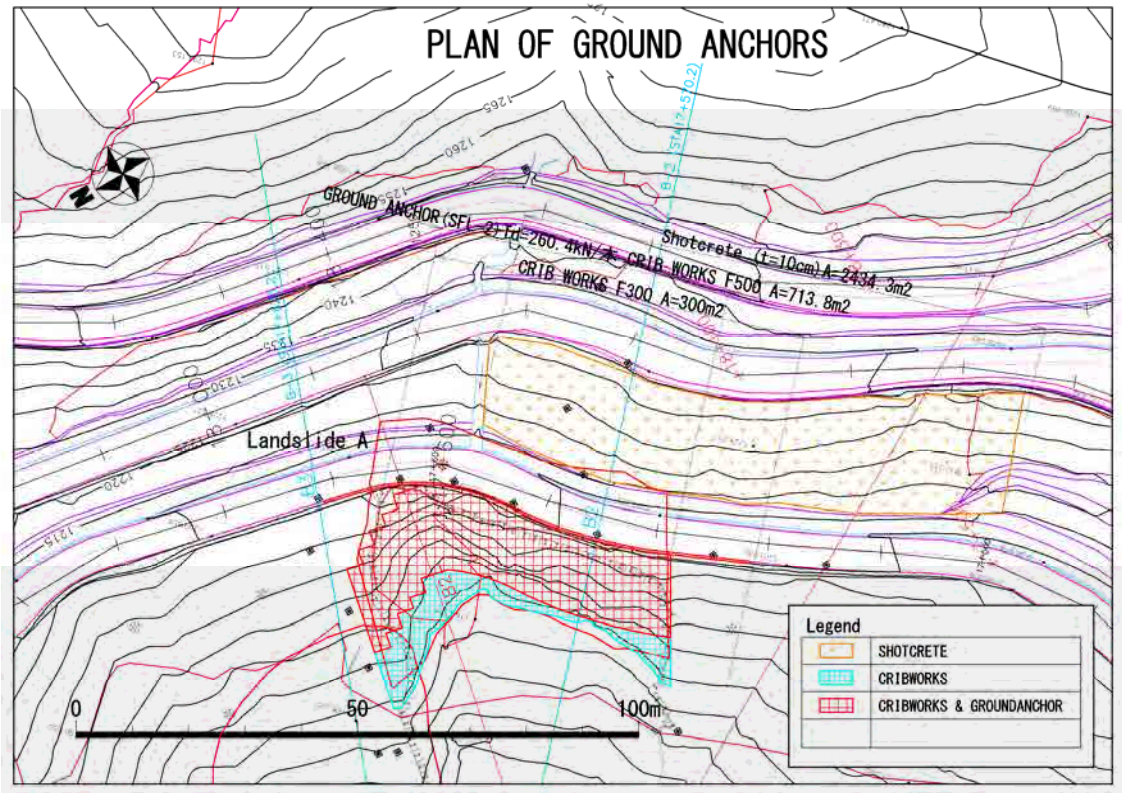
| Type | Standard | Quantity | Unit | U.P. | Direct cost(K yen) | Remarks |
|---|---|---|---|---|---|---|
| Ground anchors | SFL-2 Td=260.4KN/each | 1,600 | m | 21.8 | 34,870 | |
| Crib works | F500 equiv. | 713 | m2 | 27.9 | 19,900 | |
| Crib works | F300 | 300 | m2 | 20.0 | 6,000 | |
| shotocrete | t=10cm | 2,434 | m2 | 3.0 | 7,302 | |
| Temporary scaffold | | 8,340 | m3 | 1.5 | 12,510 | |
| | | | | | | |
| Total | | | | | 80,582 | |

Bridge design

| Type | Standard | Quantity | Unit | U.P. | Direct cost(K yen) | Remarks |
|---|---|---|---|---|---|---|
| Bridge works | Steel(L=60.0m) | 1 | set | 114,000 | 114,000 | |
| | | | | | | |
| Total | | | | | 114,000 | |

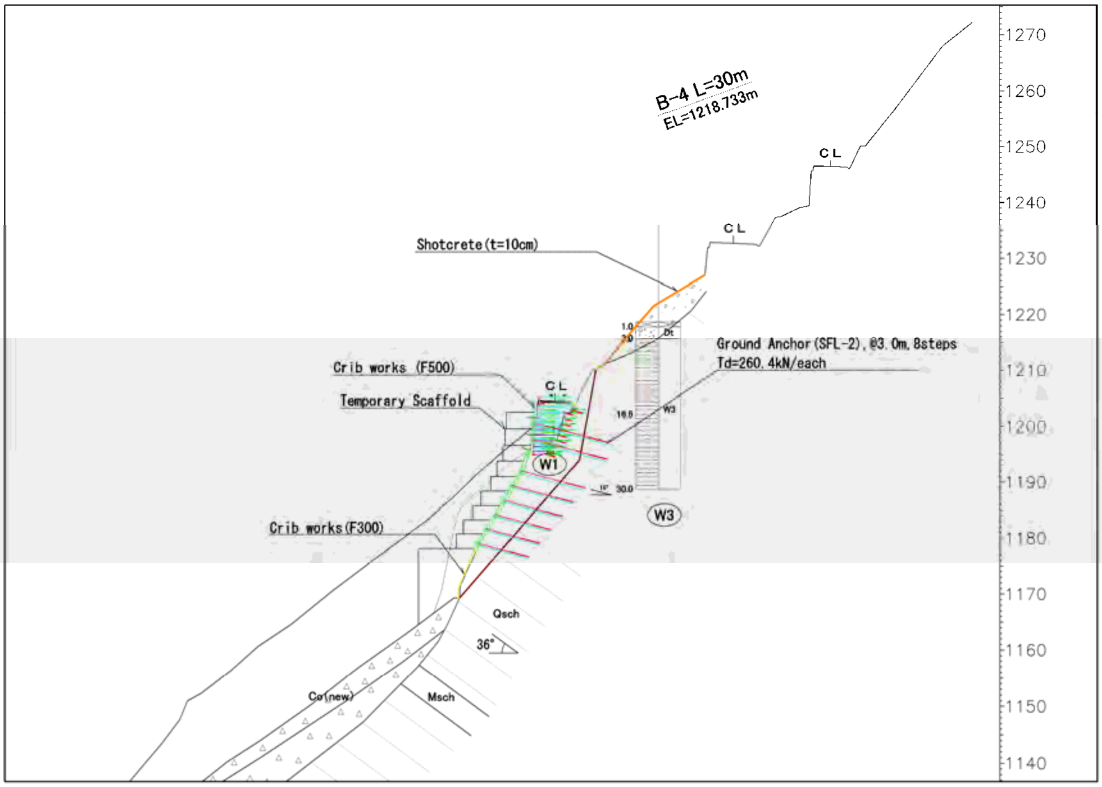
SFL: Super Flow; Td: Design load; F500:Cross section of crib works is 500 mm; F300: Cross section of crib works is 300 mm

Source: JICA Survey Team



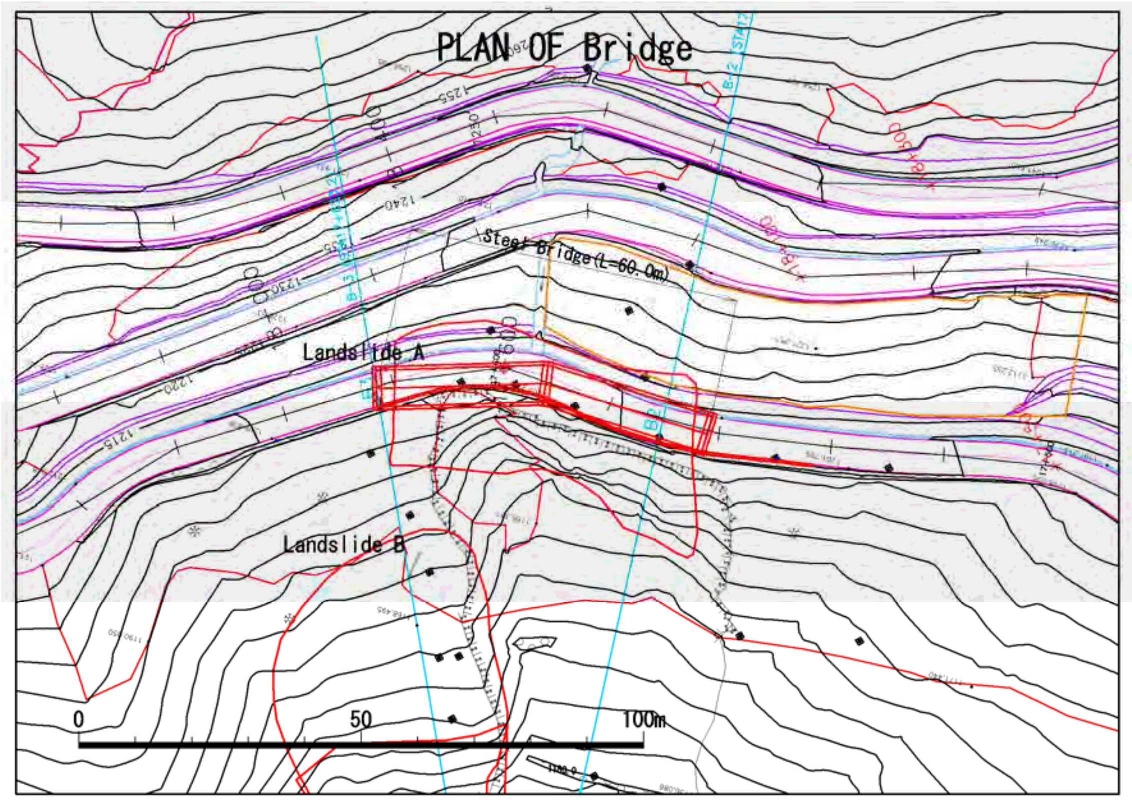

Source: JICA Survey Team

**Figure 2.2.7 Plan of Ground Anchor Design for Landslide A**



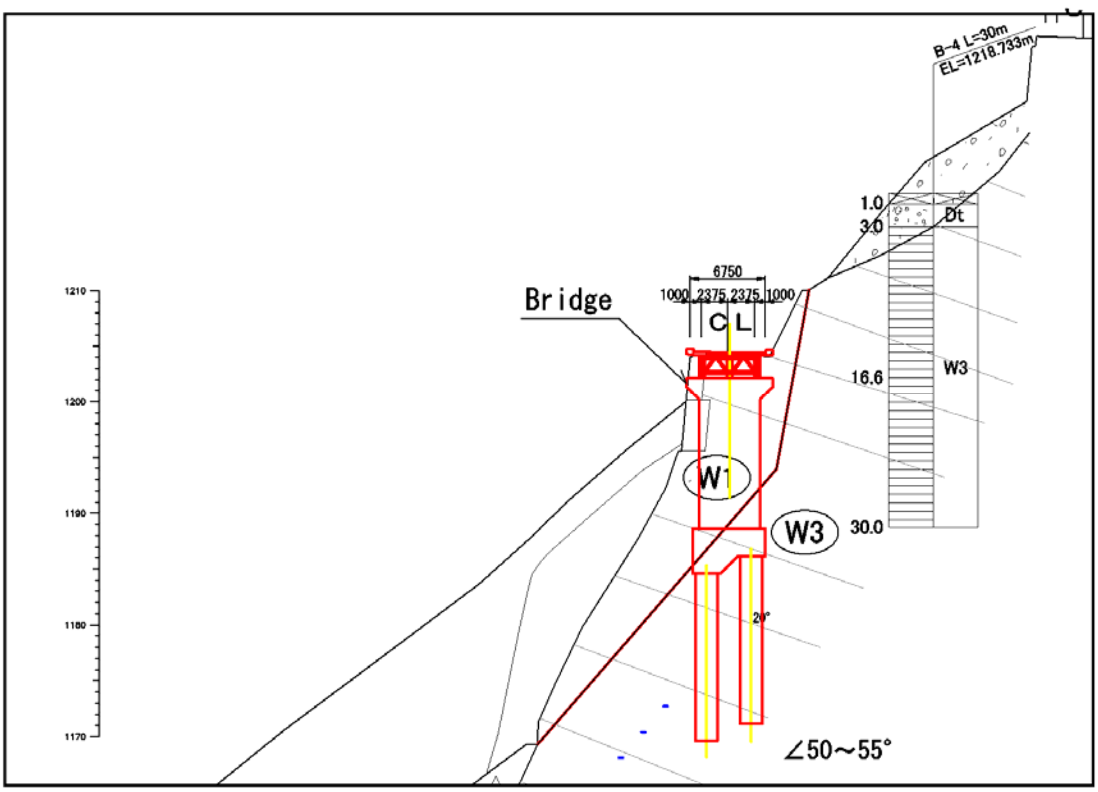

Source: JICA Survey Team

**Figure 2.2.8 Cross Section of Ground Anchor Design for Landslide A**




Source: JICA Survey Team

**Figure 2.2.9 Plan of Bridge Design for Landslide A**




Source: JICA Survey Team

**Figure 2.2.10 Cross Section of Bridge Design for Landslide A**

### (2) Landslide B (Sta. 17+600)

Dimension of landslides: 38 m wide, 83 m long and 19 m deep

Initial factor of safety: Fso=1.00. Proposed factor of safety: PFs=1.20

The analysis on the adaptabilities of countermeasures for Landslide B was carried out. The results of comparison show that ground anchors, pile works and fill works are possible to be adapted for this site, as shown in Table 2.2.5.

**Table 2.2.5 List of the Adaptabilities of Countermeasure for Landslides B**

| Countermeasure | | Adaptabilities of Landslide B | Determination |
|---|---|---|---|
| Avoidance of landslide | | Realignment is impossible due to upper road. | NG |
| Control works | Surface water drainage works | Roadside ditches have already been constructed, so inflow of surface water to this slope is low. | NG |
| | Groundwater drainage works | The landslide mass is very loose and water permeability is high. It is estimated that groundwater level to lower soon after rain and the nurture of groundwater on landslide movement is low. | NG |
| | Groundwater interception works | It is estimated that groundwater supply from outside of the landslide is low. Shotcrete will be implemented on upper slopes to prevent stormwater infiltration. | NG |
| | Cut works | These works cannot be constructed due to upper road. | NG |
| | Fill works | These works are adaptable for this landslide. | OK |
| | Erosion control works | Exclusion | NG |
| Restrain works | Pile works | These works are adaptable for this landslide. | OK |
| | Ground anchors | These works are adaptable for steep slope. | OK |

Source: JICA Survey Team

The construction costs of the three countermeasures for Landslide B are as shown in Table 2.2.6, Among the three countermeasures, the design of fill works has the least cost. Meanwhile, if pile works and ground anchors are adopted, soil disposal cost of Landslide C arises, therefore such cost is allocated for.

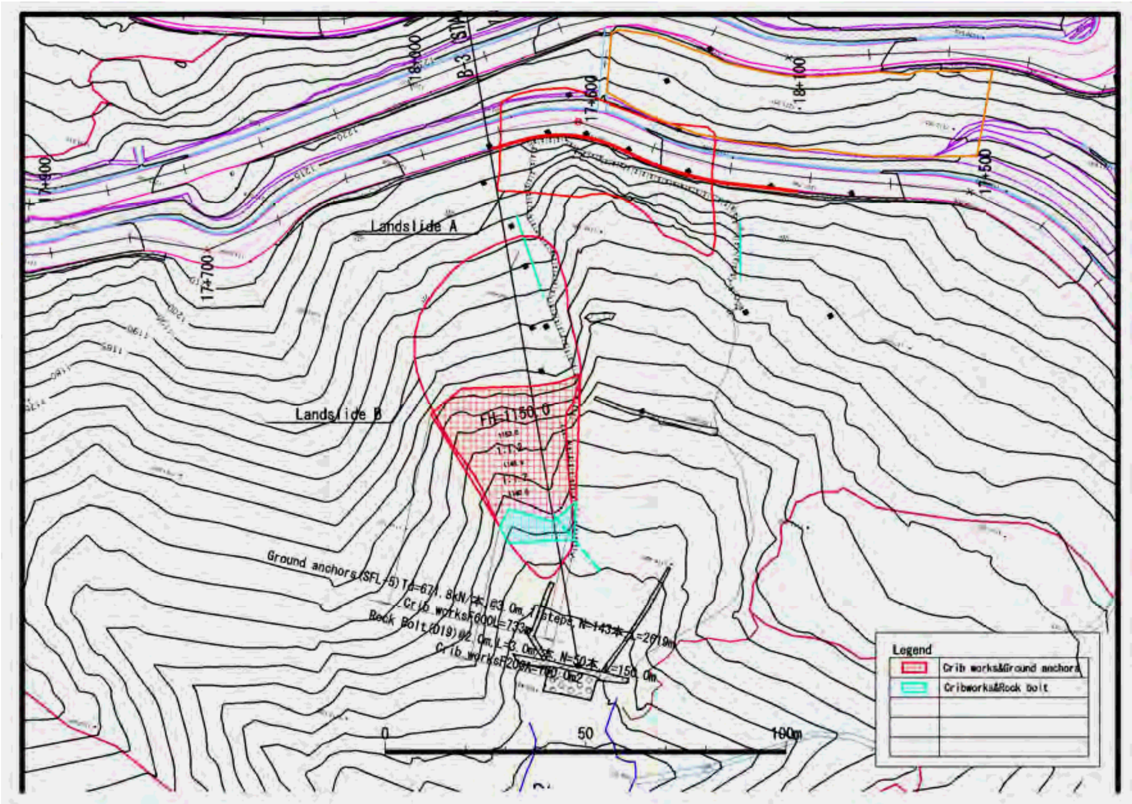
**Table 2.2.6 List of the Approximate Construction Costs for Countermeasures for Landslide B**

| Ground anchors design | | | | | | |
|---|---|---|---|---|---|---|
| Type | Standard | Quantity | Unit | U.P. | Direct cost(K yen) | Remarks |
| Ground anchors | SFL-5@3m 11Steps | 2,550 | m | 23.9 | 60,846 | |
| Crib works | F600 equiv | 714 | m | 21.0 | 15,002 | |
| Temporary scaffold | | 2,850 | m3 | 1.5 | 4,275 | |
| Crib works | F300 @2m | 100 | m2 | 20.0 | 2,000 | |
| Rock bolts | L=3m @2m | 150 | m | 18.0 | 2,700 | |
| Temporary road | | 1 | Set | 5,500.0 | 5,500 | Reference to phase 1 report |
| Soil disposal | Transport distance 20km | 74,000 | m3 | 2.1 | 155,400 | C block |
| Toal | | | | | 245,723 | |

| Pile works design | | | | | | |
|---|---|---|---|---|---|---|
| Type | Standard | Quantity | Unit | U.P. | Direct cost(K yen) | Remarks |
| Pile works | SKK570 φ550t16@1.5m L=23m | 552 | m | 48.1 | 26,568 | |
| Crib works | F300 | 2,052 | m2 | 20.0 | 41,040 | |
| Rock bolts | L-3.0m @2m2 | 3,078 | m | 18.0 | 55,404 | |
| Temporary works | | 1 | set | 20,282.4 | 20,282 | 30 % of total direct cost |
| Temporary road | | 1 | set | 5,500.0 | 5,500 | Reference to phase 1 report |
| Soil disposal | Transport distance 20km | 74,000 | m3 | 2.1 | 155,400 | C block |
| 合計 | | | | | 304,194 | |

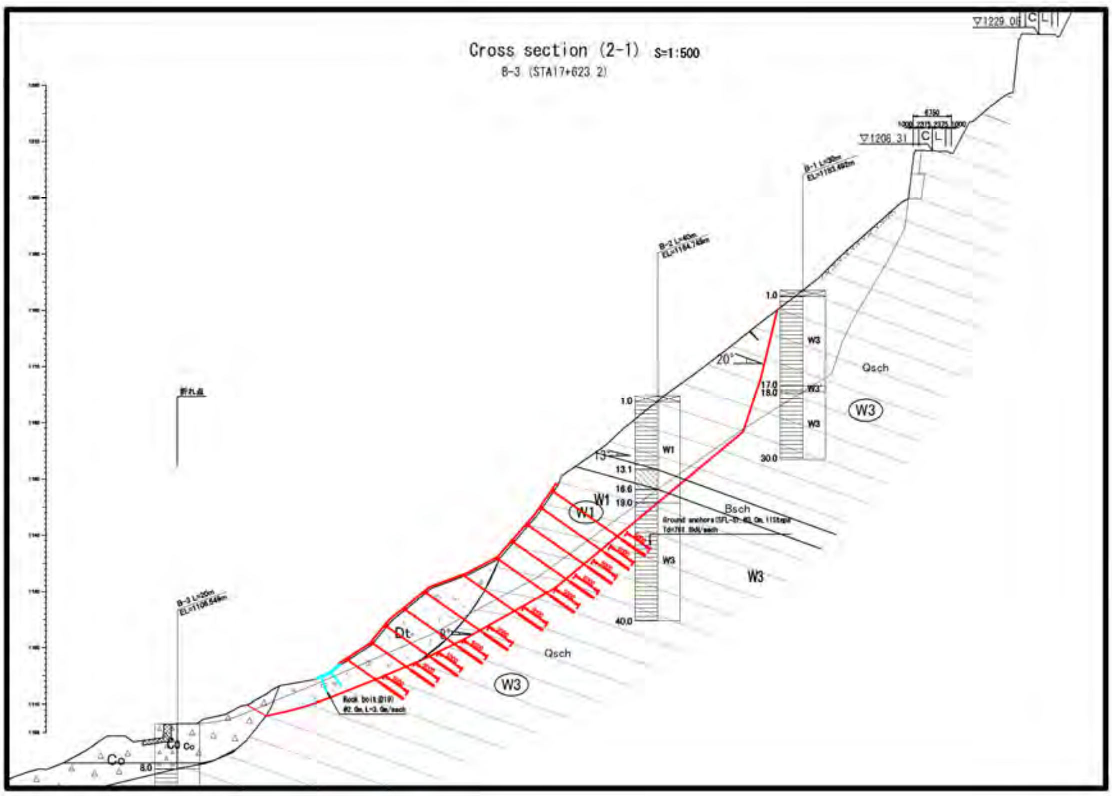
| Fill works design | | | | | | |
|---|---|---|---|---|---|---|
| Type | Standard | Quantity | Unit | U.P. | Direct cost(K yen) | Remarks |
| Fill works | | 80,000 | m3 | 1.1 | 88,000 | *1 |
| Closed conduit | | 266 | m | 25.0 | 6,650 | |
| Vegetation | | 7,800 | m2 | 0.6 | 4,680 | |
| Open ditch | | 361 | m | 3.2 | 1,155 | |
| Temporary road | | 1 | set | 5,500.0 | 5,500 | Reference to phase 1 report |
| 合計 | | | | | 105,985 | |
| | *1 Transport distance 2km Spreading,Surfacecompaction | | | | | |

Source: JICA Survey Team



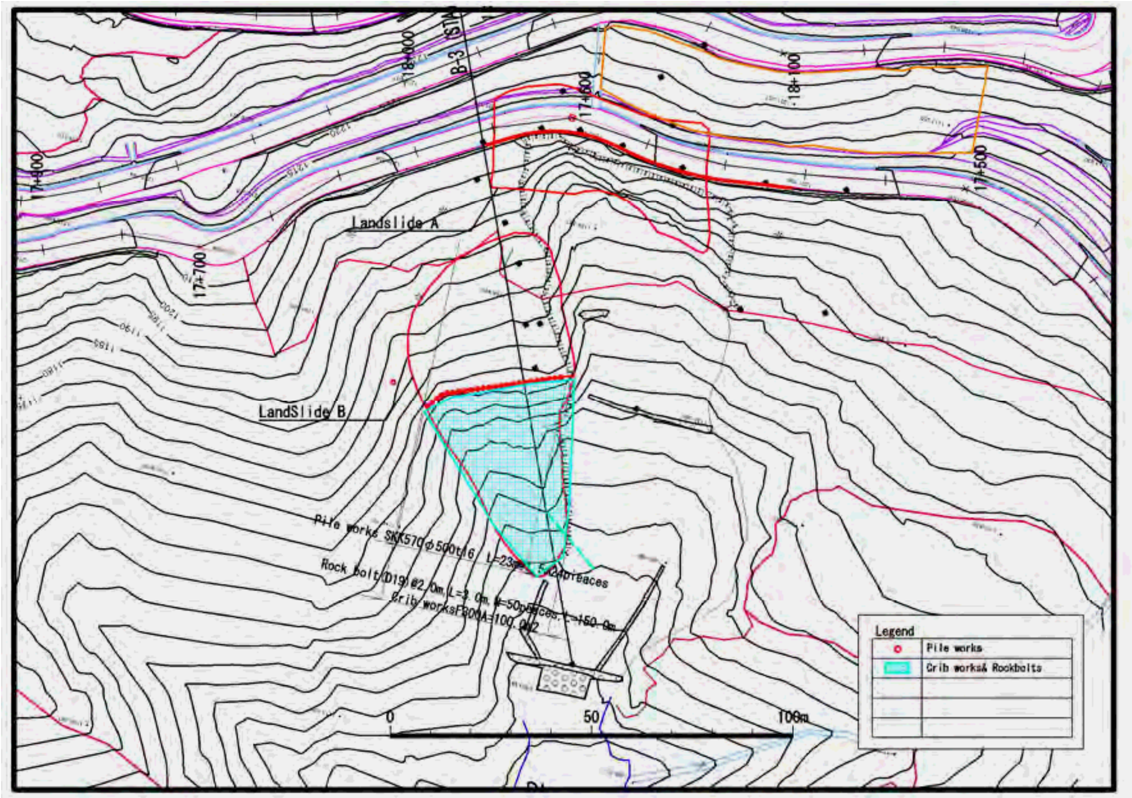
Source: JICA Survey Team

**Figure 2.2.11 Plan of Ground Anchor Design for Landslide B**



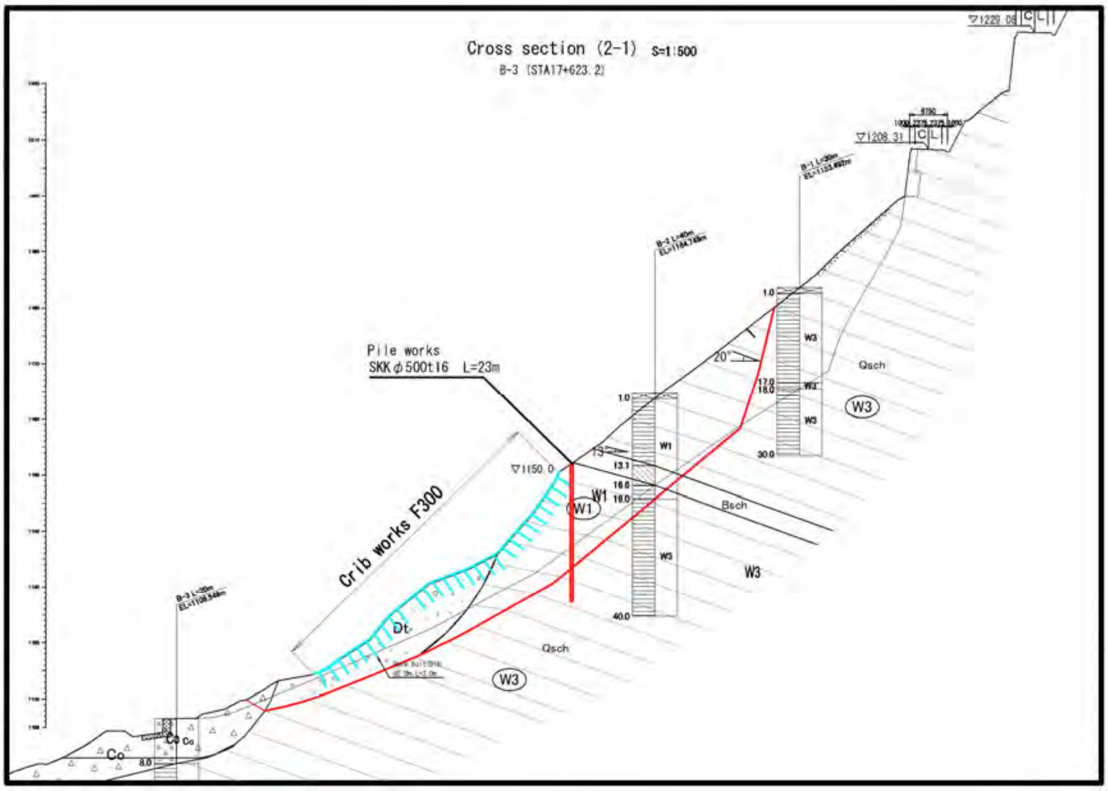
Source: JICA Survey Team

**Figure 2.2.12 Cross Section of Ground Anchor Design for Landslide B**



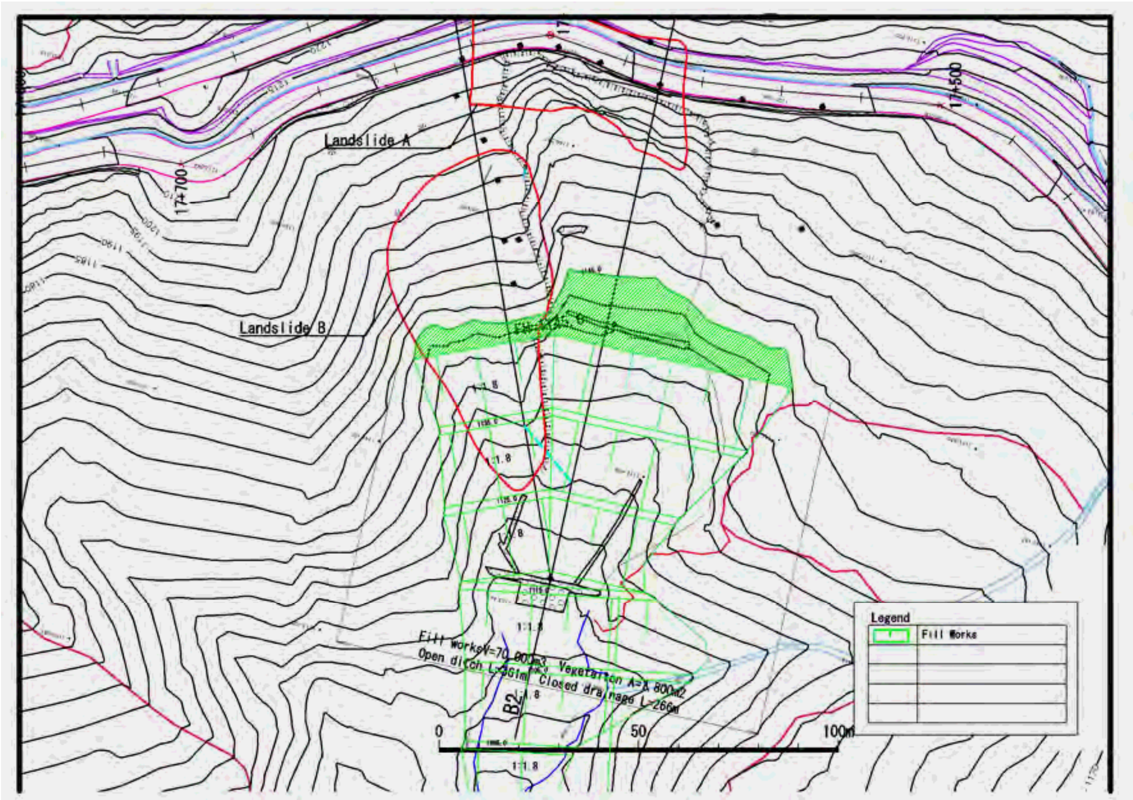

Source: JICA Survey Team

**Figure 2.2.13 Plan of Pile Works Design for Landslide B**



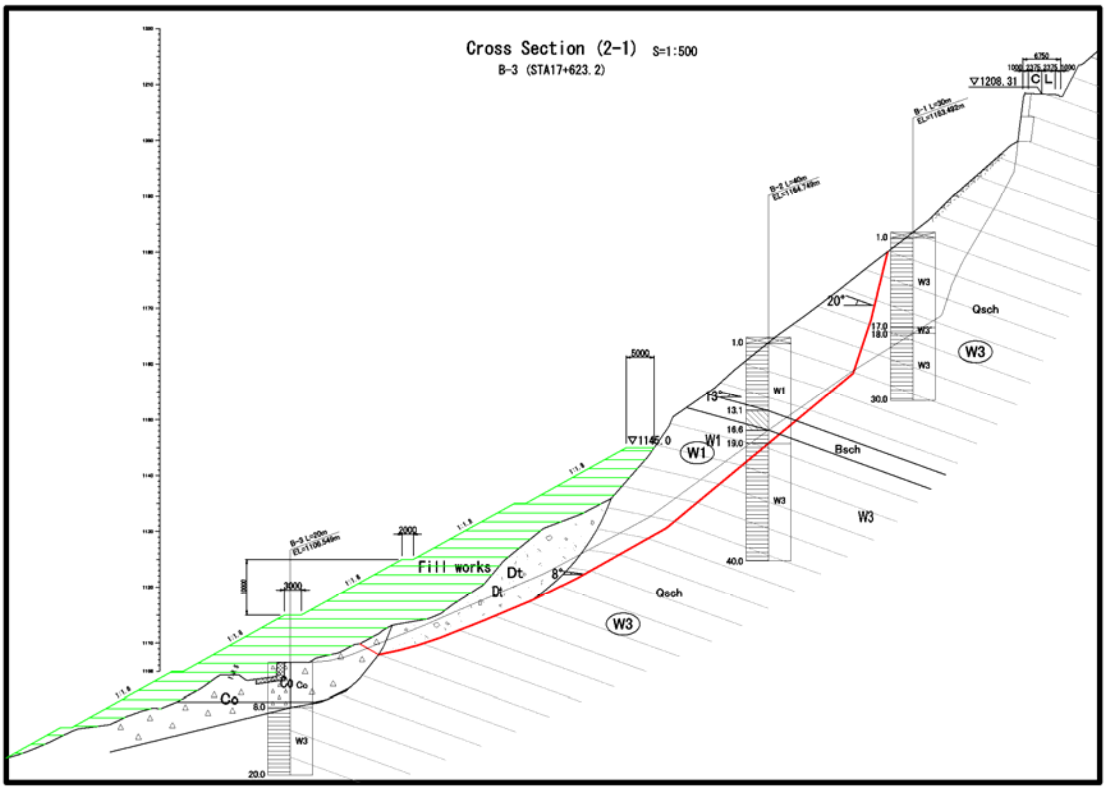

Source: JICA Survey Team

**Figure 2.2.14 Cross Section of Pile Works Design for Landslide B**




Source: JICA Survey Team

**Figure 2.2.15 Plan of Embankment Design for Landslide B**




Source: JICA Survey Team

**Figure 2.2.16 Cross Section of Embankment Design for Landslide B**

### (3) Landslide C (Sta. 18+200)

Dimensions of landslide: 70 m wide, 70 m long and 20 m deep

Initial factor of safety: Fso=0.95. Proposed factor of safety: PFs=1.20

The analysis on the adaptability of countermeasures for Landslide C was carried out. The results of comparison show that avoidance and ground anchors are possible to be adapted for this site, as shown Table 2.2.7.

**Table 2.2.7 List of the Adaptabilities of Countermeasure for Landslide C**

| Countermeasure | | Adaptabilities of landslide C | Determination |
|---|---|---|---|
| Avoidance from landslide | | Road realignment to the mountainous side is possible. | OK |
| Control works | Surface water drainage works | This works can't be constructed due to steep slope | NG |
| | Groundwater drainage works | The landslide mass is very loose and water permeability is high. So it is estimated that groundwater level will lower soon after rain and the nurture of groundwater for landslide movement is low. | NG |
| | Groundwater interception works | It is estimated that groundwater supply outside of the landslide is low. Shotcrete will be implemented on upper slopes to prevent of stormwater infiltration. | NG |
| | Cut works | These works cannot be constructed, because land designed to achieve the proposed factor of safety will be excavated from the existing road. | NG |
| | Fill works | These works cannot be constructed as there is no space available for fill works. | NG |
| | Erosion control works | Erosion control works of Sta. 17+400 implemented by GON are effective for this site. | NG |
| Restrain works | Pile works | These works cannot be constructed due to steep slopes | NG |
| | Ground anchors | These works are adaptable for steep slopes. However, landslides keep on occurring, therefore, landslide must first be stopped by fill works. But designed land form that complete proposed factor of safety (Frs=1.05) excavate existing road. | with conditions |

Source: JICA Survey Team

If ground anchors are adopted, land designed to achieve the PFs will be excavated from the existing road. In order to ensure the road alignment, deep excavation is necessary. Therefore, road realignment is suitable for this site to avoid landslides. If erosion at Sta.18+200 continues, road realignment is also appropriate. A high intensity net is required for erosion control.

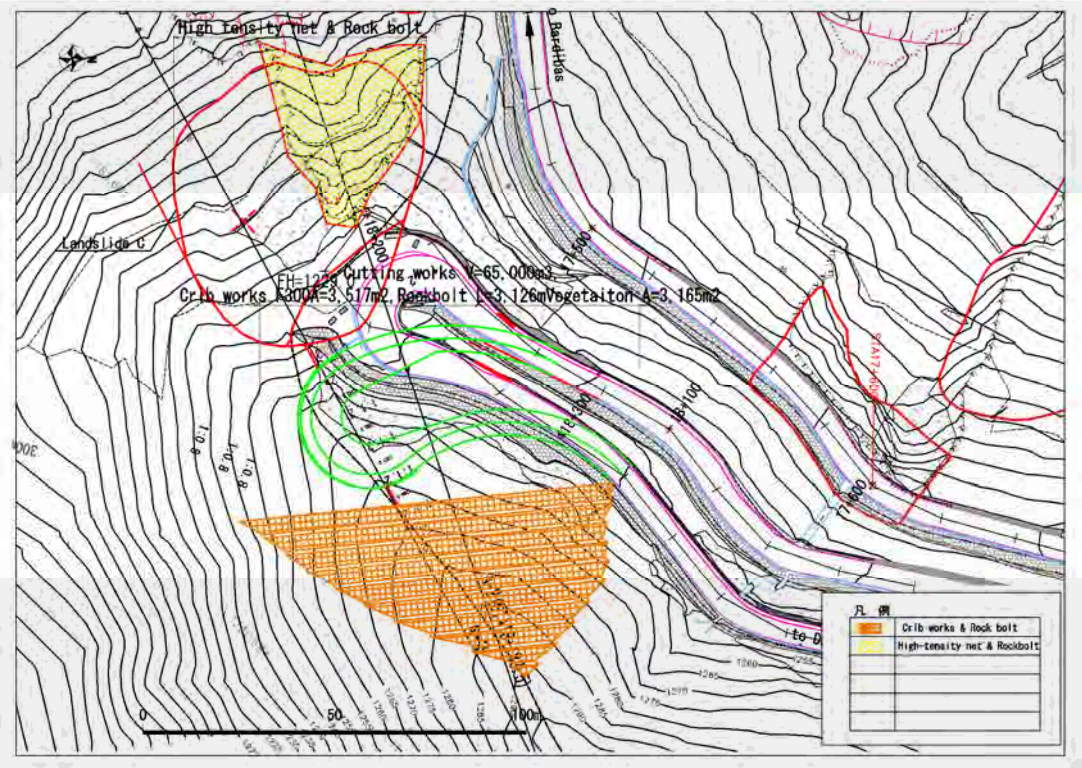
The approximate construction costs are as shown in Table 2.2.8.

**Table 2.2.8 List of the Approximate Construction Costs for Countermeasures for Landslide C**

Avoidance design

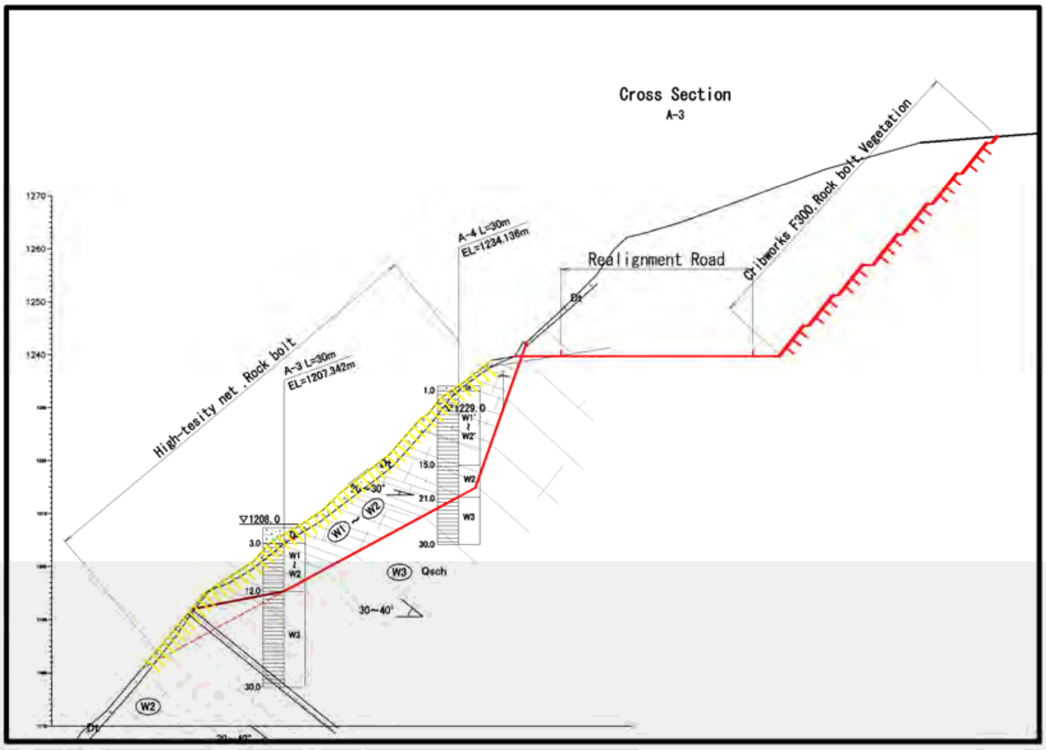
| Type | Standard | Quantity | Unit | U.P. | Direct cost(K yen) | Remarks |
|---|---|---|---|---|---|---|
| Cutting works | Soft rock | 70,000 | m3 | 0.7 | 49,000 | |
| Rock bolt | @1.5m L=2m | 3,126 | m | 18.0 | 56,272 | |
| Crib works | F300 | 3,517 | m2 | 20.0 | 70,340 | |
| Vegetation | | 3,165 | m | 0.5 | 1,583 | |
| Hihg-tensity net | | 5,329 | m2 | 23.0 | 122,567 | |
| Ancillary works | | 1 | Set | 12,000 | 12,000 | Reference to phase 1 report |
| sub total | | | | | 311,762 | |
| Soil deposit | transport distance20km | 74,000 | m3 | 2.1 | 155,400 | *1 |
| Total | | | | | 467,162 | |
| | *1 Transport distance is 20km(Transport&Spreading&Surface conpaction) | | | | | |

Source: JICA Survey Team




Source: JICA Survey Team

**Figure 2.2.17 Plan of Realignment Design for Landslide C**




Source: JICA Survey Team

**Figure 2.2.18 Cross Section of Realignment Design for Landslide C**

## (4) Layout of Countermeasures

The overall plan for countermeasures is as shown in Figure 2.2.19.

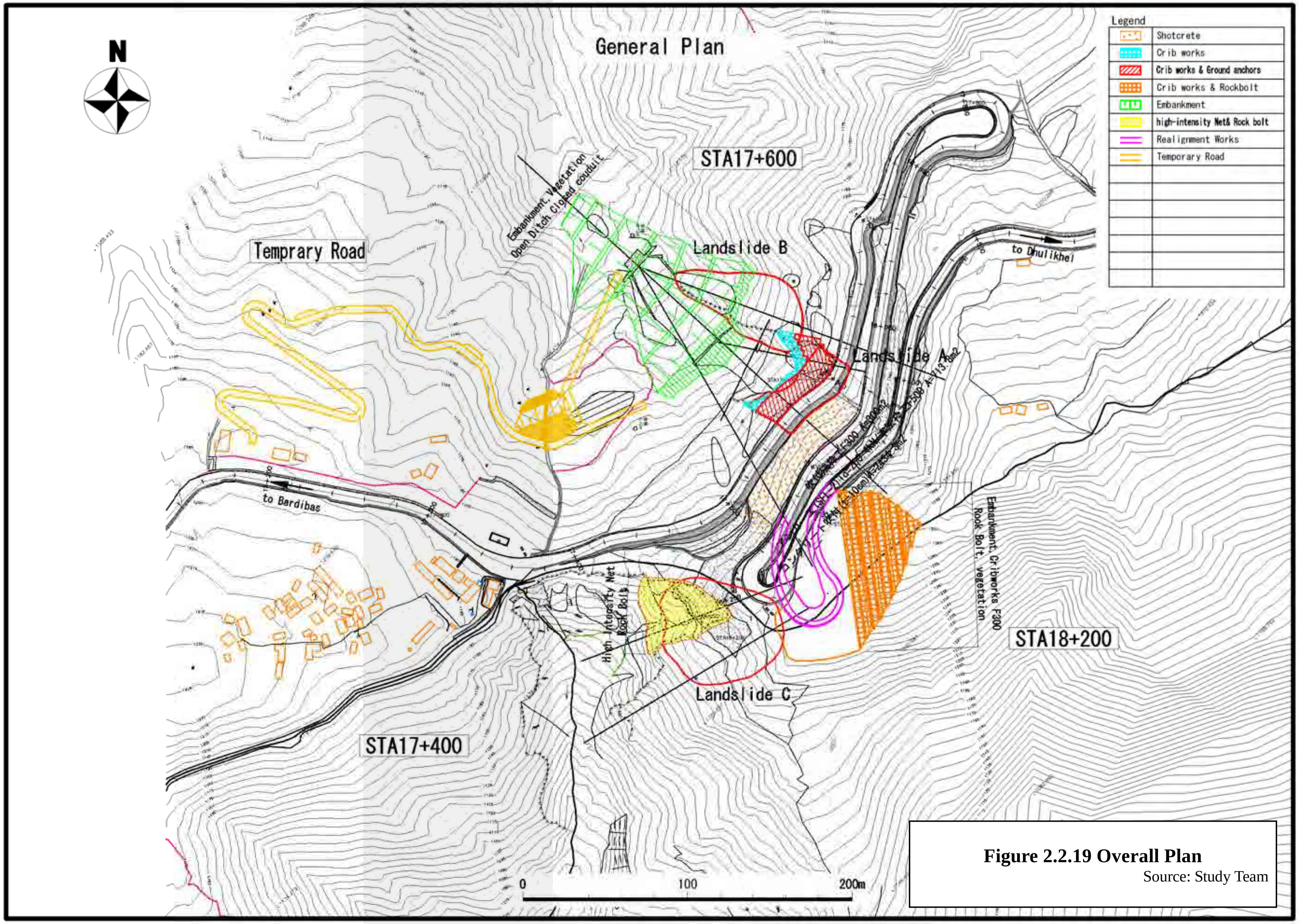



**Figure 2.2.19 Overall Plan**

Source: Study Team

### 2.2.3 OUTLINE DESIGN OF THE COUNTERMEASURE

#### 2.2.3.1 STA.17+600 (LANDSLIDE A)

**(1) Result of Stability Analysis**

The condition of stability analysis for Landslide A is as shown in Table 2.2.9.

**Table 2.2.9 Condition of Stability Analysis for Landslide A**

| Condition of Stability Analysis | Value Adopted |
|---|---|
| Initial factor of safety | Fso=1.00 |
| Proposed factor of safety | PFs=1.20 |
| Required preventive force to be provided | 953.4 kN/m$^2$ |

Source: Study Team

**(2) Ground Anchors**

The condition of ground anchors design is as shown in Table 2.2.10.

**Table 2.2.10 Conditions for Ground Anchors Design**

| Condition | Value Adopted | Standard |
|---|---|---|
| Calculus equation | Refer to below | Manual for Slope Protection, JRA*1 |
| Anchor function | Clamping effect and Straining effect | Manual for Slope Protection, JRA*1 |
| Skin frictional Resistance of anchor | 1.5 kN/mm$^2$ | Manual for Slope Protection, JRA*1 |
| Design strength of Grout | 24 kN | Manual for Slope Protection, JRA*1 |
| Allowable adhesive stresses | Prestressing Steel wire 0.8<br>Deformed prestressing steel bar 1.6 | Manual for Slope Protection, JRA*1 |
| Soil bearing capacity | 100 kN/m$^2$ | Manual for Retaining Wall, JRA*1 |

Source: Study Team *1 Japan Road Association

**(3) Calculus Equation**

The calculus equation of stability analysis adopted in accordance with the Manual for Slope Protection of JRA is as follows:

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

Where, Fs= Initial factor of safety

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

φ (°) = Internal friction angle of sliding surface

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

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

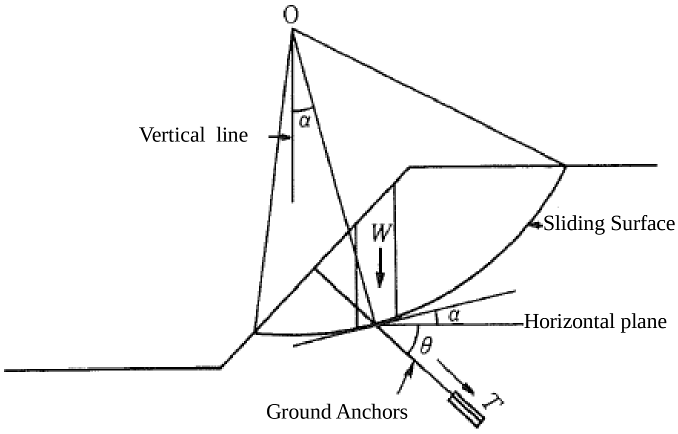
b (m) =Width of the slice (m)

W (kN/m) =Weight of the slice

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

Source: Manual for Slope Protection, Japan Road Association

Figure 2.2.20 shows the diagram for the calculus equation.




Source: Manual for Slope Protection, Japan Road Association

**Figure 2.2.20 Calculus Method of Ground Anchors**

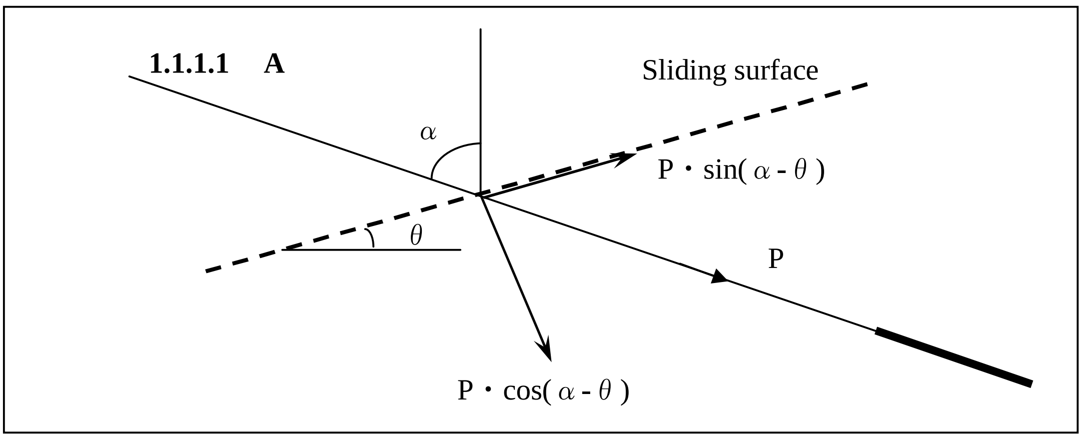
### (4) Anchor Functions

Anchors are installed to achieve the following two objectives (see Figure 2.2.21):

- Increase the resistance against shear force by applying stress normal to the sliding surface. Clamping effect = Tsin( $\alpha + \theta$ )

- Decrease the sliding force of landslide using steel members as anchors. Straining effect = Tcos( $\alpha + \theta$ )

Figure 2.2.21 shows a diagram of the forces applied by the anchors.




Source: Manual for Slope Protection, Japan Road Association

**Figure 2.2.21 Functional Description of an Anchor**

### (5) Skin Frictional Resistance of Anchors

Skin frictional resistance of anchors is determined in accordance with Table 2.2.11. The conditions of the friction zone are checked through a photograph taken during construction of Section II. The geology of the friction zone is hard rock, so a minimum value of 1.5 is adopted.

**Table 2.2.11 Recommended Skin Frictional Resistance of Anchors**

| Type of Ground | | Frictional Resistance ($MN/m^2$) |
|---|---|---|
| Bedrock | Hard rock | 1.5 to 2.5 |
| | Soft rock | 1.0 to 1.5 |
| | Weathered rock | 0.6 to 1.0 |
| | Mudstone | 0.6 to 1.2 |

| | | | |
|---|---|---|---|
| Sand and gravel | N value | 10 | 0.10 to 0.2 |
| | | 20 | 0.17 to 0.25 |
| | | 30 | 0.25 to 0.35 |
| | | 40 | 0.35 to 0.45 |
| | | 50 | 0.45 to 0.70 |
| Sand | N value | 10 | 0.10 to 0.14 |
| | | 20 | 0.18 to 0.22 |
| | | 30 | 0.23 to 0.27 |
| | | 40 | 0.29 to 0.35 |
| | | 50 | 0.30 to0. 40 |
| Cohesive soil | Representative Cohesion C | | 1.0C |

Source: Modification from Standard for Design and Construction of Anchor Works, Japanese Geotechnical Society

### (6) Allowable Adhesive Stresses

Allowable adhesive stresses are determined in accordance with Table 2.2.12. The design strength of grout is 24 kN/m$^2$, therefore, 0.8 is adopted for prestressed steel wires and 1.6 is adopted for deformed prestressed steel bars.

**Table 2.2.12 Recommended Allowable Adhesive Stresses**

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

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

Source: Modification from Standard for Design and Construction of Anchor Works, Japanese Geotechnical Society

### (7) Soil Bearing Capacity

Soil bearing capacity is determined in accordance with the values shown in Table 2.2.13. There are existing structures such as reinforced embankments and gabions in the target area. Ground anchors should only support weak stress. Therefore, 100 kN/m$^2$ is adopted for soil bearing capacity as a safety precaution.

**Table 2.2.13 Allowable Bearing Capacity**

| | | Allowable Bearing Capacity qa(kN/m2(tf/m$^2$)) | Remarks N value |
|---|---|---|---|
| Rock | -Hard rock<br>-Hard rock with many cracks<br>Soft rock and | 1000 (100)<br>600 (60)<br>300 (30) | - |
| Gravel layer | -Constant<br>-Noncontact | 600 (60)<br>300 (30) | - |
| Sandy ground | -Constant<br>-Medium constant | 300 (30)<br>200 (20) | 30-50<br>20-30 |
| Clay ground | -Very stiff<br>-Stiff | 200 (20)<br>100 (10) | 15-30<br>10-15 |

Source: Manual for Retaining Wall, Japan Road Association

### (8) Bearing Plate

Bearing plate is selected in accordance with Table 2.2.14. The construction conditions of ground anchors in the Project are listed below. It is clear that 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 2.2.14 Selection of Bearing Plate**

| Kind of Plate \ Condition | | 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: Study Team based on Manual for Ground Anchors ,NEXCO

### 2.2.3.2 STA.17+600 (LANDSLIDE B )

The most appropriate embankment design for countermeasures against landslide B is carried out.

#### (1) Embankment structure

1） Soil volume

The cut volume in Sta. 18+200 is 7.6 million $m^3$. Embankment volume is obtained by multiplying the cutting volume of 7.6 million $m^3$ with the bulking factor of soil (C). The bulking factor of soil is adopted as shown Table 2.2.15 in consideration of the points below. The calculated embankment volume is 7.6 million $m^3$ as shown Table 2.2.15.

a) Bulking factor of soil is changed by material classification and construction method.
b) In the Project, the embankment material is uniformly blended with gravel soil, soft rock and hard rock at the borrow pit. Therefore, the bulking factors of soft rock and hard rock are smaller than the values shown Table 2.2.16.
c) If the bulking factor of soil is large and the embankment swells, an adjustment of 0.6 million $m^3$ volume is possible at the crest of embankment. Conversely, if the bulking factor of soil is small and the embankment cowers, additional embankment material is necessary to stabilize landslides.
d) It is suggested that the change of embankment volume is less than 0.6 million $m^3$ in consideration of the total embankment.

**Table 2.2.15 Embankment Volume**

| Material Classification | Excavation | | Bulking Factor of Soil (c) | Embankment $m^3$ |
|---|---|---|---|---|
| | Ratio | Quantity Cu.m | | |
| Gravel Soil | 36% | 27,000 | 0.90*1 | 24,000 |
| Soft Rock | 51% | 39,000 | 1.05*2 | 41,000 |
| Hard Rock | 13% | 10,000 | 1.05*3 | 11,000 |
| Total | 100% | 76,000 | | 76,000 |

*1：The ratio of gravel, sand, silt and clay, which particle-sizes are below 0.075 mm, is unclear. Therefore, 0.9 is adopted in accordance with Table 2.2.17. Generally, 0.9 is adopted as bulking factor for soil material.
*2：Embankment material is composed of mixed gravel and soft rock in borrow pit to create a uniformly-sized material. Moreover, a bulking factor of 1.05 is adopted for soft rock as shown Table 2.2.17. The 1.05 bulking factor is the sum of the added minimum value (1.00) and 0.05.
*3：A bulking factor of 1.05 is adopted for hard rock because this material is a combination of gravel soils and soft rocks.
Source: Manual for Quantity Survey for Civil Engineering Work

**Table 2.2.16 Bulking Factor**

| Name | | L | C |
|---|---|---|---|
| Rock or stone | Hard rock | 1.65~2.00 | 1.30~1.50 |
| | Middle rock | 1.50~1.70 | 1.20~1.40 |
| | Soft rock | 1.30~1.70 | 1.00~1.30 |
| | Mass of rock, ball | 1.10~1.20 | 0.95~1.05 |
| Gravel soil | Gravel | 1.10~1.20 | 0.85~1.05 |
| | Gravel Soil | 1.25~1.40 | 1.10~1.30 |
| Sand | Sand | 1.10~1.20 | 0.85~0.95 |
| | Sand with rock or stone | 1.15~1.20 | 0.90~1.00 |
| Fine soil | Fine soil | 1.20~1.30 | 0.85~0.95 |
| | Fine soil with rock or stone | 1.40~1.45 | 0.90~1.00 |
| Cohesive soil | Cohesive soil | 1.20~1.45 | 0.85~0..95 |
| | Cohesive soil with gravel | 1.30~1.40 | 0.90~1.00 |
| | Cohesive soil with rock or stone | 1.40~1.45 | 0.90~1.00 |

L= Volume of the loosened soil after excavation/ Volume of natural ground before excavation
C= Volume of compacted soil / Volume of natural ground before excavation
Source: Manual for Slope Protection, Japan Road Association

**Table 2.2.17 Bulking Factor (1)**

| Classification | | | Bulking Factor | |
|---|---|---|---|---|
| Soil Name | | Algebraic Sign | L | C |
| Gravel Soil | Gravel | (GW) (GP) (GPs) (G-M) (G-C) | 1.20 | 0.95 |
| | Gravel soil | (GM) (GC) (GO) | 1.20 | 0.90 |
| Sand and fine soil | Sand | (SW) (SP) (SPu) (S-M) (S-C) (S-V) | 1.20 | 0.95 |
| | Fine soil | (SM) (SC) (SV) | 1.20 | 0.90 |
| Cohesive soil | Cohesive soil | (ML) (CL) (OL) | 1.30 | 0.90 |
| | Cohesive soil with high water content | (MH) (CH) | 1.25 | 0.90 |
| Mass of rock, ball | | | 1.20 | 1.00 |
| Soft rock I | | | 1.30 | 1.15 |
| Soft rock II | | | 1.5 | 1.20 |
| Middle rock | | | 1.60 | 1.25 |
| Hard rock | | | 1.65 | 1.40 |

Source: Manual for Quantity Survey for Civil Engineering Work

**Table 2.2.17 Bulking Factor (2)**

| Classification | Bulking Factor | |
|---|---|---|
| | L | C |
| Gravel soil | 1.20 | 0.90 |
| Sand and fine soil | 1.20 | 0.90 |
| Cohesive soil | 1.20 | 0.90 |

Source: Manual for Quantity Survey for Civil Engineering Work

2） Slope Gradient and Step Width

As shown Table 2.2.18, the adopted slope gradient is 1:1.8, the step width is 2 m, and the step interval is 10 m.

**Table 2.2.18 Slope Gradient and Step Width**

| Items | Condition |
|---|---|
| Slope gradient | 1:1.8 |
| Step width | 2 m |
| Step interval | 10 m |

Source: Manual for Roads Design Vol.I: Earth Work, Nippon Expressway Company

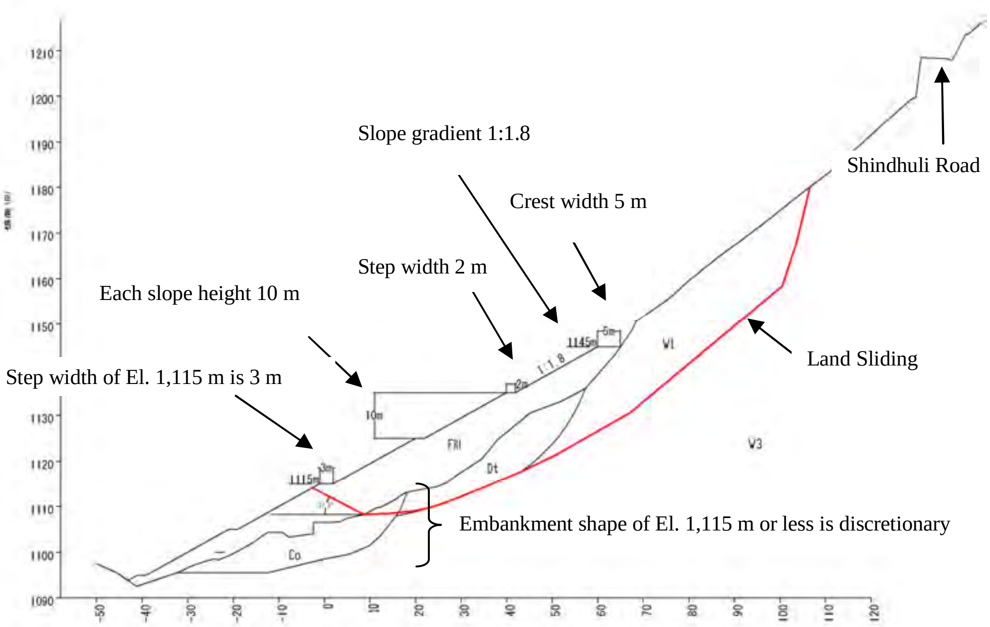
3） Embankment Condition Needed for Landslide Stability

The required embankment conditions for landslide stability are as shown in Table 2.2.19. These condition are determined by stability analysis for Landslide B.

**Table 2.2.19 Conditions Needed for Stability of Landslide B**

| Items | Condition | Remarks |
|---|---|---|
| Crest elevation | 1,450 m or more | |
| Crest width | 5 m or more | |
| Slope gradient | 1:1.8 or more | Intended for El. 1,115 m or more |
| Height of each slope | 10 m or less | |
| Step width | 2 m or more | Step of El. 1,115 m is 3 m or more for landslide stability |

Ref. : The embankment mass below at 1,115 m will not contribute to landslide stability, hence, the configuration of the embankment should be decided by its stability.




Source: JICA Survey Team

**Figure 2.2.22 Minimum Condition of Embankment needed for Landslide Stability**

4） Extent of Embankment

Embankments should not extend to agricultural lands. Hence, a minimum gradient of 1:1.8 is adopted.

5） Stability of Embankment

The factor of safety (Fs) shown in Table 2.2.20 should be fulfilled in the embankment. In the result of circular sliding analysis in the seismic scenario, if groundwater rises upward on the embankment, the Fs must be 0.968. An Fs of 0.968 is NG for proposed the design factor of safety of 1.00. For this reason, the drainage layer with a thickness of 80 cm is designed in the embankment as shown Figure 2.2.27.

**Table 2.2.20 Design Condition of Embankment**

| | Normal State | Seismic State |
|---|---|---|
| Sliding Safety Factor | 1.20 or more | 1.00 or more |

Source: Manual for Embankment, Japan Road Association

$$F_S = \frac{\Sigma\{c \cdot l + [(W - u \cdot b)\cos\alpha - k_h \cdot W \cdot \sin\alpha]\tan\phi\}}{\Sigma\left(W \cdot \sin\alpha + \frac{h}{r} \cdot k_h \cdot W\right)}$$

Where, Fs= Initial factor of safety
C (kN/$m^2$) = Cohesion of sliding surface
φ (°)= Internal friction angle of sliding surface
l（m） = Length of sliding surface acting on the slice
u (kN/m) = Pore pressure acting on the base of the slice
b (m) =Width of the slice
W (kN/m) =Weight of the slice
α (°) = Angle of the base of the slice with respect to the horizontal
Kh = Design horizontal seismic coefficient (see below)
h (m) = distance of segmentalized mass center and arc center
R (m) = radius of circular arc

Kh=Cz･Kh0=1.0×0.08=0.08

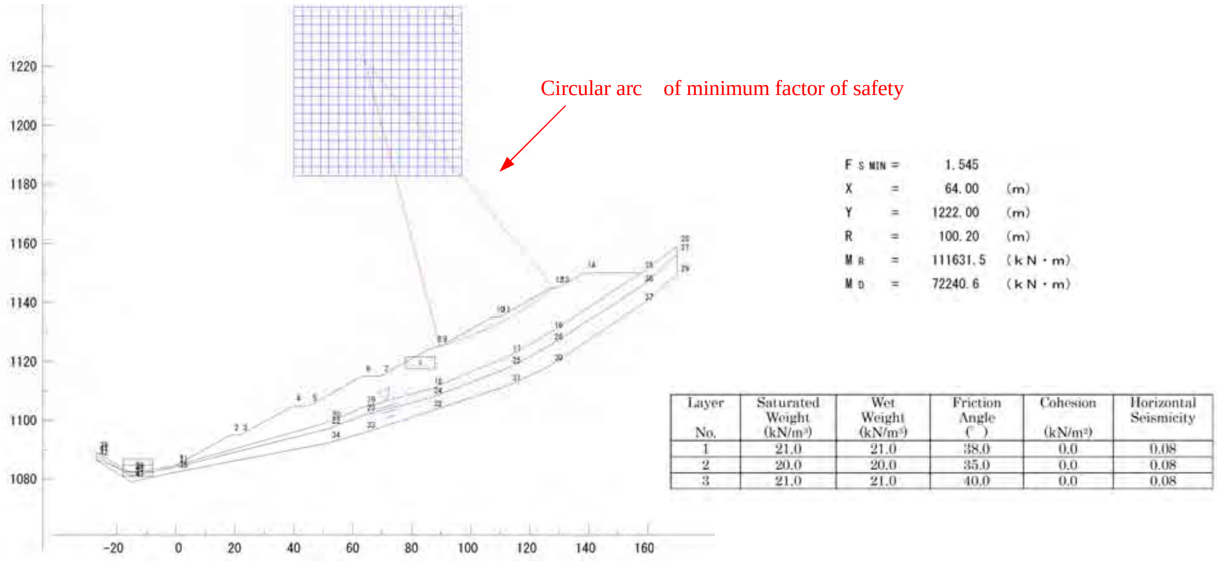
Kh0: The standard value of design horizontal seismic coefficient as shown in Table 2.2.21. Gravel bed has about 10 m of deposits in the basement, where SPT is more than 50.

Cz: Correction factor of zone. Project site is earthquake-prone, hence, 1.0 is adopted for safety.

**Table 2.2.21 Standard Value of Design Horizontal Seismic Coefficient**

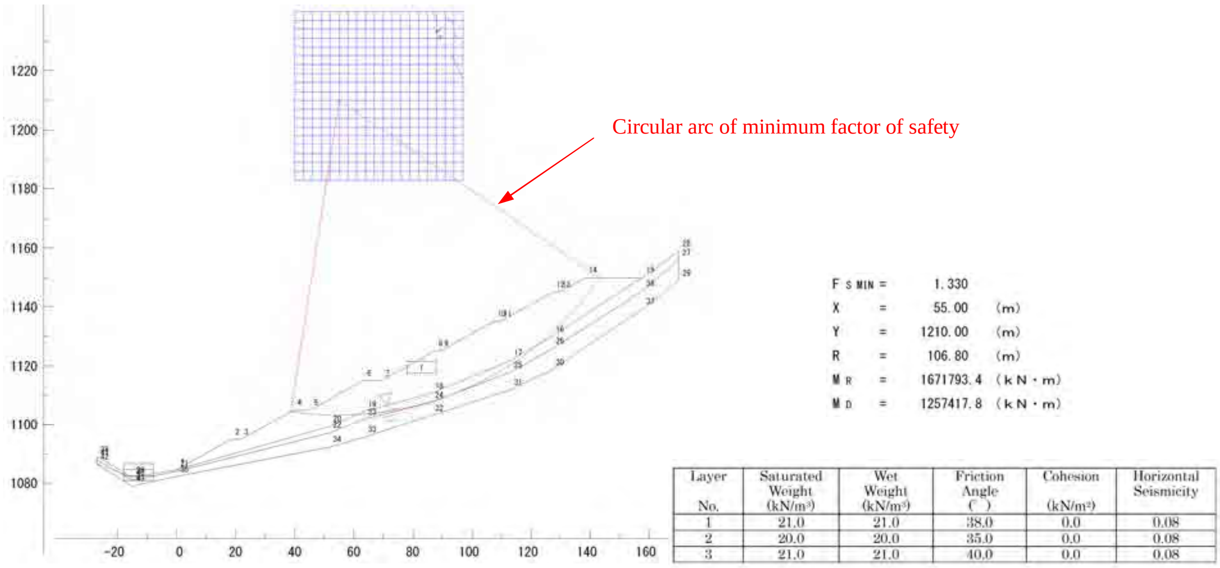
| Earthquake Motion | Ground Classification | | |
|---|---|---|---|
| | I | II | III |
| Level 1 | 0.08 | 0.10 | 0.12 |
| Level 2 | 0.16 | 0.20 | 0.24 |

Source: Manual for Embankment, Japan Road Association




| Layer No. | Saturated Weight (kN/m³) | Wet Weight (kN/m³) | Friction Angle (°) | Cohesion (kN/m²) | Horizontal Seismicity |
|---|---|---|---|---|---|
| 1 | 21.0 | 21.0 | 38.0 | 0.0 | 0.08 |
| 2 | 20.0 | 20.0 | 35.0 | 0.0 | 0.08 |
| 3 | 21.0 | 21.0 | 40.0 | 0.0 | 0.08 |

**Normal State**

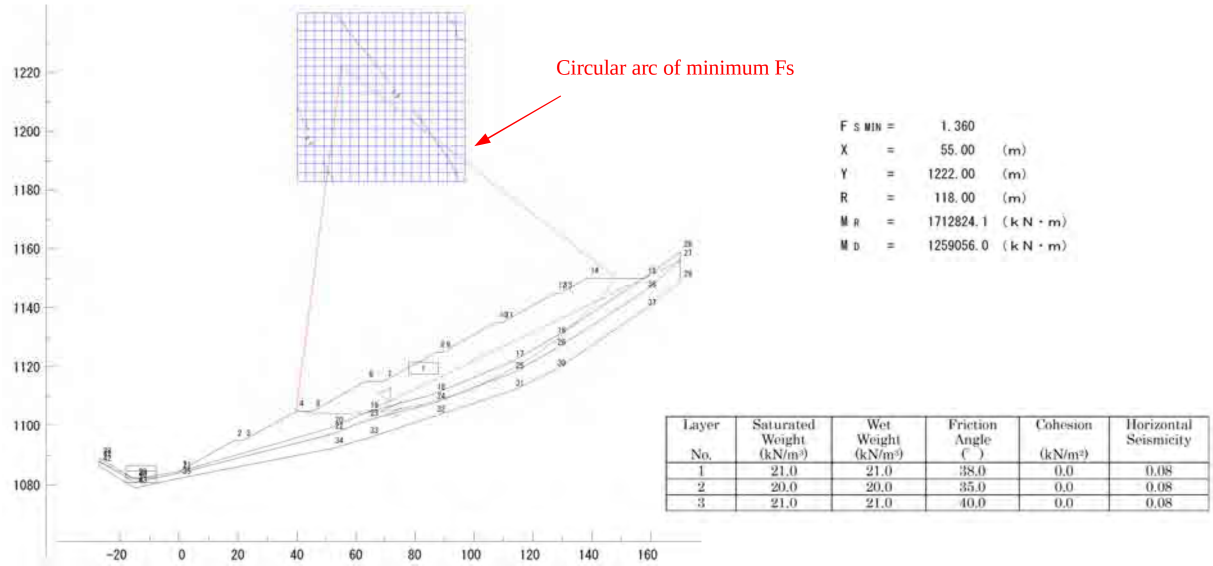



| Layer No. | Saturated Weight (kN/m³) | Wet Weight (kN/m³) | Friction Angle (°) | Cohesion (kN/m²) | Horizontal Seismicity |
|---|---|---|---|---|---|
| 1 | 21.0 | 21.0 | 38.0 | 0.0 | 0.08 |
| 2 | 20.0 | 20.0 | 35.0 | 0.0 | 0.08 |
| 3 | 21.0 | 21.0 | 40.0 | 0.0 | 0.08 |

**Seismic State**

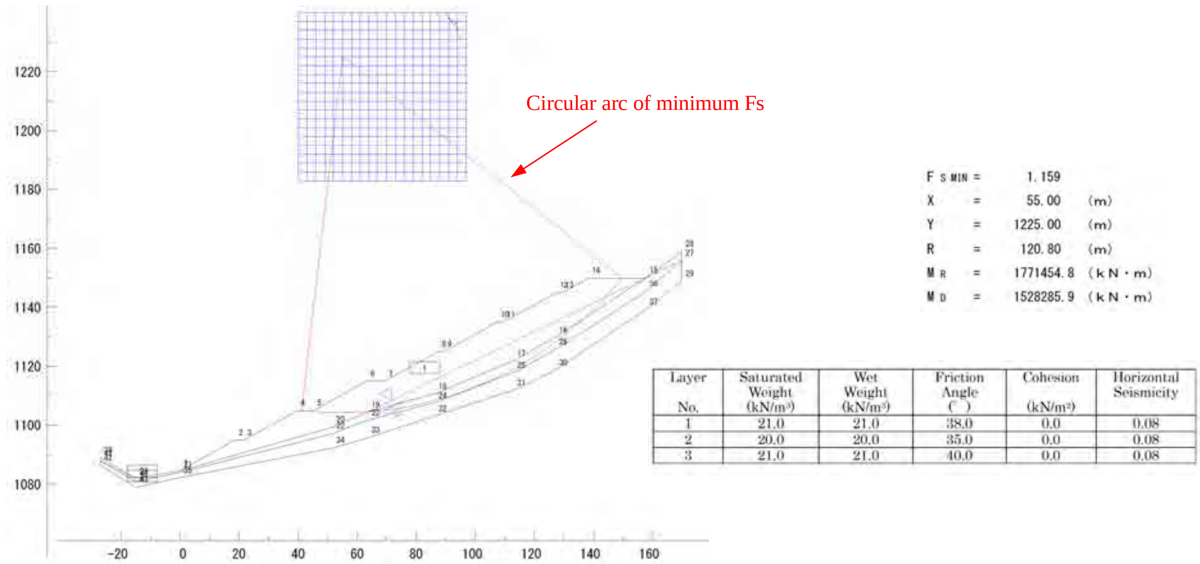
Source: JICA Survey Team

**Figure 2.2.23 Results of Circular Sliding Analysis (without Groundwater)**




| Layer No. | Saturated Weight (kN/m³) | Wet Weight (kN/m³) | Friction Angle (°) | Cohesion (kN/m²) | Horizontal Seismicity |
|---|---|---|---|---|---|
| 1 | 21.0 | 21.0 | 38.0 | 0.0 | 0.08 |
| 2 | 20.0 | 20.0 | 35.0 | 0.0 | 0.08 |
| 3 | 21.0 | 21.0 | 40.0 | 0.0 | 0.08 |

**Normal State**

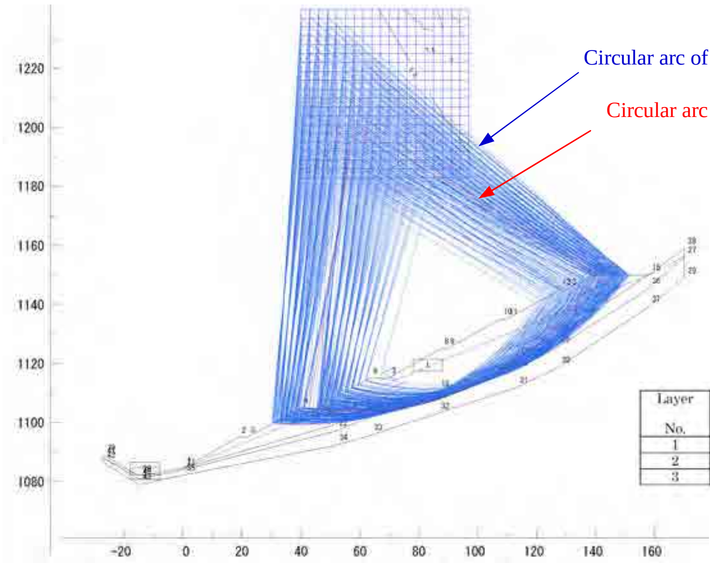



| Layer No. | Saturated Weight (kN/m³) | Wet Weight (kN/m³) | Friction Angle (°) | Cohesion (kN/m²) | Horizontal Seismicity |
|---|---|---|---|---|---|
| 1 | 21.0 | 21.0 | 38.0 | 0.0 | 0.08 |
| 2 | 20.0 | 20.0 | 35.0 | 0.0 | 0.08 |
| 3 | 21.0 | 21.0 | 40.0 | 0.0 | 0.08 |

**Seismic State**

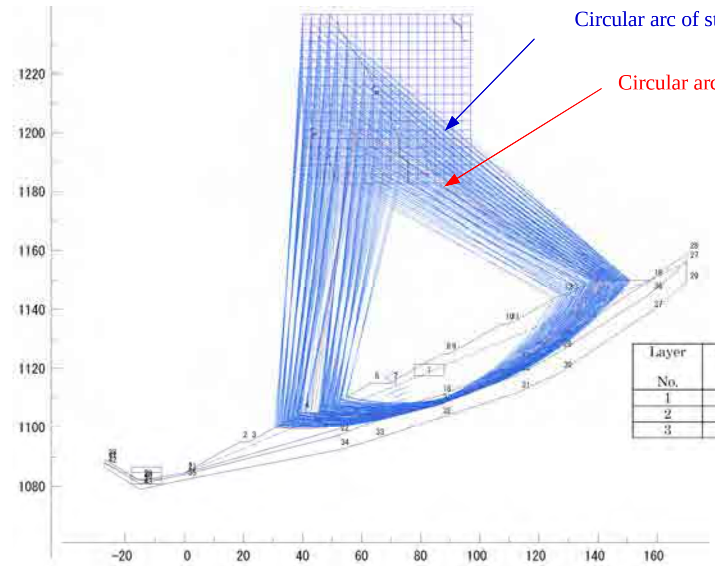
Source: JICA Survey Team

**Figure 2.2.24 Results of Circular Sliding Analysis (with Groundwater above 1,105 masl)**




| Layer No. | Saturated Weight ($kN/m^3$) | Wet Weight ($kN/m^3$) | Friction Angle (°) | Cohesion ($kN/m^2$) | Horizontal Seismicity |
|---|---|---|---|---|---|
| 1 | 21.0 | 21.0 | 38.0 | 0.0 | 0.08 |
| 2 | 20.0 | 20.0 | 35.0 | 0.0 | 0.08 |
| 3 | 21.0 | 21.0 | 40.0 | 0.0 | 0.08 |

**Normal State**




| Layer No. | Saturated Weight ($kN/m^3$) | Wet Weight ($kN/m^3$) | Friction Angle (°) | Cohesion ($kN/m^2$) | Horizontal Seismicity |
|---|---|---|---|---|---|
| 1 | 21.0 | 21.0 | 38.0 | 0.0 | 0.08 |
| 2 | 20.0 | 20.0 | 35.0 | 0.0 | 0.08 |
| 3 | 21.0 | 21.0 | 40.0 | 0.0 | 0.08 |

**Seismic State**

Source: JICA Survey Team

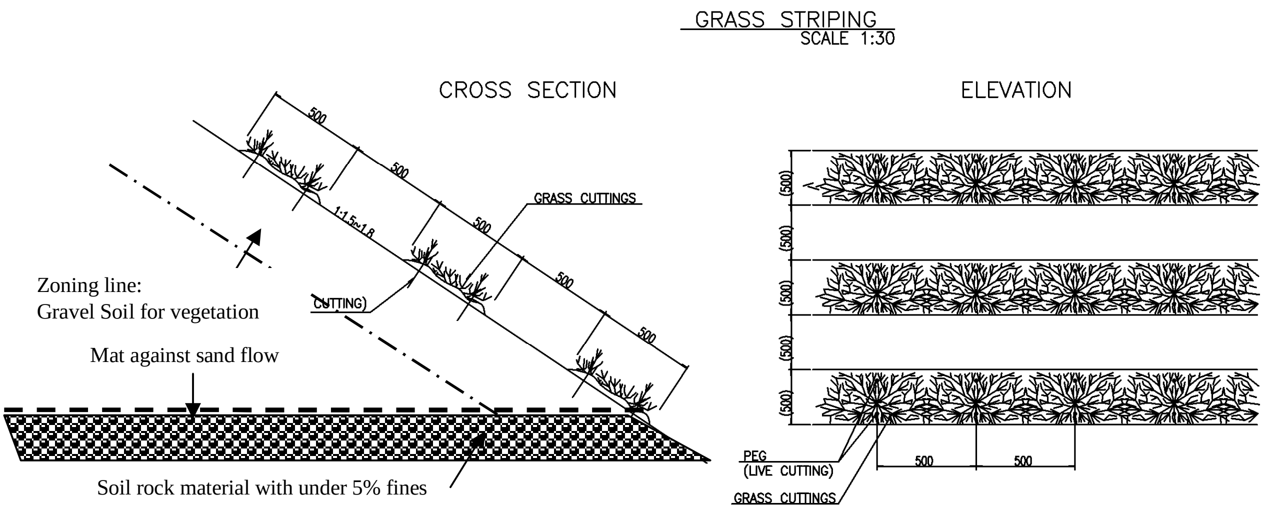
**Figure 2.2.25 Results of Circular Sliding Analysis (with Groundwater above 1,085 masl)**

6） Replacement of Existing Open Ditch

Surface drainage water gathered up at Sta. 17+380 flows naturally into the end of embankment with an open ditch (H*W＝0.90 m*0.75 m). Embankment is designed to cover this open ditch, therefore the open ditch is planned to be replaced at the boundary of the embankment and ground.

7） Vegetation Works

Vegetation works are planned to prevent erosion. Simple terracing works, which have a covering factor of 50%, are adopted in reference to the standards for Sindhuli Road Section II. However, final specifications should be decided during in-situ vegetation test. Figure 2.2.26 shows the typical set-up for vegetation works on embankment. Table 2.2.22 shows the land use for vegetation works while Table 2.2.23 lists the slope grades and geological conditions for cut slopes.




Source: JICA Survey Team

**Figure 2.2.26 Vegetation Works on Embankment**

**Table 2.2.22 Vegetation Objectives and Land Use**

| Slope Classification | | Embankment | | Cutting | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Soil | | Soft Rock | | Rock | |
| Slope Characteristics | | Easy to be eroded | Stable to an erosion | Easy to be eroded | Stable to an erosion | Easy to be eroded and weathered | Stable to an erosion and weathering | Many Cracks and possible rock fall | Stable rock or keeped stable slope |
| Geology | | B,C | A,D | B,C | A,D | E,F,H,I | | G,J | |
| No Protection Work | | | | | | | | | ◎ |
| Vegetation | Sodding | ○ | ○ | ○ | ○ | ○ | ○ | | |
| | Stepped sodding | | | ○ | ○ | ○ | ○ | | |
| | Grass striping | ○ | ◎ | ○ | ◎ | ○ | ◎ | | |
| | Sodding with straw | ○ | ○ | ○ | ○ | | | | |
| | Tree planting | ○ | ◎ | ○ | ◎ | ○ | ◎ | | |
| | Planting tree cuttings | ○ | ◎ | ○ | ◎ | ○ | ◎ | | |
| | Earthbags with sodding | ○ | ○ | ○ | ○ | | | | |
| Structure | Wet masonry | ◎ | | ◎ | ○ | ◎ | ○ | ○ | |
| | Cast-in-place concrete crib (earth-filled) | ◎ | | ◎ | ○ | ◎ | ○ | | |
| | Cast-in-place concrete crib (stone-filled) | ◎ | | ◎ | ○ | ◎ | ○ | | |
| | Shotcrete | | | | | ○ | | ◎ | |
| | Earth reinforcing | | | | | ○ | | ◎ | |
| | Gabion | ◎ | ○ | ◎ | ○ | ◎ | | | |
| | fencing | ○ | ○ | ○ | ○ | ○ | | | |

Legend) ◎:Use ○:Occasional use
Note)
①In case it is impossible to secure stable slope by vegetation only, structure will be adopted.
②In case of possible rock-fall, rock-fall prevention work will be considered.
③In case of topographical restriction, geotexitle reinforced earth wall will be considered.
Source) Study Team

Source: Basic Design Study Report on the Project for Construction of Sindhuli Road Section III

**Table 2.2.23 Slope Grades and Geological Conditions for Cutting Slope**

| Mark | Geological Classification | | Classified Slope Grade |
|---|---|---|---|
| | Major Classification | Minor Classification | |
| A | Soil | Colluviums (Gravel) | 1:0.8 - 1:1.2 |
| B | Soil | Colluviums (Soil) | 1:1.0 - 1:1.5 |
| C | Soil | Terrace deposit (Red soil) | 1:1.0 - 1:1.5 |
| D | Soil | Terrace deposit (Rock, Gravel) | 1:0.6 - 1:1.0 |
| E | Soft Rock | Hardly Weathered Slate | 1:0.6 - 1:1.2 |
| F | Soft Rock | Weathered and Joint Developed Slate | 1:0.5 - 1:0.8 |
| G | Rock | Slate | 1:0.3 - 1:0.5 |
| H | Soft Rock | Hardly Weathered Schist, Phyllite | 1:0.8 - 1:1.2 |

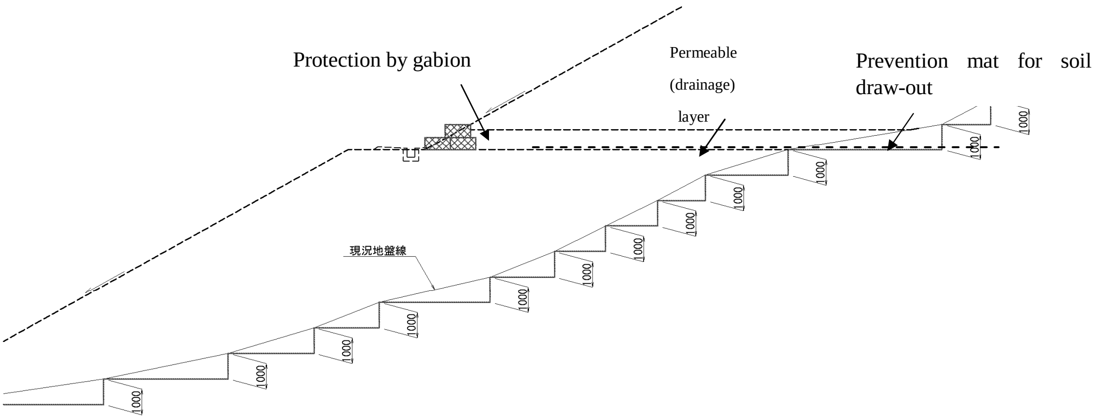
| | | | |
|---|---|---|---|
| I | Soft Rock | Weathered and Joint Developed Schist, Phyllite | 1:0.5 - 1:1.0 |
| J | Rock | Schist, Phyllite | 1:0.3 - 1:0.5 |

Source: Basic Design Study Report on the Project for Construction of Sindhuli Road Rection III

8） Treatment of Storm and Spring Water

-Treatment of Slope Surface: The volume of flow on the slope should be reduced. For this reason, open ditches are designed at the crest of embankment, boundary of embankment and ground, and cat walk. A 300 mm diameter U-ditch (U300) is adopted for open ditch based on calculations.

-Treatment of Osmosis Water in the Embankment: Although embankment material having less than 10% of fine content is highly permeable, if groundwater enters the embankment, the factor of safety then shifts under the design factor of safety. For this reason, the drainage layer with less than 5% of fine content is designed to drain osmosis water into open ditches along cat walks. In the drainage layer, particle size analysis should be conducted for quality control before filling works and permeability test after construction.




Source: JICA Survey Team

**Figure 2.2.27 Drainage Layer in the Embankment**

- Treatment of Spring Water: Closed conduits are designed for spring water. The closed conduit is composed of fiberglass reinforced plastic mortar pipes (FRPMP) with a diameter of 300 mm.

- Investigation of Volume on the Surface: As shown in Figure 2.2.29, the outflow of surface water into the embankment is 0.155 $m^3$/s. This flow is possible through U300 with a gradient of 2%. Table 2.2.24 shows the coefficients of discharge for different types of surfaces. Rainfall intensities at areas along the embankment are as shown in, while the different discharge coefficients for different flood return periods are as shown in Figure 2.2.28.

I) Outflow from Embankment Area

| Area | Rainfall Intensity (mm/h) | Area ($m^2$) | Runoff Coefficient | Average Runoff Coefficient | Outflow ($m^3$/sec) |
|---|---|---|---|---|---|
| Q1 | 60 | 6,672 | 0.5 | 0.5 | 0.056 |
| Q2 | 60 | 5,011 | 0.5 | 0.5 | 0.042 |
| Q3 | 60 | 3,814 | 0.5 | 0.5 | 0.032 |
| Q4 | 60 | 1,001 | 0.1 | 0.14 | 0.004 |
| | | 591 | 0.2 | | |
| Q5 | 60 | 1,701 | 0.2 | 0.2 | 0.006 |
| Q6 | 60 | 1,237 | 0.2 | 0.2 | 0.004 |
| Q7 | 60 | 1,047 | 0.2 | 0.2 | 0.003 |
| Q8 | 60 | 637 | 0.1 | 0.16 | 0.005 |

| | | | | | |
|---|---|---|---|---|---|
| | | 1,046 | 0.2 | | |
| Q9 | 60 | 223 | 0.1 | 0.18 | 0.003 |
| | | 676 | 0.2 | | |
| Q10 | 60 | 456 | 0.2 | 0.2 | 0.002 |
| Total | | | | | 0.155 |

Source: JICA Survey Team

II )Ditch Capacity

Ditch Type: U300 can be applied for slopes more than 2%.

| Slope | Ditch Flow Volume ($m^3$/sec) | Outflow Volume from Embankment Area ($m^3$/sec) | Estimation |
|---|---|---|---|
| 10% | 0.368 | 0.155 | OK |
| 5% | 0.260 | | OK |
| 3% | 0.202 | | OK |
| 2% | 0.165 | | OK |
| 1% | 0.116 | | NG |

Source: JICA Survey Team

**Table 2.2.24 Coefficients of Discharge**

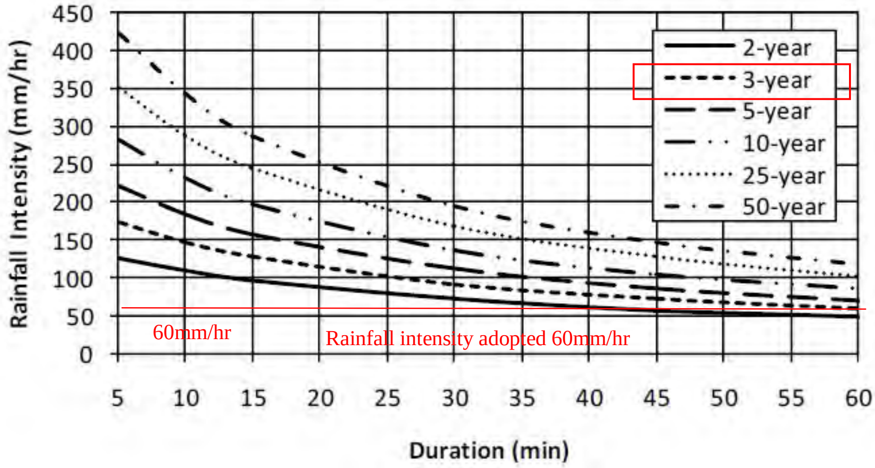
| Ground Surface | | | Runoff Coefficient | |
|---|---|---|---|---|
| Road surface | | Pavement | 0.70~0.95 | |
| | | gravel road | 0.30~0.70 | |
| Road shoulder, slope | | Fine soil | 0.40~0.65 | |
| | | Gravels | 0.10~0.30 | |
| | | Hard rock | 0.70~0.85 | |
| | | Soft rock | 0.50~0.75 | |
| Grass surface | Sandy soil | Gradient 0~2% | 0.05~0.10 | Flat place of fill Q4～Q 10：0.1 |
| | | 2~7% | 0.10~0.15 | |
| | | 7% or more | 0.15~0.20 | Slope of fill Q4～Q 10：0.2 |
| | Fine soil | Gradient 0~2% | 0.13~0.17 | |
| | | 2~7% | 0.18~0.22 | |
| | | 7% or more | 0.25~0.35 | |
| Housetop | | | 0.75~0.95 | |
| Empty land | | | 0.20~0.40 | |
| Park with many grass and trees | | | 0.10~0.25 | |
| Low sloping mountainous land | | | 0.20~0.4 | |
| High sloping mountainous land | | | 0.40~0.60 | Ground Q1～Q3：0.5 |
| Paddy field, water surface | | | 0.70~0.80 | |
| Glebe | | | 0.10~0.30 | |

Source: Manual for Road Earthwork ,Japan Road Association

**Table 2.2.25 Design Rainfall at Each Area**

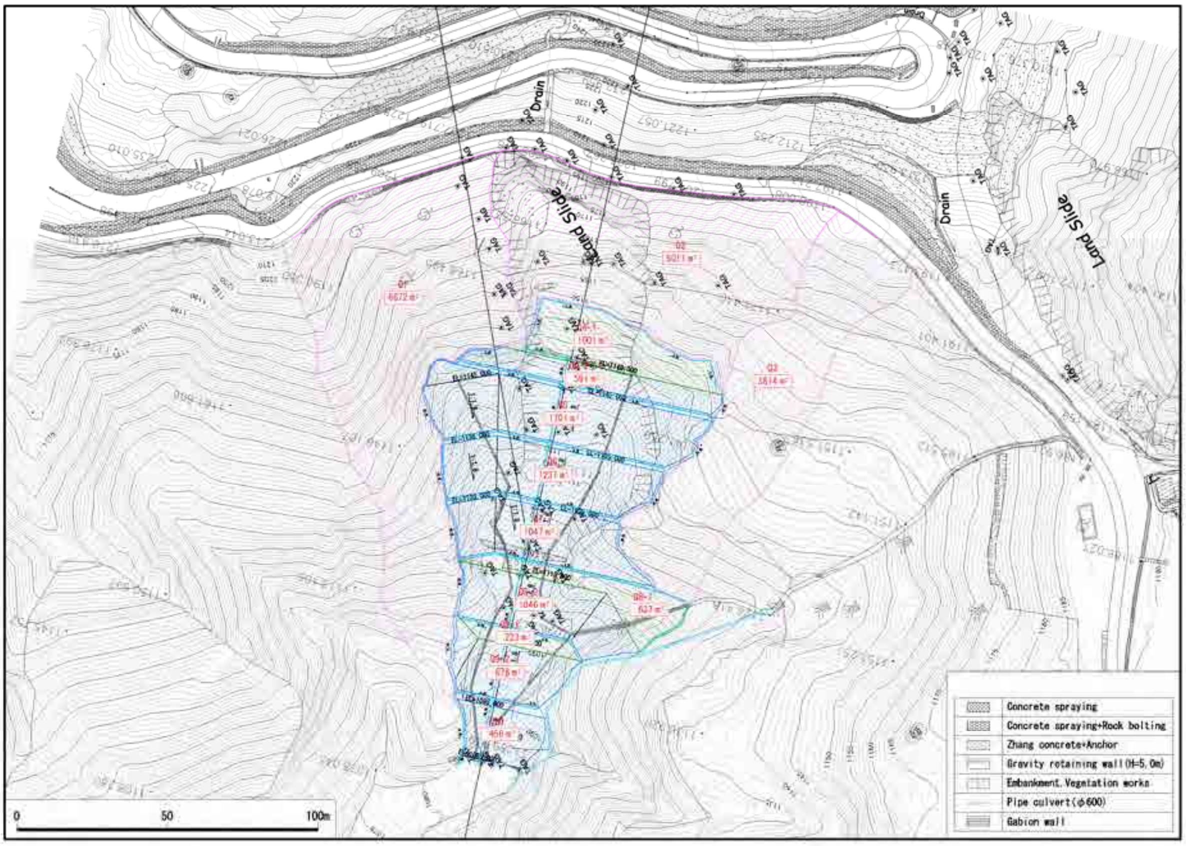
| Station | Return Period (year) | | | | | |
|---|---|---|---|---|---|---|
| | 2 | 3 | 5 | 10 | 25 | 50 |
| Sindhuli Gadhi | 169 | 206 | 245 | 300 | 368 | 423 |
| Nepalthok | 86 | 106 | 126 | 154 | 190 | 218 |
| Hariharpur Gadhi | 173 | 215 | 261 | 325 | 407 | 475 |
| Melung | 72 | 86 | 102 | 124 | 151 | 172 |

Source: Basic Design Study Report on the Project for Construction of Sindhuli Road Section III




Source: Basic Design Study Report on the Project for Construction of Sindhuli Road Section III

**Figure 2.2.28 IDF Curves of Nepalthok**




Source: JICA Survey Team

**Figure 2.2.29 Basin Zone in Embankment Area**

## (2) Temporary Road

1) Basic Design Policy

A temporary road will be constructed to carry banking materials for Landslide B at Sta. 17+600. Dump trucks will be used for material transportation. The Design Forest Road Guidelines of the Japan Forest Road Association is applied, as shown in Table 2.2.26.

**Table 2.2.26 Design Standards for Temporary Road**

| Item | Standard of Design | Summary |
|---|---|---|
| Standard Width | 3.0 m (Total Width: 4.0 m) | |
| Vertical Gradient | 14.0% (20%) | ( ) This value shows possible by short interval. |
| Minimum Radius of Horizontal Curvature | R=15 m (R=7 m) | ( ) This value shows the range of the hairpin. |
| Interval of Passing Place | Appropriate from sight | |

Source: JICA Survey Team

2) Preconditions for Construction

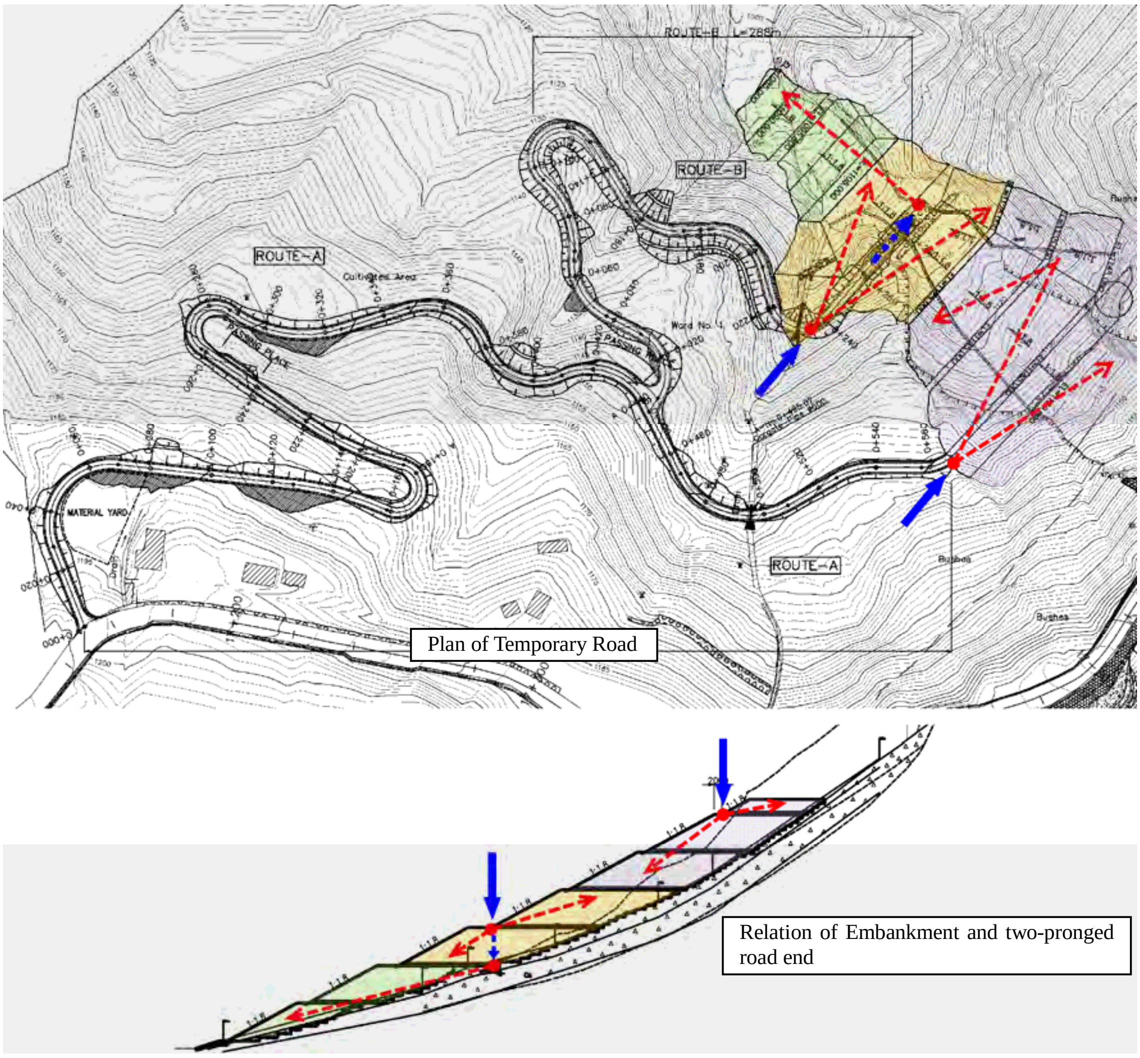
Since the topographical and geological conditions of the temporary road are very severe and complicated, it will be optional for the contractor to be responsible for construction and maintenance. The temporary road should be restored to its original state after completion of the Project.

3) Plan for the Temporary Road

Considering the topography and houses within the site, the starting point of the temporary road is planned at the vicinity of Sta. 17+150. The route is planned to avoid steep slopes in order to minimize the vertical gradient and topographical irregularities. Also, as the height of the embankment at Sta. 17+600 extends more than 60 m, the end of the route has a two-pronged fork.

Drainage is not planned as the road is a temporary structure. However, considering a steep vertical gradient and intense rainfall, rubble pavement, shoulder protection by sandbags and wide drainages are planned for protection against erosion. Furthermore, temporary pipes are planned for two existing drainage crossings.

Figure 2.2.30 shows the plan of the temporary road.




Source: JICA Survey Team

**Figure 2.2.30 Plan of the Temporary Road**

### 2.2.3.3 STA. 18+200

#### (1) Road Realignment Plan

1） Horizontal Alignments

The road will be realigned to comply with the three policies below.

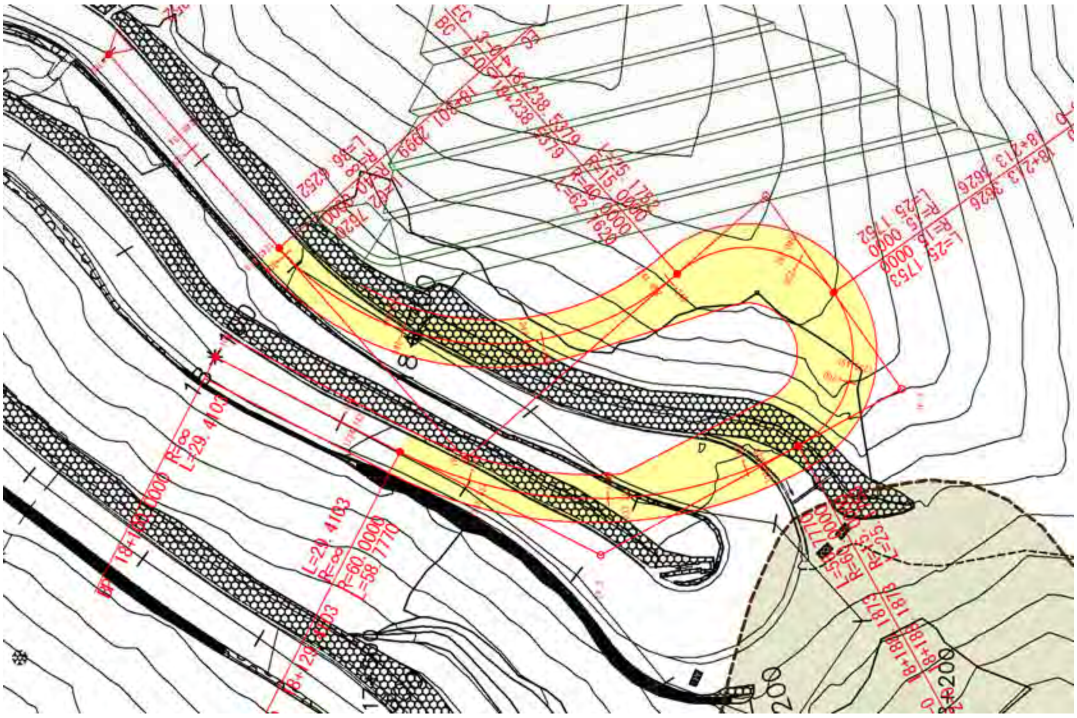
-Safety for Slope Failure Affecting the Exit Road
-To secure safe and stable traffic function
-Selection of the most suitable combination of vertical grade and horizontal radius curve was done considering traffic safety.

The following horizontal alignment plans which are isolated 5 m from the landslide area are compared as shown in Table 2.2.28.

-Case-A: Inside Realignment Plan

-Case-B: Mountain Side Realignment Plan. (Refer to Figure 2.2.31)

As a result, it was judged that Case-B is more reasonable because the incline of its hairpin curve is gentler than that of Case-A.



Source: JICA Survey Team

**Figure 2.2.31 Realignment Road Plan (Mountain Side Shift)**

2） Longitudinal Gradient Plan

Longitudinal gradient of the realignment road is planned to avoid the combination of a hairpin curve and a steep longitudinal gradient considering the longitudinal gradient of the back and front section. Especially at the hairpin curve portion, the longitudinal gradient is planned to be below 5% which is gentler than the regulation of 8% in the Road Structural Criteria of the Japan Road Association.

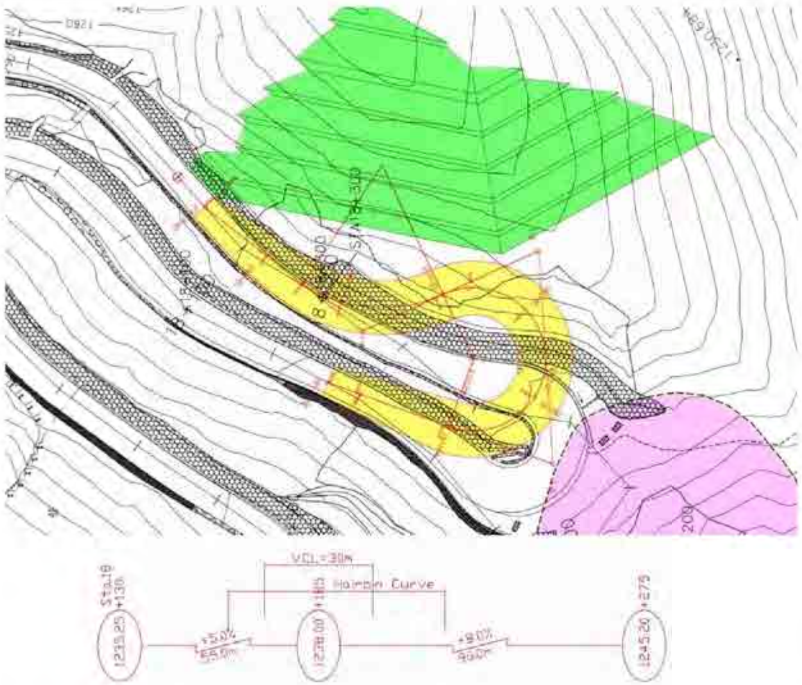
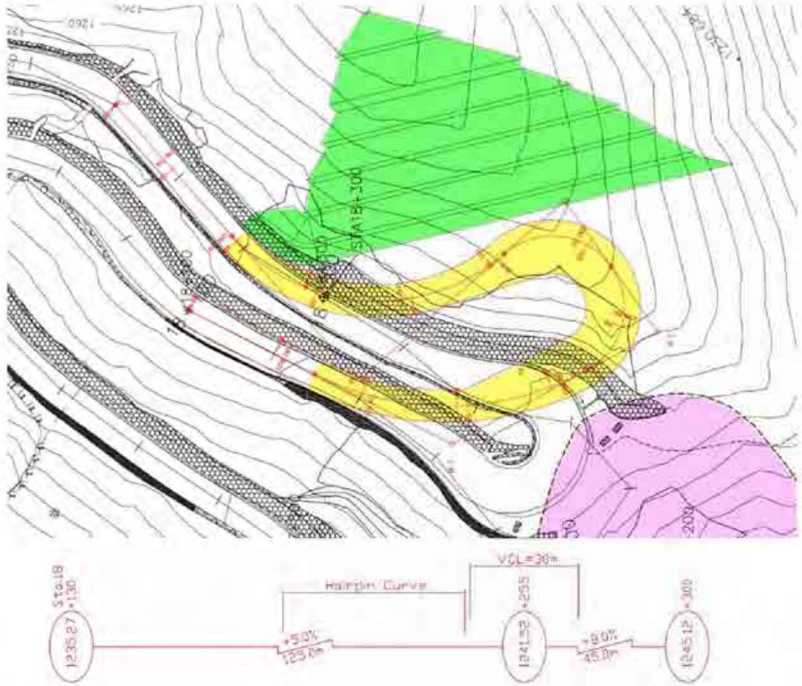
The three cases for the longitudinal realignment plan are shown in Table 2.2.27. Moreover, it has been judged that Case-1 is the most reasonable based on traffic safety, drivability and alignment balance.

**Table 2.2.27 Comparison of Vertical Grade**

| | Case-1 | Case-2 | Case-3 |
|---|---|---|---|
| Summary (Vertical Grade) | Plan of the 5% vertical slope of the hairpin curve<br>( I = 5.0% ?→ 8.0%) | Plan of the 4% vertical slope of the hairpin curve<br>( I = 5.4% ?→ 4.0% ?→ 8.8%) | Plan of the original 4.5% vertical slope<br>( I = 4.5% ?→ 7.9%) |
| Parameter (Hairpin) | Curve Radius : 15 m<br>Vertical Slope : 5.0% (<5%)<br>Super-elevation : 6.0% (<6%)<br>Combined Gradient : 7.8% (<8%) | Curve Radius : 15 m<br>Vertical Slope : 4.0% (<5%)<br>Super-elevation : 6.0% (<6%)<br>Combined Gradient : 7.2% (<8%) | Curve Radius : 15 m<br>Vertical Slope : 4.5% (<5%)<br>Super-elevation : 6.0% (<6%)<br>Combined Gradient : 7.5% (<8%) |
| Advantages and Disadvantages | The vertical section incline of the hairpin curve is superior in terms of safety and drivability by becoming 5%. | The vertical slope of the hairpin curve is gentle. However, due to the steep grade and waviness in the front and back, the curve has poor drivability. | The hairpin curve was inferior to safety as some parts have steep grade. |
| Result | ✓ Adoption | | |

Source: JICA Survey Team

## Comparative Table of The Road Realignment (Sta.18+200)

| | Case-A Inside Realignment Plan<br>The compact hairpin inward, away from the line to ensure decay | Case-B Mountain Side Realignment Plan<br>Shift hairpin mountain, away from the line to ensure decay |
|---|---|---|
| Plan Overview Diagram |  |  |



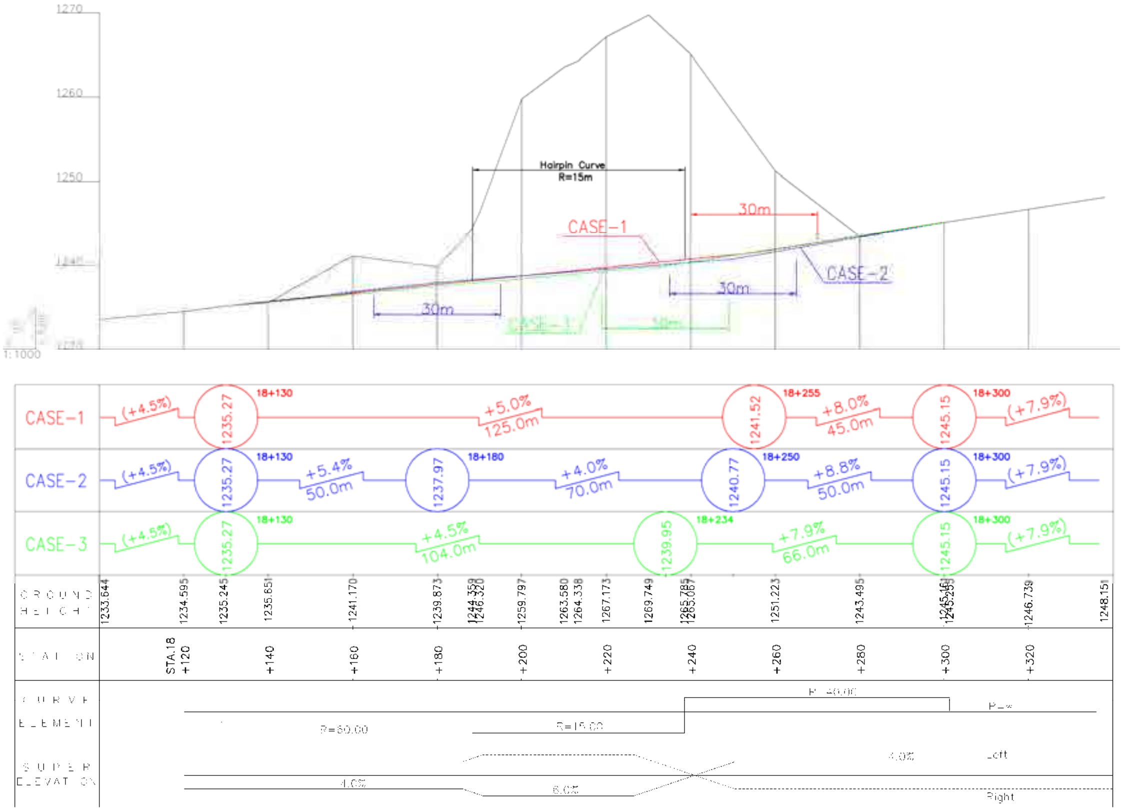
**Evaluation**

| | Case-A Comment | Case-B Comment |
|---|---|---|
| Cost | Costs are almost equal with Case-B | Costs are almost equal with Case-A |
| Design | The Vertical Grade of Hairpin Curve becomes the steep grade with 8% | The Vertical Grade of Hairpin Curve, can be less than 5% |
| Workability | Not problem in particular | Not problem in particular |
| Safety | Inferior to safety for a steep grade in hairpin curve | Excellent safety by gentle grade in hairpin curve |
| Maintenance | Road alignment have not enough margin from the landslide | Road alignment have some margin from the landslide |

| | Case-A | Case-B |
|---|---|---|
| Remarks | Cost is almost equal with Case-B. But Design and Safety are not excellent by steep grade (about 8%). Therefore, this plan is not adopted by the comprehensive evaluation with Case-B. | Cost is almost equal with Case-A. Design and Safety are excellent by gentle grade (about 8%), and driver's Line-of-Sight is no problem. In addition, road alignment have some margin from the landslide. Therefore, this plan is adopted by the comprehensive evaluation with Case-A. |
| Decision | | ✔ Adoption |

Source: JICA Survey Team

**Table 2.2.28 Alignment Comparison List**



Source: JICA Survey Team

**Figure 2.2.32 Vertical Grade Plans**

3） Geometric Design

The geometry plan of the road structure is based on the design standards of Sindhuli Road Sections II, III and IV, as shown in Table 2.2.29.

**Table 2.2.29 Adoption of Geometry**

| Item | Adoption | Section II | Remarks |
|---|---|---|---|
| Design Speed | 20 km/h | 20 km/h | Sections III and IV:<br>20~40 km/h |
| Standard Width | 4.75 m | 4.75 m | Common |
| Cross Slope | 4% | 4%（Gravel）<br>2.5%（DBST） | The cross slope is 4% with DBST in current section |
| Superelevation | 6% | 6% | Hairpin curve: 6%<br>Other curve: Omit (4%) |
| Min. Radius of Horizontal Curve | 15 m | 15 m | 40km/h : 45m<br>30km/h : 25m<br>20km/h : 15m |
| Widening of Curve | 2.25 m (R=15) | R=30: 0.00 m<br>R=25: 0.50 m<br>R=20: 1.00 m<br>R=15: 2.25 m | Mortar semitrailer |
| Min. Radius of Vertical Curve | 300 m | 300 m | |
| Ave. Vertical Grade | 7% | 7% | |
| Max. Vertical Grade | 10% (300 m) | 10% (300 m) | Max. 150 m<br>Adjacent vicinity is 4% |
| Taper of Superelevation | 1/50 | 1/50 | 30 km/h : 1/75<br>20 km/h : 1/50 |

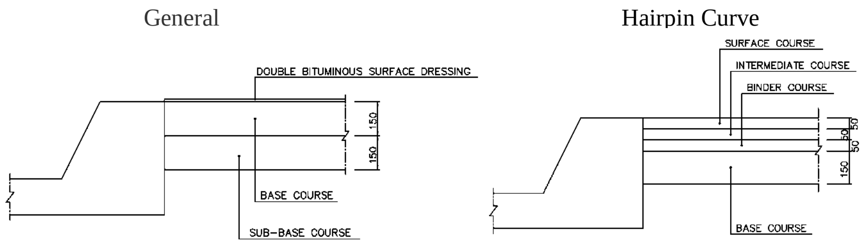
| | | | |
|---|---|---|---|
| Taper of Widening | 1/10 | 1/10 | 30 km/h : 1/15<br>20 km/h : 1/10 |
| Sight Distance | 40 m | 40 m | 20 m×2 (Single Lane) |

Source: JICA Survey Team

4) Pavement

The existing road is paved with DBST on the general section, and with asphalt on the hairpin curve, which has no problem at present. Therefore, the road pavement adopts the same method as that of the existing road: DBST on the general section which is excellent in workability and less expensive, and asphalt on the hairpin curve. Incidentally, concrete pavement is difficult to construct because there are no detours to allow the curing of fresh concrete.

Figure 2.2.33 shows the structure adopted for the pavement.




Source: JICA Survey Team

**Figure 2.2.33 Structure of Pavement**

5) Drainage

The existing road drainage system needs to be partially improved. The quantity of storm runoff is calculated based on the Road Earthwork Drainage Guidelines of the Japan Road Association. Moreover, the road drainage format is applied for drainage structures.

Side ditch is more than 45 cm deep, with the bottom at least 40 cm wide and the cross pipe with a minimum diameter of 60 cm. The drainage of cut slope is connected to the central drainage by adjustment of the benchmark gradient. The adopted vertical drainage is 60 cm wide, which will be used as maintenance pathway.

- Quantity of Storm Runoff

Runoff calculation was made using the rational formula given below. Velocity was calculated using Manning's formula.

$$Q = 1/3.6 \times C \times I \times A$$

Q : Peak rain runoff ($m^3/s$)
C : Runoff coefficient
I : Rainfall intensity (mm/hour)
A : Catchment area ($km^2$)

- Return Period

**Table 2.2.30 Return Period for Drainage Facilities**

| Facility Type | Return Period (Year) |
|---|---|
| Side ditch | 3 |

Source: JICA Survey Team

- Runoff Coefficient

The runoff coefficient was calculated based on the Road Earthwork Drainage Guidelines of the Japan Road Association. It was set to 0.4 because of the steep geographical feature of the area.

- Rainfall Intensity

The values of the rainfall intensity curve at Sindhuli Gadhi are as shown in Table 2.2.31.

**Table 2.2.31 Values of the Rainfall Intensity Curve at Sindhuli Gadhi**

| Return Period | 2 | 3 | 5 | 10 | 25 | 50 |
|---|---|---|---|---|---|---|
| Rainfall Intensity (mm/day) | 169 | 206 | 245 | 300 | 368 | 423 |

Source: Basic Design Study Report on the Project for Construction of Sindhuli Road Section III

- Drainage Capacity

| | | | |
|---|---|---|---|
| Runoff Coefficient | C= | 0.4 | |
| Rainfall Intensity | I= | 206 | |

| Quantity of rain runoff | | | | Drainage Capacity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | Area (m2) | Sum A(m2) | Quantity Qo(m3/s) | No | Form | Sec-Area A(m2) | Hydraulic Radius R(m) | Roughness n | Inclination i(%) | Capacity Qa(m3/s) | Safe rate |
| 1 | 17,100 | | | | | | | | | | |
| 2 | 4,600 | 21,700 | 0.497 | A | U-750 | 0.180 | 0.161 | 0.015 | 5.0% | 0.793 | 1.60 |
| | | | 0.497 | B | φ600 | 0.283 | 0.150 | 0.013 | 6.0% | 1.507 | 3.03 |
| 3 | 4,300 | | | | | | | | | | |
| 4 | 6,400 | 32,400 | 0.742 | C | U-750 | 0.180 | 0.161 | 0.015 | 5.0% | 0.793 | 1.07 |
| | | | | | | | | | | | |

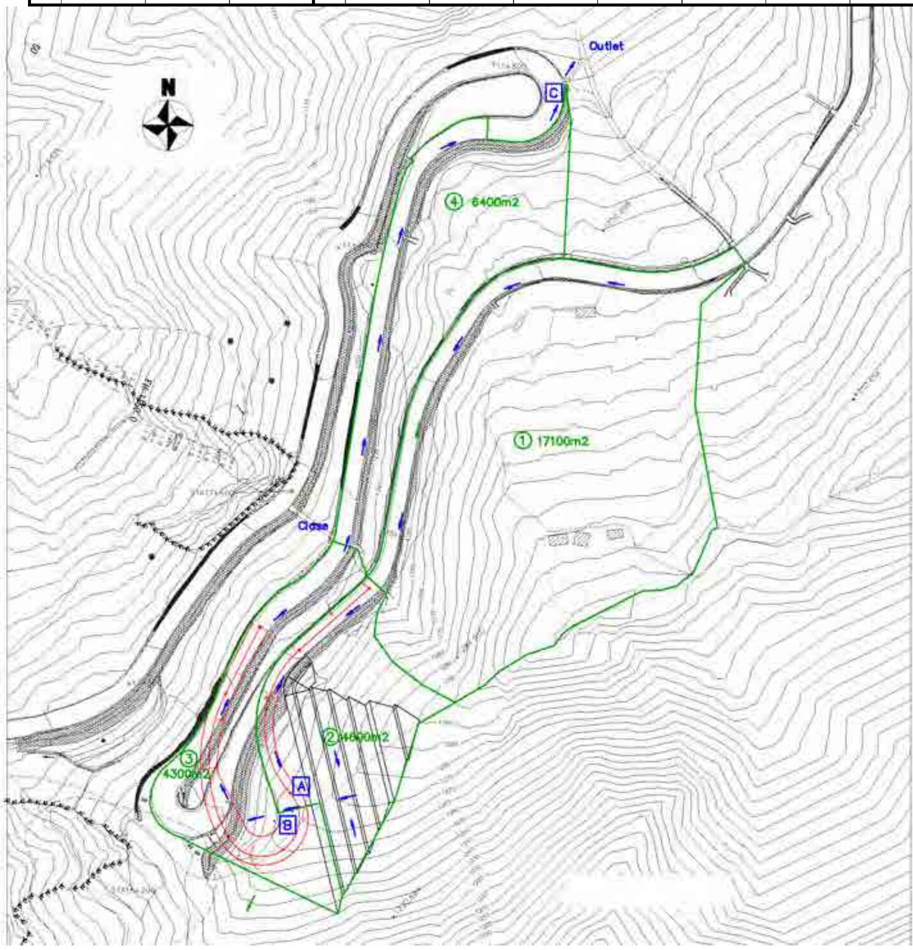



**Figure 2.2.34 Catchment Area and Drain System**

Source: JICA Survey Team

6） Concepts of Earthworks

The slope works plan was formulated based on the following concepts, which are also responses to the review comments from the JICA Council for the Project:

- Apply as much vegetation as possible to stable rocks and soil slopes
- In case cutting on stable slopes is large-scale, the grade should be steeper and slopes should have slope protection structures
- Adopt as much as possible slope protection works, which are applied widely in Nepal
- No protection works will be applied to small-scale stable rock slopes to save costs

7） Slope Grades to be Adopted

The slope grades for the cutting slope in Sections II and III were set based on the standards for the slope grade shown in Table 2.2.32. In the Project, elastic wave exploration was conducted by the Study Team. The elastic wave velocity of the cutting area is about 1.0 km/s, and it was found out that the ground around the cutting slope is not good. The stable grade is set to 1:1.2 in accordance with the scatter graph shown in Figure 2.2.35.

**Table 2.2.32 Standard Slope Grades for Cutting**

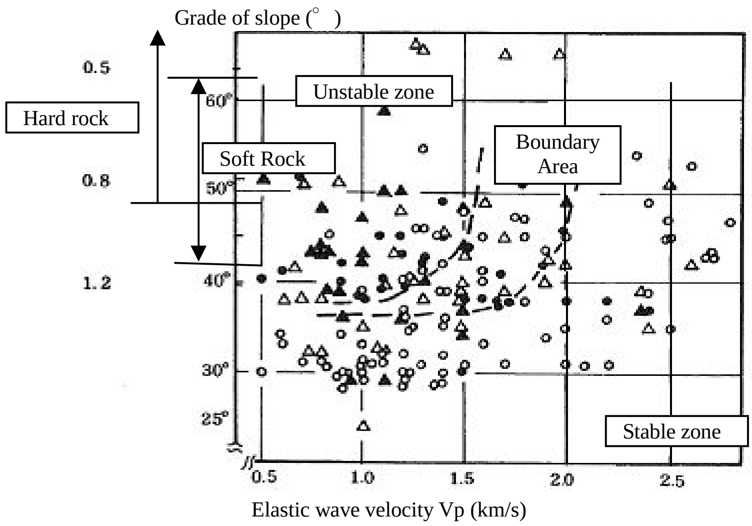
| Type of Slopes | | Grade |
|---|---|---|
| Rock | | 1:0.3 - 1:0.8 |
| Soft Rock | | 1:0.5 - 1:1.2 |
| Sandy Soil | Dense | 1:0.8 - 1:1.0 |
| | Loose | 1:1.0 - 1:1.2 |
| Gravel, Soil | Dense | 1:0.8 - 1:1.0 |
| | Loose | 1:1.0 - 1:1.2 |

Note: Except for special cases, such as failure-prone slopes and large slopes.
Source: Manual for Slope Protection, Japan Road Association

**Table 2.2.33 Slope Grades and Geological Conditions for the Cutting Slope**

| Mark | Geological Classification | | Classified Slope Grade |
|---|---|---|---|
| | Major Classification | Minor Classification | |
| A | Soil | Colluviums (Gravel) | 1:0.8 - 1:1.2 |
| B | Soil | Colluviums (Soil) | 1:1.0 - 1:1.5 |
| C | Soil | Terrace Deposit (Red soil) | 1:1.0 - 1:1.5 |
| D | Soil | Terrace Deposit (Rock, Gravel) | 1:0.6 - 1:1.0 |
| E | Soft Rock | Hardly Weathered Slate | 1:0.6 - 1:1.2 |
| F | Soft Rock | Weathered and Joint Developed Slate | 1:0.5 - 1:0.8 |
| G | Rock | Slate | 1:0.3 - 1:0.5 |
| H | Soft Rock | Hardly Weathered Schist, Phyllite | 1:0.8 - 1:1.2 |
| I | Soft Rock | Weathered and Joint Developed Schist, Phyllite | 1:0.5 - 1:1.0 |
| J | Rock | Schist, Phyllite | 1:0.3 - 1:0.5 |

Source: Basic Design Study Report on the Project for Construction of Sindhuli Road Section III




| | Mesozoic rock Paleozoic rock | Igneous rock |
|---|---|---|
| Slope Failure | ● | ▲ |
| Stable Slope | ○ | △ |

Source: Manual for Slope Protection, Japan Road Association

**Figure 2.2.35 Slope Stability (Elastic Wave Velocity-Slope Grade)**

8) Configuration of Slope (Slope Height, Width of Cat Walk and Drainage on Cat Walk)
According to the design for Section II, the slope height and the width of cat walk are 7 m and 1.5 m, respectively. However, the total slope height was planned at 50 m. Therefore, the cat walk, which is 2 m wide, is set with a single step in this slope. It is basic policy that surface drainage follows a natural flow.

9) Vegetation
Vegetation was selected in accordance with the slope categories and characteristics for Section II

as shown Table 2.2.34. At Sta. 18+200, the designed slope has seven steps. The two upper slopes are cut with a stable grade, so that such would not be vegetated since plants are expected to spread from adjacent areas. The slope of the three to six upper steps will be cut to have a 1:0.8 grade. However, a grade of 1:0.8 is not suitable for vegetation. Crib works designed to prevent slope failure become the base of vegetation, so it will be protected by sandbags.

**Table 2.2.34 Vegetation Objectives and Land Use**

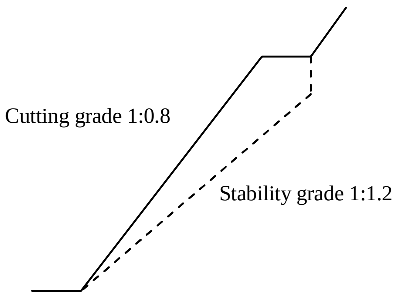
| Slope Classification | | Embankment | | Cutting | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Soil | | Soft Rock | | Rock | |
| Slope Characteristics | | Easy to be eroded | Stable to an erosion | Easy to be eroded | Stable to an erosion | Easy to be eroded and weathered | Stable to an erosion and weathering | Many Cracks and possible rock fall | Stable rock or keeped stable slope |
| Geology | | B,C | A,D | B,C | A,D | E,F,H,I | | G,J | |
| No Protection Work | | | | | | | | | ◎ |
| Vegetation | Sodding | ○ | ○ | ○ | ○ | ○ | ○ | | |
| | Stepped sodding | | | ○ | ○ | ○ | ○ | | |
| | Grass striping | ○ | ◎ | ○ | ◎ | ○ | ◎ | | |
| | Sodding with straw | ○ | ○ | ○ | ○ | | | | |
| | Tree planting | ○ | ◎ | ○ | ◎ | ○ | ◎ | | |
| | Planting tree cuttings | ○ | ◎ | ○ | ◎ | ○ | ◎ | | |
| | Earthbags with sodding | ○ | ○ | ○ | ○ | | | | |
| Structure | Wet masonry | ◎ | | ◎ | ○ | ◎ | ○ | ○ | |
| | Cast-in-place concrete crib (earth-filled) | ◎ | | ◎ | ○ | ◎ | ○ | | |
| | Cast-in-place concrete crib (stone-filled) | ◎ | | ◎ | ○ | ◎ | ○ | | |
| | Shotcrete | | | | | ○ | | ◎ | |
| | Earth reinforcing | | | | | ○ | | ◎ | |
| | Gabion | ◎ | ○ | ◎ | ○ | ◎ | | | |
| | fencing | ○ | ○ | ○ | ○ | ○ | | | |

Legend) ◎:Use ○:Occasional use
Note)
①In case it is impossible to secure stable slope by vegetation only, structure will be adopted.
②In case of possible rock-fall, rock-fall prevention work will be considered.
③In case of topographical restriction, geotextile reinforced earth wall will be considered.

Source: Basic Design Study Report on the Project for Construction of Sindhuli Road Section III

10) Reinforced Earth Method

The stability grade of the slope at Sta.18+200 is 1:1.2. However, the design grade needed at Sta. 18+200 is 1:0.8 in order to mitigate environmental impacts. Therefore, reinforced earth method for this slope is needed. The slope failure forms a delta from the stability grade of 1:1.2 and cutting grade of 1:0.8, as shown in Figure 2.2.36. The depth of slope failure is about 2 m. The dimensions of the reinforced earth method follows the experimental design method described in the Manual for Slope Protection by the Japan Road Association as shown in Table 2.2.35. Rock bolts with lengths of 3 m are adopted because the depth of slope failure is about 2 m.




Source: JICA Survey Team

**Figure 2.2.36 Model of Slope Failure**

**Table 2.2.35 Experimental Design Method**

| Items | Dimensions |
|---|---|
| Hole of drilling | More than 65 mm |
| Diameter of rock bolt | D19-D25 |
| Length of rock bolt | 2-3 m |
| Density of rock bolt | 1 lod per 2 m$^2$ |
| Degree | Right angle to slope |
| The 2 m rock bolts are adopted for slope failures with depths of 1 m, while 3 m rock bolts are adopted for slope failures with depths of 2 m. | |

Source: Manual for Slope Protection, JRA

11) Retaining Wall

Retaining walls are arranged to support the cut slope necessary for road realignment. Considering the height of walls and the geological conditions of the slope, the structure of the wet masonry wall to be applied would be either Type-A or Type-B, as shown in Figure 2.2.37.

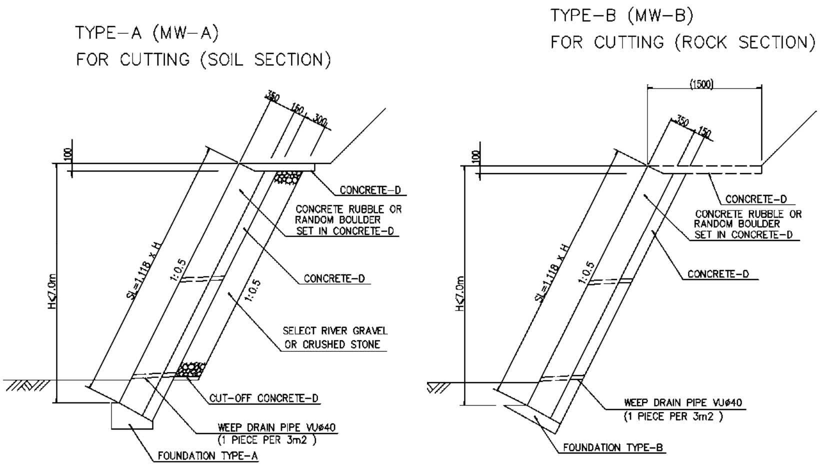



**Figure 2.2.37 Wet Stone Masonry Wall (Type-A and Type-B)**

Source: JICA Survey Team

12) Traffic Safety Facilities

Concrete barriers and delineators are planned for traffic safety and accident prevention. Delineators are installed on the hairpin curve where there are existing guard blocks with enough flat space. Table 2.2.36 shows the concepts of concrete barriers and delineators.

**Table 2.2.36 Concept of Guard Blocks and Delineators**

| Safety Facility for Traffic | Remarks |
|---|---|
| Delineator | -General section<br>-The placement interval will be set up depending on the curvature (minimum of 5 m) |
| Concrete barriers<br>L-shape pre-cast concrete | -The curve section of valley side convex<br>-Accident-prone sections with steep slopes and large height difference<br>- Zigzag sections which may cause accidents leading to serious damages. |
| Concrete barriers for warning to width reduction | -Locations where there is width reduction, such as at causeways. |

Source: JICA Survey Team

13) Demolition of Existing Structure

Road realignment may require removal of existing structures such as retaining walls and drainage. The scope of the demolition is minimal. Reinforced retaining walls and concrete barriers will be left for traffic security and stability.

14) Erosion Prevention Works

At Sta. 18+200, surface failures have occurred intermittently because of steep slopes and loosen geology. Moreover, steep slopes experience runoffs during the rainy season, which erode the surface. There is a high possibility that such surface erosion would destabilize Landslide C. Therefore, erosion prevention works are planned.

Construction condition is not good, therefore the adopted method is limited. Also, a high-intensity net that meets the requirements below is selected.

-The method is limited due to the steep slope. Also, Landslide C has been moving intermittently, thus construction has been done using safety loops and not scaffoldings.
-The slope experiences runoffs during the rainy season, therefore open type channels and structures should be adopted.
-Since the slope is loose, the surface is possible to move, therefore flexible structures should be adopted.

- The scale of slope failure is 1-2 m, therefore structures have to be designed to accommodate such scale of failure.

### 2.2.4 OUTLINE DESIGN DRAWING

The scale of the Project facility is as listed in Table 2.2.37, with the layout shown in Appendix-5.8.

**Table 2.2.37 List of the Project Facility Scale**

| Area | Item | Contents&Scale | Purpose |
|---|---|---|---|
| Landslide countermeasure （Landslide A and LandslideB） | Ground anchors | Length of construciton:50 m<br>Pieces:120<br>Length: 9.5-14.0 m, ΣL=1400 m | To deter the occurrence of landslide A which can reach up to 50 m (Sta.17+555-Sta.17+605) and cause cracks on the road. |
| | Crib works F500 | A=1,300 $m^2$,<br>Shotcrete within crib works: | |
| | Crib works F300 | A=300 m2, | |
| | Shotcrete | A=2,200 $m^2$ | To prevent infiltration of surface water. |
| | Embankment | Embankment volume: V=76,000 $m^3$<br>Vegetation: A=7,600 $m^2$<br>Drainage<br>Closed conduit: L=350 m<br>Open ditch (ground): L=350 m<br>Open ditch (embankment): L=650 m<br>Catch basin: Q=12 | Countermeasure against Landslide B. |
| Realignment (Landslide C) | Road length | L=170 m | Countermeasure against Landslide C.<br>The road is realignment to avoid Landslide B.<br>Road will be realigned in the stability zone. Road alignment and travel performance is improved.<br>Excavation at Sta.18+200 will be used as embankment material in Landslide B . |
| | Width of Road | W=4.75 m | |
| | Design speed | 20 km/hr（without hairpin curve） | |
| | Earthworks | V=76,000 $m^3$（diversion to embankment） | |
| | Pavement | Pavement: A=500 $m^2$, DBST: 500 $m^2$ | |
| | Crib works F300 | A=2,300 $m^2$<br>Sandbags within the crib works: 7,400 bags | |
| | Rock bolt | 560 lods, ΣL=1,700 m | |
| | Retaining wall | A=1,000 $m^2$ | |
| | Drainage | Drainage on the road: 200 m<br>Drainage on the cat walk: 350 m<br>Vertical drainage: 50 m<br>Pipe culvert: 10 m<br>Catch basin: Q=3 | |
| | Guard fence | Q=30 | |
| Erosion prevention works | High-intensity net | High-intensity net: A=5,500 $m^2$<br>Rock bolt: 1700 lods, ΣL=5,100 m | To protect the unstable slope, that is unstable, the road will be installed with high intensity nets and rock bolts. |

Source: JICA Survey Team

### 2.2.5 IMPLEMENTATION PLAN

#### 2.2.5.1 IMPLEMENTATION POLICY

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

- Maximize the use of local labor and construction materials for the Project for the purposes of strengthening the regional economy, generating job opportunities and promoting capacity development.

- Avoid traffic accidents caused by construction vehicles and minimize negative impacts of the Project against public transportation services.

- Minimize negative impacts to the surrounding environment such as traffic accidents, noise, vibration, exhaust gas, and dust, considering the existence of many villages and cultivated lands around the site.

### 2.2.5.2 IMPLEMENTATION CONDITIONS

#### (1) Labor Law

The contractor should manage its laborers properly with an adequate safety control plan, and should prevent conflicts with local laborers. In any circumstance, the contractor should abide by the labor laws and regulations enforced in Nepal.

#### (2) Traffic Control and Safety Management During Construction

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.

Furthermore, traffic signs should be installed at access-restricted and traffic-controlled locations to avoid accidents within the working area. Public relations on safety should be actively implemented as well.

There are possible danger zones at the site due to steep topography, cutting in narrow working spaces, deep structure excavations at valley side, etc. Therefore, rock-fall prevention works, installation of safety fences and designation of access-restricted areas should be carried out.

#### (3) Consideration for Surrounding Environment and Residents

It is required to consider the surrounding environment and its residents in order to minimize the negative impacts due to construction. The following measures are to be conducted:

- Low speed driving of construction vehicles (maximum speed of 10 km/hr)
- Use of low-noise and low-vibration types of generators

#### (4) Construction During the Rainy Season

Dangerous works on the steep slope, such as high intensity net works at Sta. 18+200, should be avoided during the rainy season. It is necessary to formulate a construction schedule assuming that works cannot progress during the rainy season.

#### (5) Transportation of Construction Materials to the Site

All construction materials will be transported along Sindhuli Bazar Road. Under this condition, the supply of construction materials must be ensured since it greatly influences the progress of construction. Hence, it is necessary to provide a transportation route in Sindhuli Road.

#### (6) Important Items on Quality Control

The life span of countermeasures depends much on the quality of the main structures of the Project such as anchoring materials and concrete structures. Therefore, the quality of anchoring materials and concrete should be controlled with great care.

#### 2.2.5.3 SCOPE OF WORKS

The revised scope of works to be undertaken by the GOJ and GON are as shown in Table 2.2.38.

**Table 2.2.38 Scope of Works undertaken by GOJ and GON**

| Responsibilities of GOJ | Responsibilities of GON |
|---|---|
| - Consulting services for detailed design, preparation of tender documents, assistance to DOR in tender process, and construction supervision<br>- Construction of countermeasures in the drawings<br>- Installation and removal of temporary facilities (construction yard)<br>- Protective measures against environmental pollution during the execution of construction works<br>- Procurement, import and transport of equipment and materials required for the improvement works and re-export of imported equipment | - Free provision of site (land), temporary facilities and other construction activities for the execution of works<br>- Execution of environmental monitoring<br>- Compensation to private houses and land around the site<br>- Removal and relocation of existing public utilities<br>- Free provision of traffic control and management for existing roads<br>- Execution of traffic safety awareness training for local residents, students, bus passengers and driver, and police officers<br>- Proper O&M for all completed facilities<br>- Advice and support to local residents for effective use of vacant land |

Source: JICA Survey Team

#### 2.2.5.4 CONSULTANT SUPERVISION

**(1) Supervision**

After signing of the Exchange of Notes (E/N) and Grant Agreement (G/A) between GON and GOJ regarding the detailed design, construction work and consulting services, JICA would recommend the consultant to carry out the detailed engineering design and preparation of tender documents.

The consultant would assist DOR in the tender process for construction work, i.e., pre-qualification, tender opening and evaluation, and subsequent negotiation, to conclude the contract between DOR and the successful tender.

The engineering services for construction supervision will commence with the acceptance of the construction contract and the issuance of a Notice to Proceed (N/P) to the contractor.

The consultant shall perform the duties in accordance with the criteria and standards applicable to the construction works and shall exercise the authority as designated engineer under the contract, to supervise the works of the contractor.

The consultant, within its capacity as the engineer, shall directly report to DOR and JICA Nepal Office on site activities, and issue field memos or letters to the contractor concerning various matters, including progress, quality, safety and payment for the works under the Project. In addition, the consultant shall report to the Embassy of Japan in Kathmandu, when required.

After one year from the completion of construction, the final inspection for defects liability shall be conducted as the final task of the consultant.

**(2) Implementation Organization**

The resident engineer will be basically stationed at the construction site and will conduct both construction supervision and project management. The designated specialists are as follows:

<u>- Chief Engineer</u>

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

Constantly remain on-site during the construction period to execute coordination and liaison for all the project activities for ensuring smooth the progress and management of all technical aspects. Conduct related activities such as management of materials, quality, safety, routine activities, workmanship, progress, schedule and payment. Moreover, coordination and discussions will be initiated.

- Slope Protection Engineer

Responsible for the quality of related works, such as ground anchor work, rock bolt reinforcement works and high intensity net works; assigned during significant operations; execute engineering judgment; and render advice for the shop drawings of Japanese engineers at the appropriate time, which is necessary since modification after commencement of works is difficult.

- Geotechnical Engineer

Assigned at the beginning, middle and later stages of earth removal works; execute engineering judgment for geological conditions of the cut slope.

#### 2.2.5.5 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. Quality certificates for purchased materials are required. Moreover, for materials, the quality condition of the contractor and supplier are confirmed for natural materials such as base course materials and aggregates. If it is judged that the quality control condition of a supplier is not sufficient, the consultant must request to revoke the test certificate to a different technical supplier in Nepal or overseas.The quality control plan needed in the Project is as shown in Table 2.2.39.

**Table 2.2.39 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 |

| Item | | | Test Method | Frequency |
|---|---|---|---|---|
| | Tension and settlement | Degree of set | Measurement of Degree | |
| | | Tensioning force | Measurement of Load | |
| | | Load-extension | Load-extension Diagram | |
| | | Confirmation of Settlement | Multi-cycle Confirmation Test | 6 anchors |
| | | | Single-cycle Confirmation Test | 114 anchors |
| | Treatment of the head | Treatment of the head | Measurement of Anti-corrosion Coating | Each hole |
| Crib Works | Material | | Certificate of Quality | All material |
| Concrete | Material | Cement | Quality Guarantee, Chemical & Physical Analysis | All material lots, once/half year |
| | | Water | Chemical Analyses | Every source |
| | | Admixture | Quality Certificate, Chemical Analyses | Every lot |
| | | Fine Aggregate | Bulk Specific Dry Gravity, Water Absorption, Sieve Gradation, Fineness Modulus, Clay and Friable Particles | Every material site |
| | | Coarse Aggregate | Bulk Specific Dry Gravity, Water Absorption, Sieve Gradation, Abrasion, Clay and Friable Particles, Sodium Sulfate Soundness | Every material site |
| | Mixing Test | | Compressive Strength (Cylinder Mold) | Every mixing test |
| | Placing | | Slump, Temperature, and Air Content | Every batch |
| | Test | | Compressive Strength (7 days, 28 days) | Daily |
| Re-bar | Material | | Mill Sheet, Tensile Strength | Annually or semi-annually |
| Base | Mixed Materials | | Liquid Limit, Plastic Index, Sieve Gradation, Maximum Dry Density (Compaction) | Every mixing |
| | Placing | | Field Density (Compaction) | Every 50 m |
| Temporary Road | Material | | Certificate of Quality, Feature Size | All material |
| Embankment | Material(Before construction) | | Minimum and Maximum Index Density Tests or Compaction Characteristics Tests | At first, as necessary |
| | | | Particle-Size Analysis Test | |
| | | | Specific Gravity | |
| | | | Moisture Content Test | |
| | | | Specific Gravity and Water Absorption Test W | |
| | | | Corrosion Content Test | |
| | | | pH Test | As necessary |
| | | | Phosphoric Acid Absorption-Index Examination | |
| | Construction (after construction) | | Field Density Test | At first, As necessary |
| | | | Field Permeability Test | As necessary |
| | | | Soil Hardness Testing | As necessary |
| Rock Bolt | | | Certificate of Quality, Feature Size | |
| High Intensity Net | | | Certificate of Quality, Feature Size | Each lot |

### 2.2.5.6 PROCUREMENT PLAN

#### (1) Labor

All kinds of laborers are available to be procured in Nepal and to quote the unit price cost based on the minimum requirement daily basis unit cost for the labors fixed in each district (DCC rate), which is announced every August and September.

Unskilled laborers can be procured near the site. However, particular and advanced skilled laborers in Nepal work in neighboring countries like India as well as in the Middle East, where construction is booming. Therefore, the number of skilled laborers for road construction has become limited in recent years. The assumed locations for procuring main labors are as shown in Table 2.2.40.

**Table 2.2.40 Assumed Locations for Procurement of Laborers**

| List of Laborer | Sindhuli District | Other Districts in Nepal | Japan | Note |
|---|---|---|---|---|
| Foreman | | ○ | | |
| Skilled Laborer | | ○ | | |
| Common Laborer | ○ | ○ | | |
| Rebar Worker | | ○ | | |
| Form Worker | | ○ | | |
| Heavy Equipment Operator | | ○ | | |
| Driver | ○ | ○ | | |
| Traffic Controller | ○ | ○ | | |
| Guard man | ○ | ○ | | |

Source: JICA Survey Team

#### (2) Construction Materials

The construction materials available in Nepal include natural materials, such as aggregates, stones, embankment materials, and timber. Cement, reinforcing bars, gabion wires, bituminous material and fuel are also available in local markets in Nepal. However, in order to ensure quality, special and quality items which are not available in the local markets must be imported from Japan. These include such materials used for anchor works, scaffolding, high intensity nets, and crib work frames. The procurement plan for major construction materials is as shown in Table 2.2.41.

**Table 2.2.41 Procurement of Construction Materials**

| Items of Construction Materials | Nepal | Third World Countries (e.g. India) | Japan | Note |
|---|---|---|---|---|
| Cement | ○ | | | Nepalese/Indian products are available |
| Aggregate (Coarse, Fine), Boulder | ○ | | | |
| Concrete Admixture | ○ | | | |
| Reinforcing Bars | ○ | | | Nepalese/Indian products are available |
| Gabion Wire | ○ | | | Export is possible |
| Bituminous Materials | ○ | | | Imported items available |
| Wood/Plywood | ○ | | | |
| Fuel (Diesel, Gasoline) | ○ | | | Imported items available |
| Materials for Ground Anchor | | | ○ | Quality and durability reasons |

| | | | | |
|---|---|---|---|---|
| Materials for Scaffolding | | | ○ | Quality and durability reasons |
| Materials for High Intensity Net | | | ○ | Quality and durability reasons |
| Materials for Crib Work Frame | | | ○ | Quality and durability reasons |
| Plaque Plate on Monument | | | ○ | Quality and durability reasons |

Source: JICA Survey Team

### (3) Construction Equipment

In Nepal, there are no equipment lease companies, and contractors own a limited number of equipment. Therefore, the equipment required for a long-term construction project in the remote area of Sindhuli District will be procured from Japan. The locations for procuring major construction equipment are as shown in Table 2.2.42.

**Table 2.2.42 Procurement of Major Construction Equipment**

| Items of Construction Equipment | | Nepal | Third World Countries (e.g. India) | Japan | Note |
|---|---|---|---|---|---|
| Bulldozer | 21 t | | | ○ | |
| Backhoe | 0.8 $m^3$ | | | ○ | |
| Dump Truck | 10 t | | | ○ | |
| Vibration Roller | 8-10 t | | | ○ | |
| Concrete Batching Plant | 30 $m^3$/hr | | | ○ | |
| Truck Mixer | 4.4 $m^3$ | | | ○ | |
| Boring Machine | 55 kW | | | ○ | |
| Aggregate Plant | 30 t/hr | | | ○ | |
| Electric Generator | 10.5-150 kVA | | | ○ | |
| Air Compressor | 3.5-11 $m^3$/min | | | ○ | |

Source: JICA Survey Team

### (4) Transportation Path

Construction materials and equipment procured from Japan will be shipped to Kolkata Port and then transported by land. The distance from Kolkata Port to the construction site is about 750 km. The transportation route is as shown in Figure 2.2.38.

## 2.2.6 SOFT COMPONENT PLAN

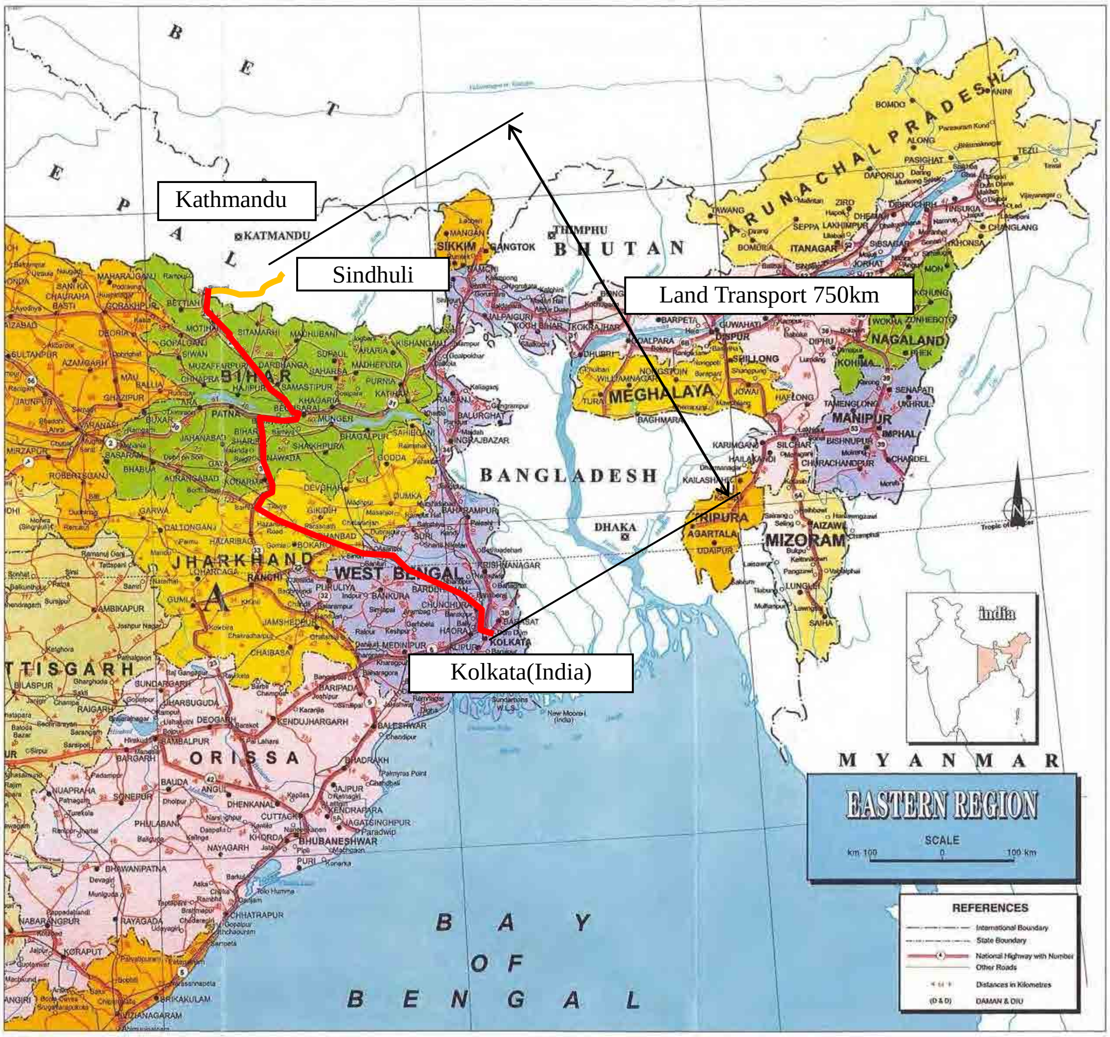
Soft component works will not be implemented.

## 2.2.7 IMPLEMENTATION SCHEDULE

After the signing of E/N and G/A between GON and GOJ, the consultant will immediately carry out the detailed engineering design and preparation of tender documents for the construction works, under Japan's grant aid scheme. Consulting services for detailed design would be completed in 2.5 months simultaneously in Nepal and Japan.

Initially, the consultant will assist DOR for about four months in the tendering process for construction works, which includes pre-qualification, tender opening and evaluation, and subsequent negotiations to conclude the contract between DOR and the successful tender. The signed contract will then be verified by GOJ.

After issuance of N/P, construction will commence. The estimated duration for construction of the project would be 25 months in total. The tentative implementation schedule is as shown in Table 2.2.43.




Source: India Map by India Tourism Authority (modified by Study Team)

**Figure 2.2.38 Transportation Route from Kolkota Port to the Project Site**

**Table 2.2.43 Tentative Implementation Schedule**

| Stage | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Detailed Design & Tender Assistance | Site Survey | ■ | | | | | | | | | | | | | | | | | | | | | | | | |
| | Detailed Design in Japan | □ | □ | □ | | | | | | | | | | | | | | | | | | | | | | |
| | Preparation of Tender Documents in Japan | □ | □ | □ | | | | | | | | | | | | | | | | | | | | | | |
| | Approval of Tender Documents | | | ■ | ■ | | | | | | | | | | | | | | | | | | | | | |
| | Preparation of Tender Documents in Japan | | | | □ | | | | | | | | | | | | | | | | | | | | | |
| | Tender and Contract | | | | | | ■ | | | | | | | | | | | | | | | | | | | |
| Construction | Preparation & Mobilization | ■ | | | | | | | | | | | | | | | | | | | | | | | | |
| | Sta.17+600 | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| | Sta.18+200 | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| | Demobilization | | | | | | | | | | | | | | | | | | | | | | | | | ■ |

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 road, spoil bank, borrow pit, construction yard and storage of materials and equipment);

To clear, level and reclaim land prior to the commencement of the Project;

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

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 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 nationals 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; and

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.

### 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 site clearance following the compensation of private residents in the project area;

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

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

#### 2.3.2.2 DURING CONSTRUCTION

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

To provide the right to use river gravel for free;

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 conduct all procedures regarding the diversion of traffic from the existing road and pedestrian tracks, and to secure land required for diversion;

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

To conduct all procedures regarding the diversion of water supply from existing facilities, and to implement such required diversion;

To secure traffic in Sections I, II and IV of Sindhuli Road;

To conduct environmental monitoring through DOR; 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 environmental monitoring and inspection through DOR;

To conduct traffic safety awareness training for bus commuters, drivers and traffic police;

To offer advice for regional development;

To maintain roads in cooperation with DWIDP;

To organize the network for O&M on the entire Sindhuli Road.

## 2.4 PROJECT OPERATIONS PLAN

### 2.4.1 NECESSARY O&M WORKS DURING CONSTRUCTION

An existing road (Section II) exists at the site, and Sindhuli Road Sections I and II would be used as haul road during construction. These roads should be maintained in good condition so that materials and equipment could be transferred to the construction site. It was considered that DOR has sufficient number of staff and funds to conduct such kind of maintenance works.

### 2.4.2 NECESSARY DAILY AND ANNUAL ROUTINE O&M ITEMS AFTER CONSTRUCTION

O&M activities need to be conducted on a daily basis, including cleaning of road facilities, simple maintenance of slopes, and small-scale repairs. These involve clearance of sediments in the drainage and patching of surface cracks and potholes. These activities have already been implemented by DOR for the opened sections of the road. DOR engineers of the Sindhuli Road Project office have conducted periodic observations to obtain information on the road condition, which will be utilized in carrying out efficient maintenance works.

Annual O&M activities include repairs of damaged ditches, cross drains, DBST surfaces, etc., and medium-scale rehabilitation works for slopes, retaining walls and other structures damaged or destroyed by disasters that occur almost every year. These works are carried out by contractors which are selected through a tendering process. The necessary daily and annual routine O&M items are as shown in Table 2.4.1.

**Table 2.4.1 Necessary Daily and Annual Routine O&M Items**

| Category | Structure | Activity |
|---|---|---|
| Daily | Side ditch | Removal of debris, simple repair |
| | Culvert | Removal of debris, simple repair |
| | Drainage works | Removal of debris, simple repair |
| | Slope | Grass cutting, removal of collapsed deposit |

| | | |
|---|---|---|
| | Road surface | Sweeping, patching of cracks and potholes |
| | Sign board | Removal of dirt |
| | Shoulder | Reshaping, simple repair |
| Annual | Side ditch | Repair of damaged portion |
| | Culvert | Repair of damaged portion |
| | Drainage works | Repair of damaged portion |
| | Retaining wall | Repair of damaged portion |
| | Road surface | Resealing of surface |
| | Slope | Repair of damaged portion |

Source: Study Team

### 2.4.3 PERIODIC O&M ITEMS AFTER CONSTRUCTION

Periodic O&M activities to be carried out for the Project are mainly for the overlay of DBST, painting of ancillary works, and repair of drainage structures. It is preferable that such works are conducted once in every three to five years. Furthermore, repairing the gabion wires is important as well. These works are carried out by contractors which are selected through a tendering process. The necessary periodic O&M items are as shown in Table 2.4.2.

**Table 2.4.2 Necessary Periodic O&M Items**

| Category | Structure | Activity |
|---|---|---|
| Periodic (once every five years) | Road surface | Sealing of DBST, overlay<br>Re-pavement of gravel base course |
| | Sign board | Painting, re-installation |
| | Others | Medium-/large-scale repair, repair of gabion wire |

Source: Study Team

### 2.4.4 URGENT REHABILITATION WORKS AND PREVENTIVE MAINTENANCE

In the Project area, including the haul road, unexpected natural disasters such as slope collapse and landslides are sometimes caused by heavy rains. In case the scale of such disasters is too large, it might be difficult for DOR to deal with the damages. However, based on experiences in Sections II and IV, normal-scale rehabilitation works can be conducted by DOR if sufficient budget is secured. Removal of collapsed deposit, urgent repair, detour route construction, traffic control and urgent countermeasures are conducted by DOR staff.

Preventive works against rockfall, collapse, failure and scouring are planned at necessary occasions.

## 2.5 PROJECT COST ESTIMATION

### 2.5.1 INITIAL COST ESTIMATION

The estimated initial costs of obligations of the recipient country are as shown in Table 2.5.1.

**Table 2.5.1 Estimated Initial Costs of Obligations of the Recipient Country**

(Unit Price: NRs 1,000)

| Item | Content | Quantity | Price (Remarks) |
|---|---|---|---|
| Land Use/Compensation | New Road at Sta. 18+200 | | Not required (public land) |
| | Land for excavating/filling | | Not required (public land) |
| | Material Cost at Borrow Site (167 NRs/$m^3$,Kamala River) | 20,000 $m^3$ | 3,340 (DOR) |

| | | | |
|---|---|---|---|
| | Compensation for land use of temporary access road (600/ha) | 12,800 m$^2$ | 770 (DOR) |
| | Land for camps of consultants office, house, etc. (Sindhulimali) | 10,000 m$^2$ | 600 (DOR) |
| | Land for cement plant (Sta. 13+300) | 3,000 m$^2$ | 180 (DOR) |
| | Land for stockpiling machines, equipment and materials (Sta. 17+200) | 3,000 m$^2$ | 180 (DOR) |
| Relocation of Public Facilities | Movement of water supply pipe at Sta. 17+600 | 200m | 5 (DOR) |
| IEE | Initial Environment Examination | one set | 500 (DOR) |
| Environmental Monitoring | ( once a month) (75/month) | 24 months | 1,800 (DOR) |
| Bank charge | Authorization to pay | one set | 1,500 (DOR) |
| Other Expenses | | one set | 430 |
| Total | | | 9,305 |

Source: JICA Study Team

The estimated initial cost of obligations of the recipient country is about NRs 9,305,000 including land use and compensation, relocation of public facilities, IEE, environmental monitoring and others.

### 2.5.2 O&M COSTS

O&M Costs for the Entire Sindhuli Road is shown in Table 2.5.2.

Maintenance cost for daily cleaning of road facility surfaces and others is approximately NRs 11,200,000 (JPY 12,790,000) per year. In addition, maintenance cost for regular maintenance works once a year and urgent rehabilitation works will be required. The annual maintenance cost to secure the sound maintenance of the entire Sindhuli Road is estimated to be NRs 74,750,000 (JPY 85,364,000). Although this corresponds to only about 3.7% of DOR's maintenance budget for FY 2010/2011, DOR is expected to have a sufficient expenditure capacity because DOR is planning to make priority allocation to this roads.

**Table 2.5.2 O&M Costs for the Entire Sindhuli Road**

| Category | Item | Cost | |
|---|---|---|---|
| | | NRs 1,000 | JPY 1,000 |
| (1) Daily maintenance | Cleaning, reduction of deposit, grass cutting, etc. | 11,200 | 12,790 |
| (2) Annual repair | Repair of road surface, side ditch, etc. | 7,000 | 7,994 |
| (3) Repair conducted once in five years (converted to annual cost) | Overlay, reshaping, repair of structures, repainting of traffic signs and steel structures, etc. | 38,000 | 43,396 |
| (4) Urgent rehabilitation works | Removal of collapsed soil, urgent rehabilitation, construction of detour route, etc. | 8,000 | 9,136 |
| (5) Preventative works | Preventative works against rock-fall, collapse, scouring and mudflow, etc. | 8,400 | 9,593 |
| (6)Landslide Monitoring (once a month) | Tiltmeter, Borehole inclinometer, Load meter of anchor, Visual inspection of Crib works, anchor works, Rock bolt works | 1,200 | 1,370 |
| (6) Monitoring after completion | Monitoring after completion of construction | 950 | 1,085 |
| Total | | 74,750 | 85,364 |

Source: DOR Project Office

Countermeasures planned in this project will not need to be maintenance, however O&M as shown in Figure 2.5.3 will be required. O&M of Drainage and Road surface have been conducted as a part of road maintenance of the entire Sindhuli Road. Hence additional maintenance cost is not required. On the other hand, Load meter of anchor and Visual inspection of Crib works, anchor works, Rock bolt works should be included the Landslide Monitoring.

**Table 2.5.3 O&M required for Countermeasures in this project**

| Item | Contents of O&M |
|---|---|
| Crib works and anchor works | Load meter of anchor, Visual inspection |
| Crib works and Rock bolt works | Visual inspection |
| Drainage (Road, embankment, cutting) | Cleaning, reduction of deposit, grass cutting, repair |
| Road surface | Repair of road surface |

# *Chapter 3*
# *Project Evaluation*

# CHAPTER 3 PROJECT EVALUATION

## 3.1 RECOMMENDATIONS

### 3.1.1 PRECONDITION FOR EXECUTION OF THE PROJECT

The precondition for execution of the project is described in Clause 2.3.

### 3.1.2 PRECONDITION AND EXTERNAL CONDITION FOR ACHIEVEMENT OF THE PROJECT

Practical operations and maintenance (O&M) system and organization for road maintenance will be built up in “THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD” which is being implemented currently by JICA. The road traffic of Sindhuli Road shall be kept sustainable by utilizing newly made O&M system.

## 3.2 PROJECT EVALUATION

### 3.2.1 PROPRIETY

Sindhuli Road with its total length of 160 km connects Dhulikel on the Arniko Highway (31 km eastward from Kathmandu) to Bardibas on the East-West Highway crossing the Terai Plain. It is recognized as one of the most important routes of the SRN and is prioritized as per the project list of the master plan. In the SRN, the project is stated as a support for poverty reduction and improvement of road network in Terai and middle hilly area for the purpose of achievement of the national development plan and from a national economical point of view. Furthermore, the Sindhuli Road construction will contribute to the improvement of stability, safety and economic growth of Nepal.

This project is to keep the safety from Sta. 17+400 to Sta. 18+200, which is the area with the highest probability of occurrence of critical sediment-related disaster in the Sindhuli Road. If the project is not implemented, there is a high probability of long-term road closure. The project is necessary to keep permanent road function. This project is justified for implementation under the grant aid scheme.

### 3.2.2 EFFECTIVENESS

According to the basic design results executed under the study, the project implementation would generate the following benefits:

#### 3.2.2.1 QUANTITATIVE EFFECTS

Running distance of traffic from Kathmandu to Bardibas in Terai Plain will be reduced about 140 km after the entire Sindhuli Road is constructed. And, roundtrip between Kathmandu-Central Terai Area that requires eight hours of travel time can eventually be done in just five hours.

In addition, project evaluation is carried out through benefit-cost ratio (B/C), economic net present value (ENPV) and economic internal rate of return (EIRR) analysis, all of which are generally employed in the evaluation of public works. Their indexes are evaluated as shown in Table 3.2.1.

In Sta. 17+600, B/C is 3.18 while in Sta. 18+200, B/C is 6.01. It is clear that this project has high investment effect. Prompt implementation is expected to generate higher investment effect.

**Table 3.2.1 Examination of Cost Benefits**

| Site | BCR | ENPV | EIRR |
|---|---|---|---|
| Sta. 17＋600 | 3.18 | 677,531,956 | 35% |
| Sta. 18＋200 | 6.01 | 2,296,729,117 | 60% |

Source: Study Team

### 3.2.2.2 QUALITATIVE EFFECTS

The following shows the benefits from the project:

a. Risks of interception of transportation to Kathmandu Valley will be reduced and stable supply of goods will be realized. Thus, damage to capital functions will be avoided and the lives of 2.51 million citizens will become stable.

b. By the implementation of this project, the psychic stability of road user (removal of unrest about road closure, etc.) and peripheral people will be improved.

c. Farm villages will be connected to the market, and thus, cash crop farming will be promoted and regional economy will be activated along the road.

d. Travel time will be reduced, with the commuters benefiting from safe transportation and traffic, thus, stable supply of goods within the region will be promoted. Moreover, the improvement of access to public services and welfare facilities including hospitals is expected.

e. By opening the all-weather road, areas along the road that have been less developed in terms of commerce, fabrication and housing industries will be developed. Investment effects will be improved which will contribute to regional development and poverty reduction of 1.54 million citizens living along the road.

Therefore, this project is considered to be of high priority and is supposed to bring about effective results.