資料２　実施機関との打合せに関するテクニカルノート

Technical Note : Design Concept

① Reply on the Reconsideration requested by DOR

② Geological Condition

③ Hydraulic characteristics

Design Concept

【Ensuring traffic safety】

As in sections II and IV of the Sindhuli Road, the lowest values of the geometric elements like the radius of horizontal curvature, vertical gradient etc. have been applied at sections where avoidance of high geometric standard is deemed necessary from the perspective of ensuring traffic safety.

【Disaster-resistant Alignment】

Learning from bitter experiences in the past, the alignment passing along the riverside has been avoided to the possible extent so as to avoid the occurrence of serious damage similar to those experienced in the Sindhuli Road section IV during the 2002 flood.

【Risk reduction of traffic accidents】

Bypass road has been considered at villages and communities to reduce the impacts like community severance, traffic accidents, access to farm and grazing lands etc. on the local people.

【Mitigation of relocation of houses】

The horizontal alignment has been planned by effectively utilizing the pilot road built by DOR and to minimize the number of relocation of houses.

【Reduction of earth work volume (Environment friendly)】

The horizontal alignment has been planned in reference to the construction method of the Sindhuli Road section II and IV and the Jiri Road with view to minimizing the slope works.

① Reply on the Reconsideration requested by DOR

1. 3+200 Steep Topography

As shown in the figure below, the center line passes above the steep topography area. The center line has been determined from the condition of continuity.

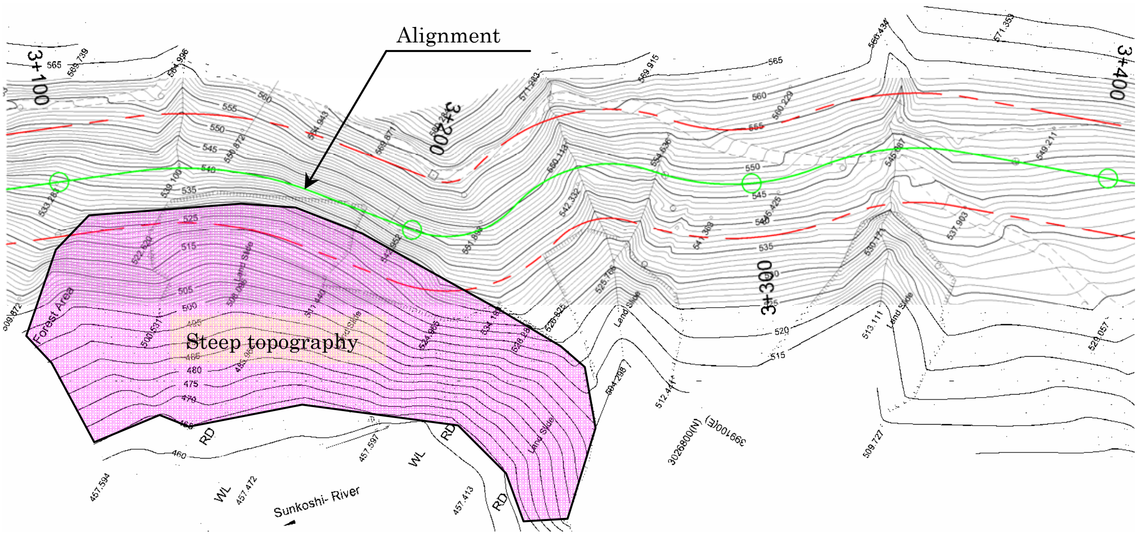


Fig. 1- Center line near station 3+200

2. 15+500～16+500 Koshi bank and appropriate location for crossing

Two routes are considered possible along this section, one along the foot of the hill and the next farther away from the hill. There are several houses, a school and a temple as well as cultivated land along the foot of the hill. If the center line passes along this area, about half the number of houses in Mulkot and large portion of cultivated land would be affected. Local people seem to be against the center line that passes along their land and houses and were complaining during the field investigation.

The proposed center line runs along the section presently being used as the pilot road. Sunkoshi River flows more than a hundred meters away from the center line. It was learnt from the hearing from the locals during the field investigation that the water from Sunkoshi has, not to their knowledge, risen up to the proposed road area. Therefore, it is assumed that the road will not be affected by Sunkoshi.

However, the crossing at Bhote Khola needs to be modified in accordance with the natural condition investigation to be conducted during the B/D, as it was not in the scope of the TOR.

3. 19+200～19+700 fragile geography and site for crossing

The center line is the modified alignment of the EIA center line in view of avoiding the houses to be in ROW.

The right side of the alignment is cultivated land, and the Sindhuli River is further right. The left side of the alignment, which is also a cultivated land, is more than ten meters higher than the right side and is slanted about 10 percent towards the left. A number of houses are located at the verge.

The shifting of the proposed alignment towards the left will require relocation of these houses as well as shorten the distance which would higher the vertical gradient. On the other hand, shifting it towards the right side will require long cut and fill.

During field investigation, the topography was not considered poor (fragile?) for if compacted more than N-value 4 could be maintained.

4. 24+600～25+300 steep cross slope, nearly 50m high depth cut may necessary

This section passes along a very steep ridge of the hill. The River Sindhuli flows along the foot of the hill. A large scale of cut is predicted but still has been proposed for following reasons.

(1) The pilot road established by the DOR has horizontal curvature of 6m radius and vertical gradient more than 10% and thus, does not satisfy the geometric requirements of roads.

(2) A tunnel could have been considered as an alternative, but at this stage, due to the insufficient investigation data and taking account of the presence of fault across the ridge, constant maintenance, lack of construction experience, and the safety of traffic, it has been judged not appropriate. According to the discussion with our experienced tunnel engineer, he could not recommend tunnel because of high risk, especially existence of fracture zone. It is out of our scope that various investigations are indispensable for reconsidering the possibility of a tunnel.

(3) The proposed alignment is 1.1 km long and approximately half to that of the road (2.4 km expected) along the pilot road. and therefore is economical.

(4) The pilot road can be used as an access road during the construction period of this section.

(5) Please refer ② Geology Fig. 2.

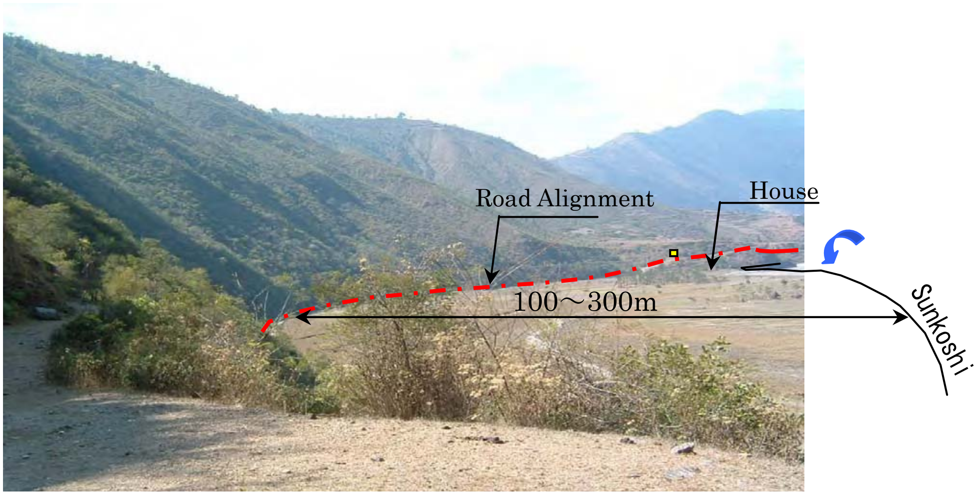
5. 26+600～27+900 （flood plain of Sunkoshi, Heavy protection work may require）

The mountainside of this section is unstable slope covered by a colluvial deposit and occurs slope collapse at the whole stretch of this section. It is recommended to avoid cutting slopes, which may cause to induce the collapse or landslide.

The low water channel of Sunkoshi River is located more than 100m apart from the foot of mountain (proposed alignment).

Even if water level rises to the mountain foot level at the time of the flood, flood velocity is small, and a road may not be damaged by the flood (Refer to ③ hydraulic characteristic).

And a private house exists in the floodplain, and it was confirmed that the water level of the Sunkoshi River had never come up to the mountain foot level in the past by the hearing from the local inhabitant



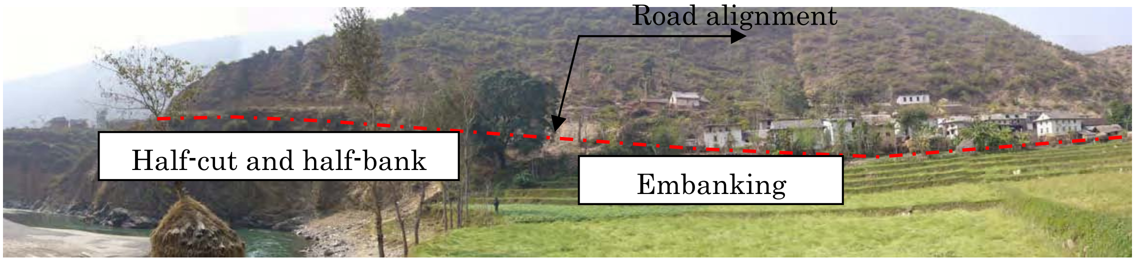
6. 29+200～29+400 （Steep Vertical Gradient）

In this section, the alignment rises from the low agricultural land of the Gajulidaha Village to the mountainous area. The vertical gradient of existing road is about 12% on average. And, about ten private houses is located just beside the left side of existing road.

If the alignment is shifted to mountain (left) side, the vertical gradient is gentle slightly but the houses to be relocated increase remarkably.

Though it is an rough review, a vertical gradient is set at about 8-10%, and it is planned embanking at the low agricultural land and half-banking and half-cutting at the mountainous area.

From now on, when the vertical gradient is planned all the line, the horizontal alignment may be changed slightly.



7. 29+900～30+700 （Large scale revetment and training dike）

This mountainside section is unstable steep slope area, which is covered by a colluvial deposit, and slope collapse occurs at the whole section. As shown in the photograph, an alluvial fan is active and large-scale slope failure can be seen around STA 30+000. Because of the geological condition of the section, if the alignment is shifted to mountain side, it can be foreseen that large-scale mountainside cutting is required and it may cause a new landslide and slope failure.

Moreover, due to the geometrical requirement of road, the alignment must be shifted to mountain side at connecting section (opposite side of the ridge : Gajulidaha).

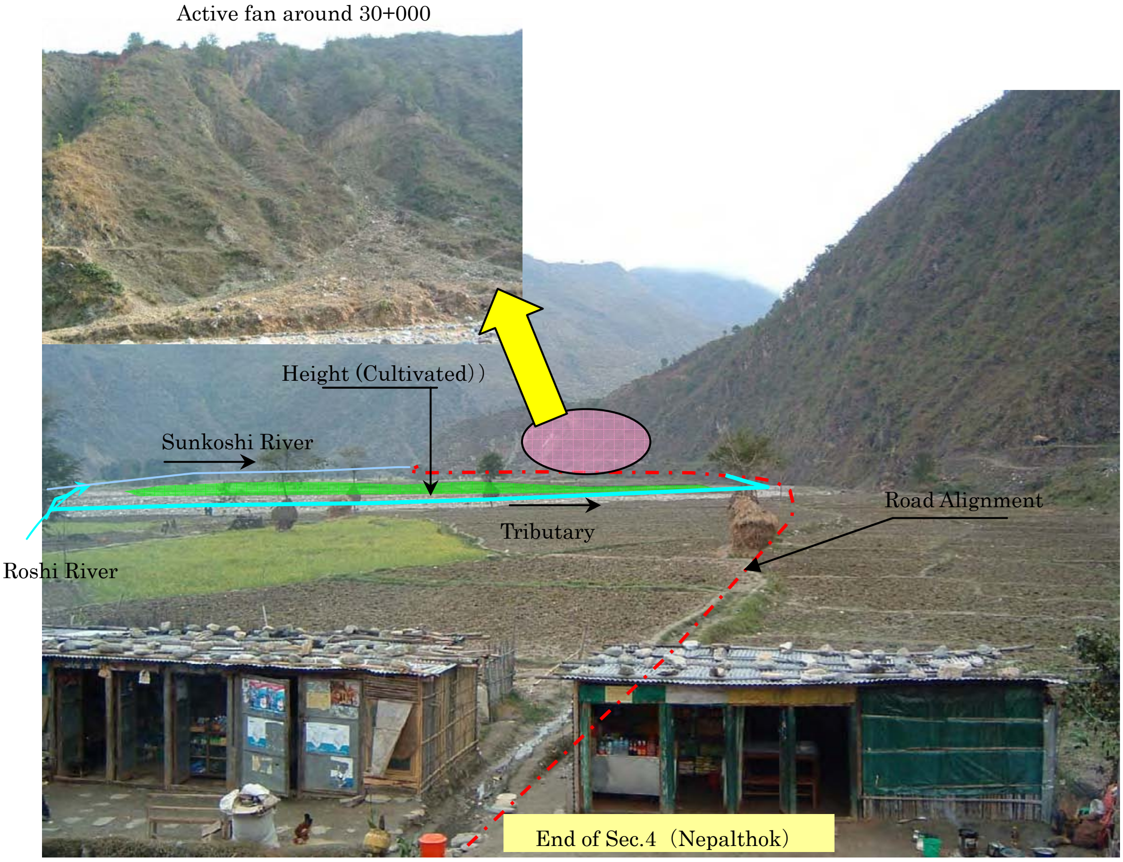
There are so many houses to be relocated at the three stepped mountainside slope of Gajulidha Village.

On the other hand, the Rosi River joins the Sunkoshi River at the neighboring flood plain. The riverbed slope is gentle there so that the flow velocity of the Rosi River declines and the alluvial fan is forming. This alluvial fan pushes aside the main stream of Sunkoshi River to the left bank and many tributaries run from the pivot of fan. One of tributaries separated by the Heights flows to the mountain side on the right bank, and this tributary runs and joins main stream of the Sunkoshi River around 29+800. This tributary of fan has small discharge and velocity.

As the erosive and conveyance action of the river depends on velocity and discharge, such tributary doesn't cause severe erosion and scouring.

During flood, the width of a river of this section is presumed several hundred meters, and velocity and depth of flow are assumed small.

And, the proposed alignment runs nearer the mountain side than EIA alignment.


Active fan around 30+000
Height (Cultivated))
Sunkoshi River
Roshi River
Tributary
Road Alignment
End of Sec.4（Nepalthok）

② GEOLOGICAL CONDITION OF THE ROAD ALIGNMENT BETWEEN KHURKOT AND NEPALTHOK, SINDHULI DISTRICT

The proposed road alignment between Khurkot and Nepalthok – Sector III of Banepa-Sindhuli-Bardibas Road is located within Sindhuli District. Geologically, the road alignment runs through the Lesser Himalayan Zone of central Nepal. The alignment mainly falls on phyllites and meta-sandstones of the Kuncha Formation of the Nawakot Complex. The first few kilometres passes through schists of the Raduwa Formation and parts of the road pass through slates and phyllites of the Benighat Slates. Similarly, parts of the road alignment also runs through alluvial, colluvial and residual soils and recent river deposits.

GEOLOGICAL SETTINGS OF NEPAL HIMALAYA

The Nepal Himalaya is located in the central part of the Himalayan arc and extends about 800 km. Like the other sectors of the Himalayan range, Nepal Himalaya is also divided into five tectonic zones, from south to north respectively (Table 1). The tectonic zones generally extend to east-west directions and run almost parallel to each other (Figure 1).

Table 1: Tectonic zones of Nepal Himalaya

Tectonic zone	**Thickness** (m)	**Age**	**Lithology**
Terai	1,500	Recent	Alluvium
Siwaliks (Sub-Himalaya)	5,000-6,000	Mid-Miocene to Pleistocene	Sandstone, mudstone, conglomerate
Lesser Himalaya	15,000	Precambrian-Eocene	Slate, phyllite, schist, quartzite, marble, granite
Higher Himalaya	5,000-12,000	Precambrian-Paleozoic	Schist, gneiss, migmatite, granite
Tibetan Himalaya	10,000-15,000	Cambrian-Paleogene	Shale, limestone, sandstone

Terai

The Terai forms the southern most tectonic unit of the Nepal Himalaya, having elevation from 100 to 200 m from mean sea level. To the north, it is often delineated by an active fault, the Main frontal Thrust (MFT). The Terai is covered by Recent alluvium. The basement topography of the Terai is not uniform. There appear to be a number of transverse ridges and valleys at the base of alluvial cover.

Siwaliks

This tectonic zone is bounded on the north by the Main Boundary Thrust (MBT) and on the south the Main Frontal Thrust (MFT), and is situated between the Lesser Himalaya and Indo-Gangetic Plain. It consists of fluvial deposits of Middle Miocene to Pleistocene age accumulated as a result of rapid upheaval of the Himalaya. The Siwaliks are divided into: 1) the Lower Siwaliks consisting of finely laminated sandstone, siltstone, and mudstone, 2) the Middle Siwaliks comprising of medium- to coarse-grained sandstones, and 3) the Upper Siwaliks composed of conglomerate and boulder beds. The dun valleys within the Siwaliks are made up of Quaternary fluvial sediments.

Lesser Himalaya

The Lesser Himalayan zone lies between the Siwaliks to the south and the Higher Himalaya to the north. Both the southern and the northern limits of the Lesser Himalayan zone is represented by the thrust fault: the Main Boundary Thrust (MBT) to the south and the Main Central Thrust (MCT) to the north. It is mainly composed of sedimentary and meta-sedimentary rocks such as slate, phyllite, schist, quartzite, limestone, dolomite, etc. The age of these rocks ranges from Precambrian to Eocene. There are also some granitic intrusions. Nappe and klippe like tectonic structures have made complexity in the Lesser Himalayan geology.

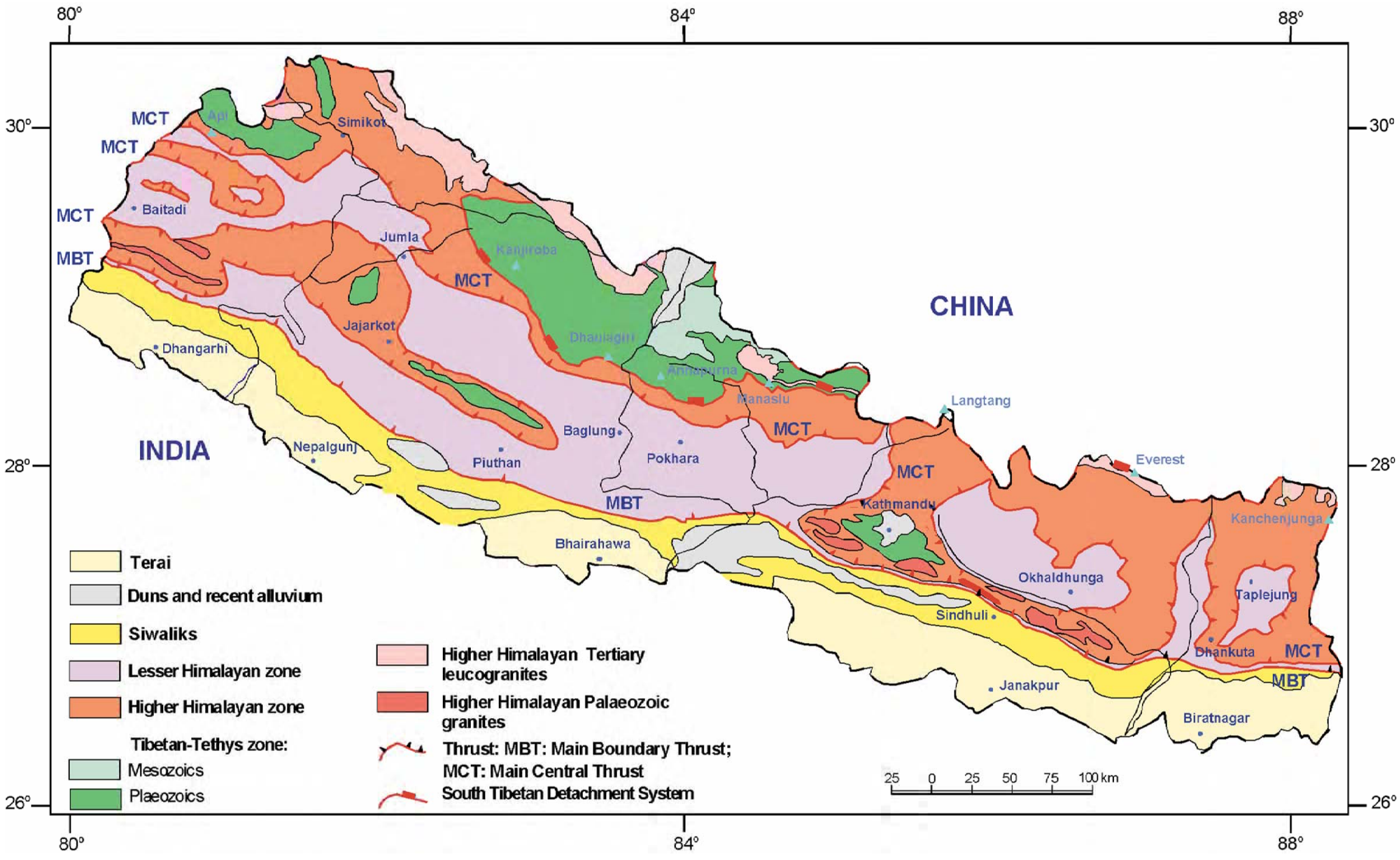


Figure 1: Geological map of Nepal

Higher Himalaya

This tectonic zone occupies the high mountains, and lies between the Lesser Himalaya to south and the Tibetan-Tethys Himalaya to the north, which is separated by the Main Central Thrust (MCT) in the south and north by a normal fault known as the South Tibetan Detachment System (STDS). High-grade, kyanite-sillimanite bearing gneisses, schists, and marbles are the main rock types of this zone. Granites are found in the upper part of this zone.

Tibetan-Tethys Himalaya

The Tibetan-Tethys Himalayan zone begins at the top of the Higher Himalayan zone and extends to the north in Tibet. The northern border of the Tethys Himalaya is represented by a fault, which stretches along the Indus and the Tsangpo rivers referring to as the lndus-Tsangpo Suture (ITS) and South Tibetan Detachment System (STDS) in the south. The rocks of this zone contain a number of various fossils. Most of the Himalayan peaks, including Mt Everest, Manaslu, Annapurna, and Dhaulagiri, belong to the Tibetan Himalaya. This zone is composed of sedimentary rocks such as shale, limestone, and sandstone.

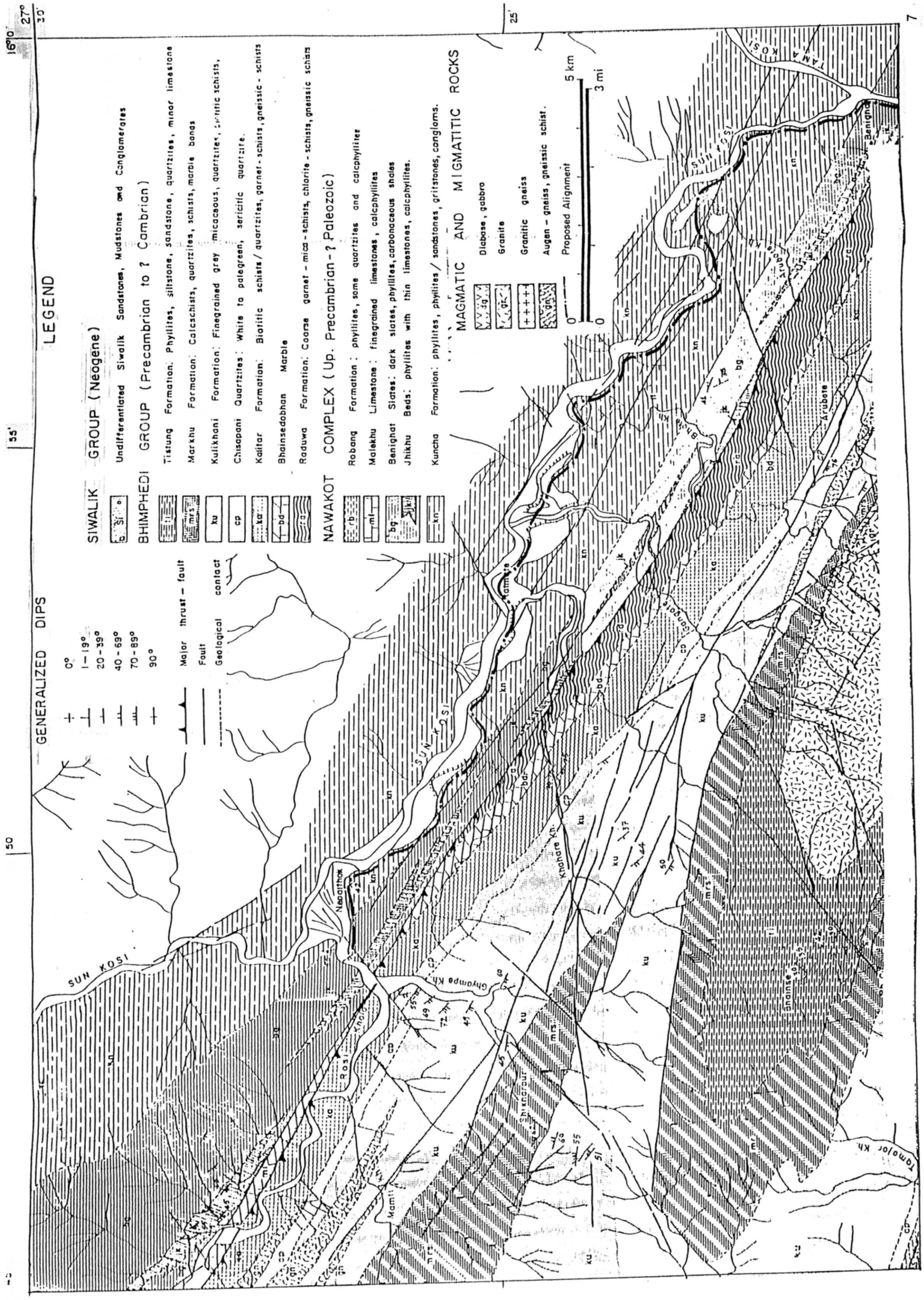
REGIONAL GEOLOGY

The rocks of the central Nepal are divided into two complexes, viz. Kathmandu Complex and Nawakot Complex (Table 2, Stocklin and Bhattarai, 1981). The rocks of the Kathmandu Complex are thrust over the Nawakot Complex along the Mahabharat Thrust (MT) (Figure 2).The Nawakot Complex consists of low-grade metamorphic rocks such as phyllites, slates and quartzites, and meta-sedimentary rocks like limestones and dolomites. It is subdivided into the Lower and Upper Nawakot groups, the two being separated by a disconformity (Table 2). The Kathmandu Complex is subdivided into the Bhimphedi Group that comprises relatively high-grade metamorphic rocks, and the Phulchowki Group of sedimentary and low-grade metamorphic rocks (Table 2).

Table 2 Lithostratigraphic Divisions of the Lesser Himalaya, Central Nepal (Modified from Stocklin and Bhattarai, 1981)

Complex	Group	Formation	Age	Lithology
		Godavari Limestone	Devonian	Green-purple argillaceous limestones
		Chitlang Formation	Silurian	Dark-violet slates and white quartzites
	Phulchauki	Chandragiri Limestone	Cambrian-Ordovician	Fine-grained yellow-brown limestones
		Sopyang Formation	Cambrian	Dark argillaceous limestones and marly slates
		Tistung Formation	Early- Late Cambrian	Grey slate, metasandstones and phyllites
	-------------	-------------------------	----------------------	-------------------**Transitional Contact**--------------------
Kathmandu		Markhu Formation		Schists, quartzites and marbles (50%)
		Kulekhani Formation		Fine-grained biotite schists and micaceous quartzites
				White of pale green quartzites
	Bhimphedi	Chisapani Quartzite	Precambrian	Dark grey-green mica schists and quartzites
		Kalitar Formation		Coarse-grained white marbles
		Bhainsedobhan Marble		Coarse-grained dark green-grey garnetiferous schists
		Raduwa Formation		________**Mahabharat Thrust (MT)**____________
________	_________	__________________	_________________	
		Robang Formation		Green-grey sericitic-chloritic phyllites & white
	Upper		Post-Early Paleozoic	quartzites
	Nawakot	Malekhu Limestone		Light yellow - dark grey dolomitic limestones
		Benighat Slates		Dark argillaceous slates
	***************	**************************	*************************	****************Unconformity*************************
Nawakot		Dhading Dolomite		Light bluish grey stromatolitic dolomites
		Nourpul Formation		White-pink strongly ripple marked quartzites &
	Lower		Lower Paleozoic	phyllites
	Nawakot	Dandagaon Phyllite		Dark green phyllites
		Fagfog quartzite		Orthoquartzites with several phyllite intercalations
		Kuncha Formation		Green phyllites, phyllitic metasandstones and gritstones
________	__________	_________________	_________________	______ **Main Boundary Thrust (MBT)** ________

Figure 2: Geological map of study area (modified after Stocklin and Bhattarai, 1981)



The studied road alignment comprises low-grade to high-grade metamorphic rocks of the Kuncha Formation of the Lower Nawakot Group, the Benighat Slates of the Upper Nawakot Group and the Raduwa Formation of the Bhimphedi Group (Kathmandu Complex) (Figure 2).

Kuncha Formation (kn)

The majority of the road corridor runs through the Kuncha Formation, which is the oldest formation of the Nawakot unit and perhaps of the entire Lesser Himalaya of Nepal. In the study area, the formation consists of a monotonous sequence alternation of phyllites, phyllitic quartzites and phyllitic gritstones. The phyllites have silky luster and are blue-grey and green-grey in colour.

Benighat Slates (bg)

In the study area, the Benighat Slates is consists of dark black slates and phyllites. Carbonate rocks are also frequently intercalated. The Benighat Slates has probably tectonic contact with the Kuncha Formation (?).

Raduwa Formation (ra)

The main rock type is a mica schist of coarse crystalline aspect. Red garnet is particularly characteristic and occurs in great abundance, sometimes in crystals up to 1 cm in diameter. The Mahabharat Thrust (MT) separates the Raduwa Formation with the Benighat Slates.

Soils

Genetically, the soils in the study area can be classified as alluvium, colluvium, and residual soil. All types of soils are often silty gravel and occasionally clayey silt. Gully erosion and translational and rotational slides occur in these soils.

Alluvial soils are deposited along the terraces. Alluvial soils in many places are almost completely weathered and are turned to residual soils. The alluvial soils are found at places much higher than the present river levels due to the upliftment of the Himalayas. The road alignment also passes the recent flood plains and alluvial fans. Colluvial soils are distributed on hill slopes of the study area. Residual soil area includes the soil formed owing to weathering of rocks and old alluvial soils. The thickness of these soils varies place to place.

The areas with less than 1 m cover of soils can be considered as rocky areas. Soil cover of 2-3 m is considered here as thin, that with 3-6 m as moderately thick and more than 6 m as thick.

GEOLOGICAL CONDITION OF THE ROAD ALIGNMENT

Chainage 0+000-0+800 Km

The first 150 m of the road corridor passes through the alluvial deposit (Photo 1), in which an alluvial fan also lies approximately between chainage 0+070 and 0+080. The fan seems not so active. Therefore, there may not be stability problem. Then the road alignment runs through the moderately thick colluvial material for about 250 m. Here the alignment follows the foot trail. After that it runs on the right bank of the Sunkoshi River, where the exposed rocks are schists and gneisses belonging to the Raduwa Formation of the Kathmandu Complex (Photo 2). The rocks are moderately to highly weathered. Near the Bhalu Khola, the rocks are slightly weathered. The dipping directions of the rocks are opposite to the natural slopes (towards SSW), but wedge failure is possible towards NE due to the intersection of two joints J1 and J2 (Figure 3). However, the wedges in the area are very small in nature.

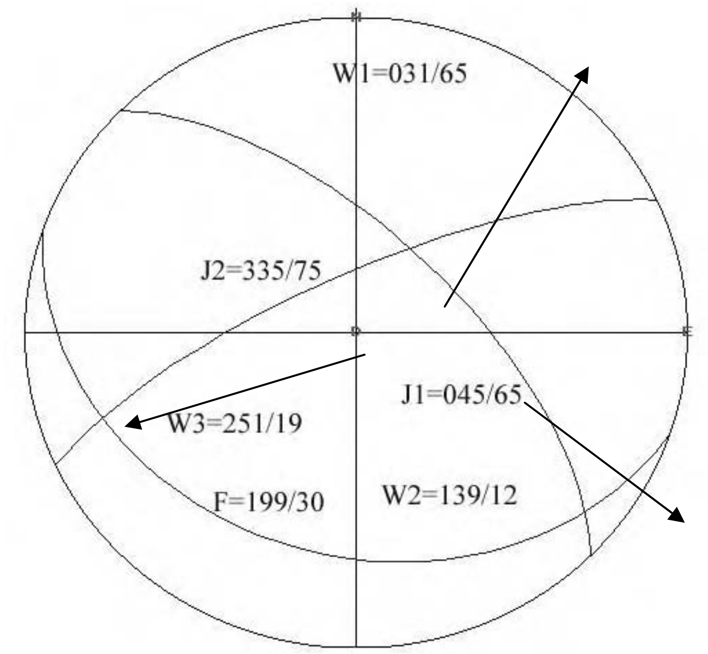


Figure 3: Stereographic projection of discontinuities measured near the point OS 810 of EIA study (2006). The projection is done on lower hemisphere.

Chainage 0+800-2+500 Km

At first the alignment crosses the fan of the Bhalu Khola for about 50 m. Then it passes through thin to moderately thick colluvial deposits. Near about the Bhadaure Khola, there exist thick alluvial deposits. Probably the Mahabharat Thrust runs near this point that separates the Raduwa Formation of the Kathmandu Complex and Benighat Slates of the Nawakot Complex. After that the alignment runs along the thin to moderately thick colluvial slopes (Photo 3 and 4) and also crosses several fans (Photo 3). The fans seem not active. The rocks in this chainage are basically represented by slates of Benighat Slates. Some limestone beds are also intercalated with the slates. The rocks are fresh to slightly to moderately weathered. Minor foldings are observed within the rock formation. The alignment passes the road on the right bank of the Sunkoshi River and follows the RTO road alignment (Photo 5 and 6). The road alignment direction and dipping of the bedrocks are opposite to oblique in direction (Photo 7 and Figure 4). Though the stability condition along the alignment is more or less good, there may cause some slope failure on colluvium.

Chainage 2+500-4+400 Km

This chainage is covered with rocks of phyllites of the Kuncha Formation. Metasandtones are also intercalated with phyllites. The rocks are moderately to highly weathered and fractured. Some parts of the section are covered with the residual soil (red in colour) and moderately thick colluvial deposits (Photo 8 and 9). The road alignment direction and dipping of the bedrocks are opposite to oblique in direction. Few slope failures are observed in this stretch (Photo 8). The main cause of the slope failures are bank undercutting, highly weathered rock along the proposed road alignment and geologic structure. Nearby the slope failure, a lineament (fault?) seems to pass through (Figure 2).

Chainage 4+400-6+750 Km

From the beginning of this sector to approx. 4+650, the alignment runs on the alluvial terraces and then it crosses the Nigule Khola (Photo 10) and follows mostly the RTO alignment (Photo 11, 12, 13 and 14). Then it runs through the residual soils produced from alluvial deposits (alluvial deposit composed of more than 80% boulders of granite). The moderate to thick residual soils are red to reddish brown in colour (Photo 11 and12). Some badlands are formed in this residual soil.

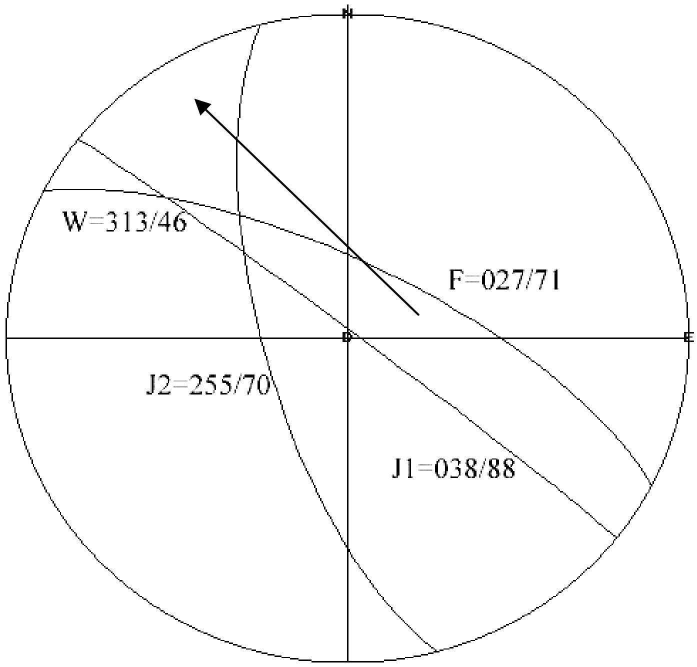


Figure 4: Stereographic projection of discontinuities measured near BM 50 of the EIA (2006). The projection is done on lower hemisphere.

Chainage 6+750-7+700 Km

From the Shitalpati village, colluvial deposits are found on the proposed road alignment, which more or less follows the trail (Photo 15). The colluvium is comprised of boulders of slate, phyllite and quartzite. The colluvium deposits are moderately thick. Approximately between 7+200 and 7+300, the bedrocks are observed.

Chainage 7+700-10+100 Km

Between these chanaiges the proposed alignment runs through thick residual soil deposits. Badlands are observed between 7+700 and 8+400 (Photo 16). The residual soils are product of the alluvium deposits. The big boulders of granite and gneisses can be found within the residual soils (Photo 17 and 18). Intensive gully erosion is observed on the residual soils deposit section. The stability condition after 8+400 is good (Photo 19) and the area has good cultivation (Photo 20 and 21). The bedrocks are not exposed anywhere within these chainages (Photo 22). Here, the proposed road alignment has not followed the RTO road alignment.

Chainage 10+100-11+600 Km

The road alignment crosses the Arubote Khola (Photo 23) and then runs through thin colluvial deposits up to 11+000. In this stretch, some parts of the road alignment (approx. 10+500 to 10+700) passes on the alluvium deposits (cultivated land) (Photo 24). Here, the road has not followed the RTO corridor. From 11+000 to Khahare Kholagaon the road alignment passes through the alluvial deposits.

Chainage 11+600-14+500 Km

The road alignment passes through moderate to thick colluvial deposits and follow nearly to the RTO road alignment (Photo 25, 26, 27, 28, 29 and 30), and lies between Khahare Kholagaon and Gahate village. The colluvium is comprised of big boulders, angular shaped quartzites and phyllites. In some places the bedrock of the quartzite and phyllite also exposed along the proposed road alignment, and moderately to highly weathered. Dip direction of the exposed rocks and the alignment of the road is oblique to opposite in direction, indicates less possibility of instability. However, the steepness of the rock slopes in this sector may cause instabilities after road cutting.

Chainage 14+500-15+100 Km

This section lies between Gahate village to Mulkot. The bed rocks are represented by phyilite and quartzite of the Kuncha Formation. These rocks are moderately weathered. Within these chainages thick colluvial deposits are having thickness more than 6 m. The colluvial deposits are composed of boulders and cobbles of the phyllite, schist and quartzite with matrix of silt and sand. Due to the silty portion in the colluvium and steep slope causes the slope failures. Nearby the slope failure (Photo 31 and 32), a lineament (Figure 2) seems to pass through. The fractured rocks on the hill slope are found at chainages between 15+000 and 15+100 (Photo 33). The stereographic projection of the rock mass shows that the area is relatively stable (Figure 5). Only one oblique joint dipping towards NE may cause some problem during the road cutting.

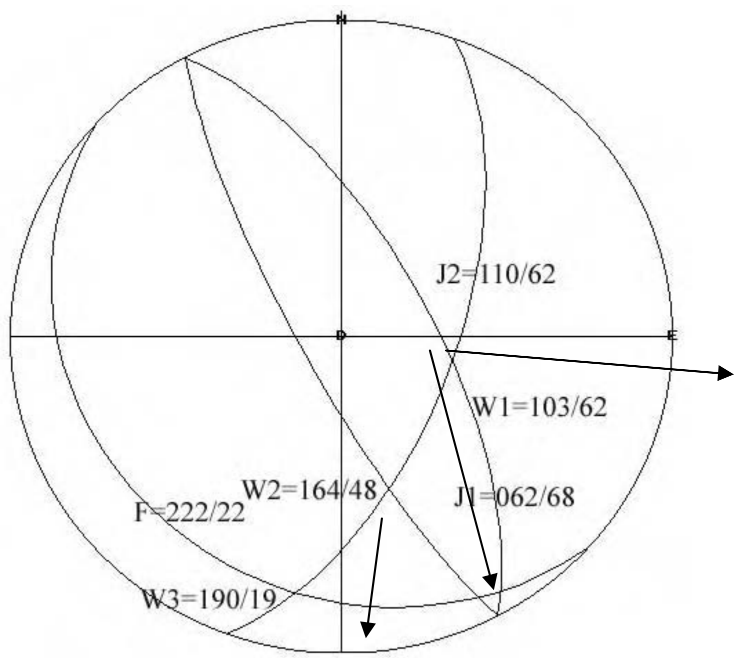


Figure 5: Stereographic projection of discontinuities measured near Ch. 15+000. The projection is done on lower hemisphere.

Chainage 15+100-16+750 Km

Within this section, the road alignment passes through alluvial deposits follow the left side of the Mukuteshwan Temple. The alluvial deposit is very thick, now used for cultivated land (Photo 34). The hill side of the alignment is covered by the colluvial deposit. The stability condition of the road alignment is good.

Chainage 16+750-19+400 Km

Between these chainages the road alignment passes through mostly on residual soil that is the weathering product of thick alluvium deposits (Photo 35). Ramtar and Saitar lie within the section. Beneath the residual soils, more than 20 m thick alluvial deposits of the Sunkoshi River can be seen. The topography is gentle on the road alignment and steep at the foot of the hills. A small stretch between 17+900 and 18+100, the road alignment passes through thin colluvium and rocky zone (Photo 36) and near 18+500 (Photo 37).

Chainage 19+400-21+400 Km

After crossing Gangate Khola (Photo 38), the road alignment goes down to Katahare village, passes through the alluvial deposits (cultivated land) and then through thick residual soil (Photo 39). In the upper part of the chainage 20+300, badland topography is observed.

Within the section between 21+000 and 21+400, the road alignment runs on the alluvial fan (cultivated land) of the Dhamile Khola (Photo 40) and does not follow the RTO road. The thickness of the alluvium deposit is more than 6 m. The RTO road alignment followed about 300 m upstream from the proposed road alignment at the Dhamile Khola. The RTO road alignment section is rocky area (mainly the phyllite and quartzite) of slightly weathered condition. On the left bank of the Dhamile Khola, bedrock exposures are found.

Chainage 21+400-23+150 Km

In the beginning of the sector upto 21+850, mainly colluvial deposits are found on the road alignment. The rocks of the phyllite and quartzite are also observed in some parts of this stretch (Photo 41). The rocks are more or less stable and alignment and the dip direction of the bedrocks are opposite. Then the alignment runs on the residual soil derived from alluvium. The hill slope is mainly covered by colluvial materials ranging in thickness from 2 to 6 m.

Chainage 23+150-24+400 Km

In the beginning, the road alignment passes through the rocky area basically composed of quartzite. The rocks are moderately weathered. The dip direction of the bedrocks and natural hill slope is in same direction (Photo 42). So there is possibility of plane failures (Figure 6). Thick colluvium deposits are found on the rocks. Then the colluvial and residuals soils with thickness of more than 3 m are encountered upto the crossing of the Sadhi Khola. The last sector of the road alignment lies on the colluvium.

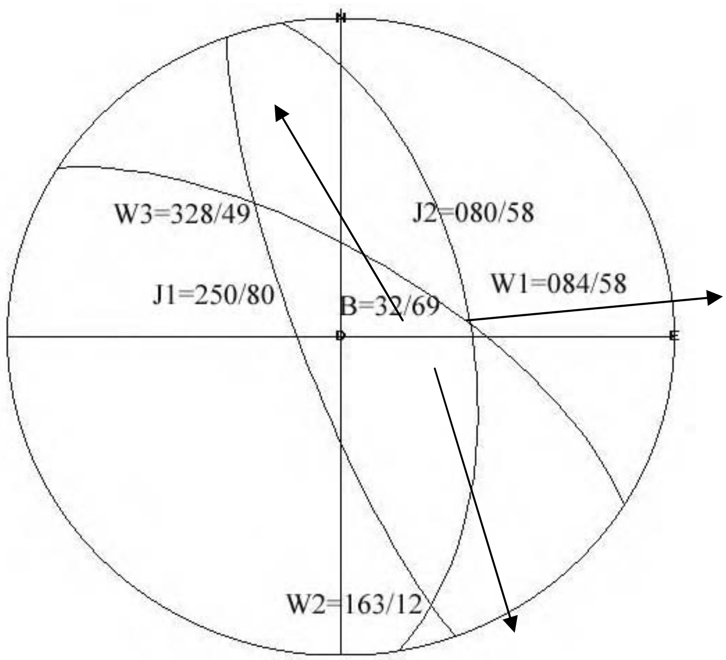


Figure 6: Stereographic projection of discontinuities measured near Ch. 23+000. The projection is done on lower hemisphere.

Chainage 24+400-25+150 Km

This is the steep rock slope mainly composed of the rocks of quartzite and phyllite (Photo 43, 44 and 45). The rocks are moderately to slightly weathered having three sets of the joints. In places, the road corridor has also thin cover of colluvial deposits. The alignment of road and the dipping of the bedrocks are oblique to each other (Figure 7). However, possibility of wedge failure can not be ignored upto 25+100. A faulted anticlinal axis passes at about 25+100. The fault does not seem to be active.

The discontinuities measured between 25+100 and 25+150 show that the dipping of the bedrocks are opposite to hill slope however wedge failure is possible (Figure 8).

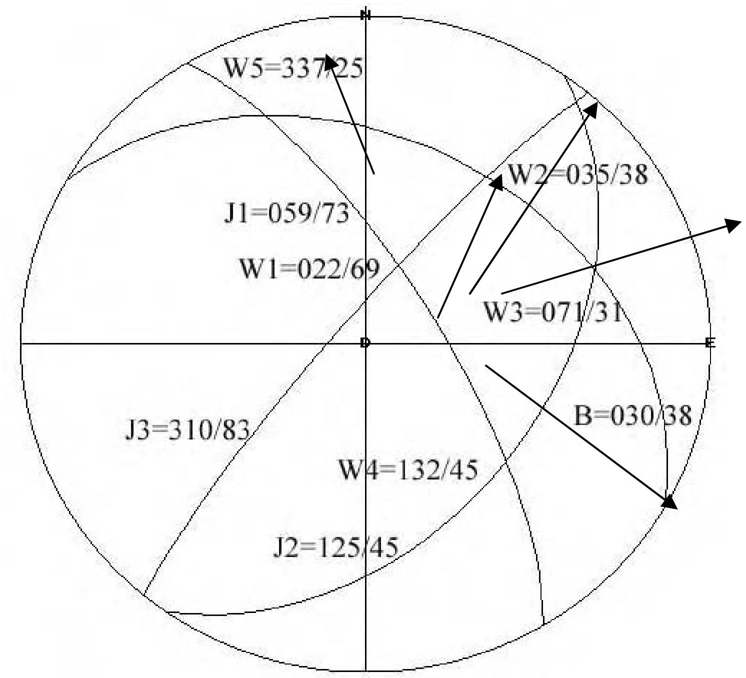


Figure 7: Stereographic projection of discontinuities measured near 25+050. The projection is done on lower hemisphere.

There are possible three alternatives after crossing the Sadhi Khola:

1) to follow the existing the trial road
2) to follow the existing trail along the right bank of the Sun Koshi, and
3) to drive a tunnel to reach near 25+150

Merits and demerits of the alternative I:

a) Only improvement of grade may suffice to construct road.
b) The slope is weak and a part of the alignment runs through the Sadhi Khola

Merits and demerits of the alternative II:

a) The grade of the alignment is gentle.
b) Rock cutting on steep slope is difficult and road construction will be highly complicated between Ch. 25+050 and 25+150.

Merits and demerits of the alternative III:

a) The length of the road will be shorter and avoids the rock cutting of the alternative II and flood plains of the alternative I.
b) It should pass through a fault.

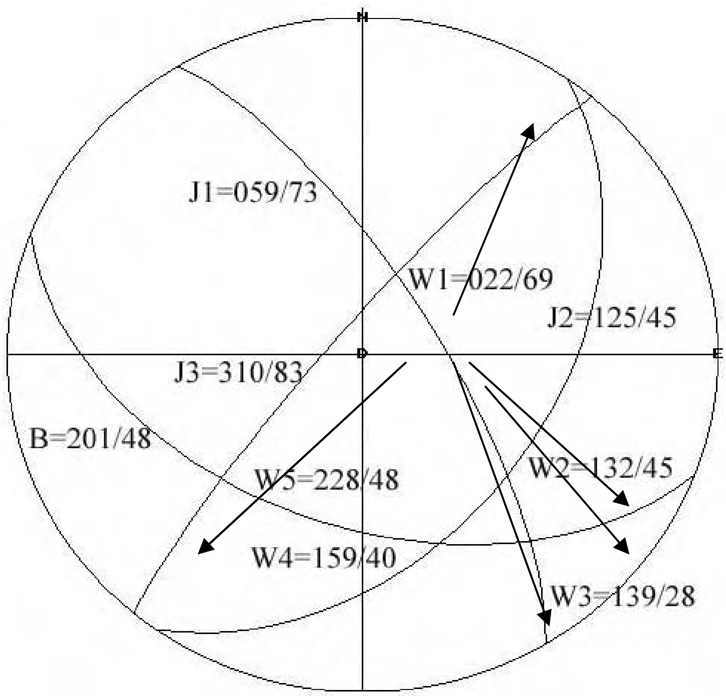


Figure 8: Stereographic projection of discontinuities measured near 25+125. The projection is done on lower hemisphere.

Chainage 25+150-26+400 Km

The road alignment is composed of thick colluvium deposits and also the moderately weathered rocks of quartzite and phyllites. The alignment of the road and the dipping of the bed rock are opposite to each other and some places the alignment and the dipping of the bed rocks are oblique direction. At the end of this sector, slates of the Benighat Slates are also encountered. The rocks are highly feactured and moderately to highly weathered.

Chainage 26+400-27+550 Km

The bedrocks (slate and limestone of the Benighat Slate) are exposed on the hill side (Photo 46). The road alignment runs on the flood plain of the Sunkoshi River (Photo 47). Silty sand to sand and cobble and pebble are observed on the wide valley. For the stability of the road corridor, it is better to avoid slope cutting.

Chainage 27+550-29+800 Km

Along the road alignment mainly the alluvial deposits are found (Photo 48, 49, 50, 51, 52 and 53). Thin to moderately thick alluvium of the Sunkoshi River are composed of boulders of granite, quartzite. A deep gully is formed at the hill side of the Ch. 29+250 on old alluvium partially changed to residual soil. Only in few places, small rock outcrops are observed along the alignment. The rocks are well observed at the right bank of the Sun Koshi (Photo 49, 50 and 53). The discontinuities at the cliff near 29+800 are projected on a sphere (Figure 9). Though the foliation plane is counter dipping, however there is a possibility of joint plane failure towards N.

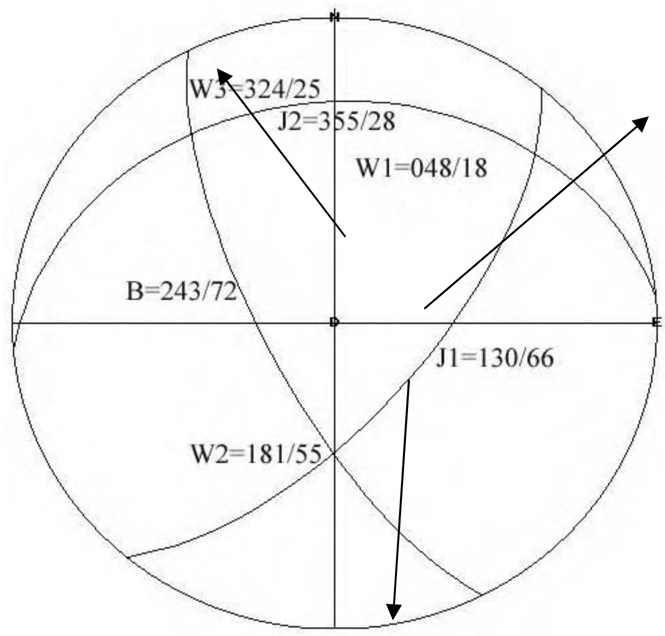


Figure 9: Stereographic projection of discontinuities measured near 29+800. The projection is done on lower hemisphere.

Chalnage 29+800-31+023 Km

The alignment runs mainly on the flood plains of the Roshi Khola (Photo 57). The alluvial deposits are thick boulders of quartzites, granite and gneiss. The bedrocks are exposed on the hill slopes. They belong to Kuncha Formation and the rocks are mainly represented by phyllites, which are fractured and highly to moderately weathered. In places, the rocks are changed into the residual soil. Thin layers of the colluvium (mainly phyllite and schist) and topsoil (0.5 to 1 m thick) are found lying over the bedrocks. At this sector some slope failures are encountered (Photo 54 and 56). An active fan is found at 30+000 (Photo 55). But these will not have effect if the road alignment does not pass through the hill slope. The road alignment and attitude of the bed rock are oblique direction. However, there is possibility of rock failure (Figure 10).

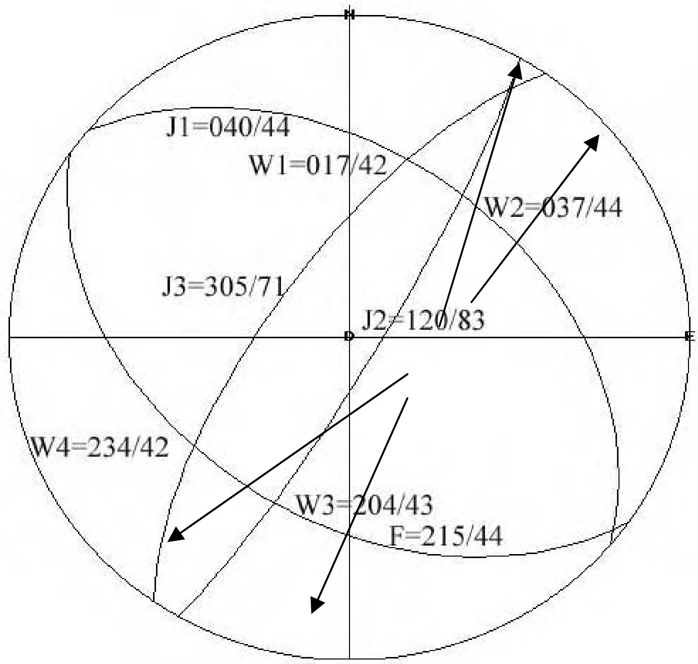


Figure 10: Stereographic projection of discontinuities measured near 30+900. The projection is done on lower hemisphere.

ABBREVIATIONS / GLOSSARY

Alluvium (Alluvial soil) - Detrital material deposited by a river, e.g. on the flood plains.
Anticline - A fold that is convex upwards with the oldest rocks in the core.
Bedding/Bedding plane - Surface parallel to the surface of deposition in the that divides sedimentary rocks. It is caused by changes in mineralogy, grain-size, colour, etc.
Boulder - Rock fragments having diameters greater than 256 mm.
Colluvium (colluvial soil) - Fragments of rocks deposited at the toe of a failed slope.
Conglomerate - A coarse-grained clastic sedimentary rock composed of rounded or sub-rounded fragments larger than 2 mm in size and bounded by siliceous or argillaceous materials.
Cross-bedding - Internal structure of a sedimentary bed characterized by the presence of inclined thin laminae (foresets) and the bed is generally separated from the top sets and bottom sets.
Dip - The angle between any planar discontinuity surface and a horizontal plane measured in a vertical plane perpendicular to the discontinuity.
Dip-slope - Topographic surface dipping in the same direction as the underlying beds. It is often more or less parallel to them.
Discontinuity - A plane cutting a rock mass. Discontinuities of similar strike and dip form a set.
Drainage pattern - The arrangement and dispension of shears which a drainage system is etching into the land surface.
Fault - A fracture or fracture surface where block movement has occurred parallel to itself.
Flood plain - A flat land bordering a river, mainly at lower reaches with alluvium deposited by river.
Foliation - Parallel orientation of platy minerals in metamorphic rocks.
Fossil - An organic remain in the rock, preserved since sometime in the geological past.
Fold - Any non-planar configuration of rock resulting from deformation.
Formation - A litho-stratigraphic rock unit used as a basis for geological mapping, having some common character and are mappable as a unit.
Gneiss - A metamorphic rock of coarse grain size, characterized by mineral banding, in which the light minerals (quartz and feldspar) are separated from the dark ones (mica and/or hornblende).
Granite - A coarse-grained igneous rock having granular texture with megascopic quartz (25% in average), feldspar, and mica or other coloured minerals.
HFT - Himalayan Frontal Thrust
JICA - Japan International Cooperation Agency
Joint - Fracture in rock mass almost vertical or transverse to bedding/foliation along which no

appreciable movement occurred in the direction parallel to the fracture.

Limestone - A bedded sedimentary rock consisting chiefly of calcite minerals ($CaCO_3$).

Marble - A granular crystalline metamorphosed limestone.

MBT - Main Boundary Thrust

Metasandstone - Metamorphosed sandstone

Metamorphic rocks - Rocks that have changed mineralogically and/or texturally in a solid state as a result of change in temperature and pressure in the earth's crust.

Miocene - An Epoch of the Tertiary Period between the Oligocene and the Pliocene Epochs.

MT - Mahabharat Thrust

Pebble - Rock fragments which have a diameter between 4-64 mm.

Persistence - Prolongation of a discontinuity in a rock mass.

Phyllite - A cleaved argillaceous rock of the medium-grade metamorphism (between slate & schist). The mica minerals impress a silky sheen to cleavage surface.

Plane failure - A rock slide occurring along a plane of discontinuity.

Quartzite - A metamorphic rock consisting essentially of quartz

Residual soil - Soil formed in place by the disintegration and decomposition of rock and the consequent weathering of constituent material. It is presumed to be developed from the same rock on which it rests.

Reverse fault - A fault along which the hanging wall has moved relatively upwards.

Rockslide - The downward and usually rapid movement of newly detached segments of the bedrock sliding on bedding, foliation or joint (plane failure) or along the intersection of two discontinuities (wedge failure).

Rock Topple - A rock failure that occurs through gradual opening of discontinuities dipping parallel and steeply to and into a steep rock slope. Rock topple also occurs when discontinuities cut rock mass lying over another incompetent (weak) rock mass.

Rotational slide - The downward slipping of a mass of unconsolidated material or loose rock measuring as a unit or as several subsidiary units with backward rotations on an almost horizontal axis parallel to the slope from which it descends.

Sandstone - A sedimentary rock composed essentially of sand grains in a matrix of clay or silt. Quartz and feldspar form the major constituents.

Schist - A metamorphic rock that has a tendency to split due to the presence of folia of flaky and elongated minerals.

Shale - A fine- grained sedimentary rock made up of clay or mud.

Siltstone - A fine-grained sedimentary rock principally made up of silt-sized grains.

Slate - A fine-grained low-grade metamorphic rock possessing well-developed fissility (slaty cleavage).

Spacing - Perpendicular distance between the two adjacent joints of the same set.

Structural pattern - The geometrical relationship between the discontinuities (bedding, foliation, and joints) in a rock mass.

Syncline - A fold that is convex downwards with the youngest rocks in the core.

Thrust fault (thrust) - A low-angled (>30o) reverse fault.

Translational slide - A movement of material where the failure surface at depth is roughly parallel to the ground surface.

Watershed - Boundary to adjacent drainage system.

Weathering - The process of disintegration and decomposition of minerals and rocks as a consequence of exposure to the atmosphere and to the action of frost, rain and insolation.

Wedge - A volume of rock defined by two intersecting discontinuities.

Width (aperture/opening) - The perpendicular distance between the adjacent walls of a discontinuity.

ROCK WEATHERING GRADES

Weathering grade	Description
1a	Fresh rock. No visible sign of weathering.
1b	Faintly weathered. Discoloration on major joint surfaces.
2	Slightly weathered. Discoloration of all discontinuity surfaces or throughout rock.
3	Moderately weathered. Up to 50% of rock material decomposed and/or disintegrated to soil. Rock can be a continuous mass, or core stones.
4	Highly weathered. More than 50% of rock material decomposed or disintegrated to soil. Rock mass is discontinuous.
5	Completely weathered. All rock material decomposed and/or disintegrated to soil. Original mass structure still largely intact.
6	Residual soil. All rock material converted to soil. Mass structure and material fabric destroyed.

Source: Geological Society Engineering Group Working Party, 1977. The description of rock masses for engineering geology, Engineering Geology 10 (4) pp. 355 - 388.

③ Study on hydraulic characteristic of Section 3

1. Estimation of the Discharge at River Channel Control Point

River Channel Control Point：Khurkot Suspension Bridge（Refer to **Cover Map**）

Case 1 — 6m depth (Assumed Section for Eatimation)

80m width

Section A= 80m×6m= 480 m2

Hydraulic radius R= 480÷92= 5.22 m

Coeff. of roughness n= 0.035 (same value as Sec. 4's)

Inclination Ie=Ib= 0.0023 (Aberage Inclination of Sec. ３'s Riverbed)

velocity v = $1/n \times R^{2/3} \times I^{1/2}$

= 4.12 m/sec

Discharge Q= A × v＝ 1,979 m3/sec

Case 2 — 7m depth (Assumed Section for Eatimation)

80m width

Section A= 80m×7m= 560 m2

Hydraulic radius R= 560÷94= 5.96 m

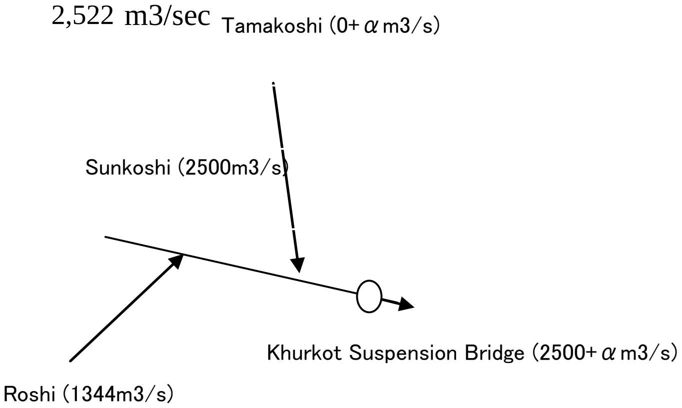
Coeff. of roughness n= 0.035 (same value as Sec. 4's)

Inclination Ie=Ib= 0.0023 (Aberage Inclination of Sec. ３'s Riverbed)

velocity v = $1/n \times R^{2/3} \times I^{1/2}$

= 4.50 m/sec

Q= A×v＝ 2,522 m3/sec



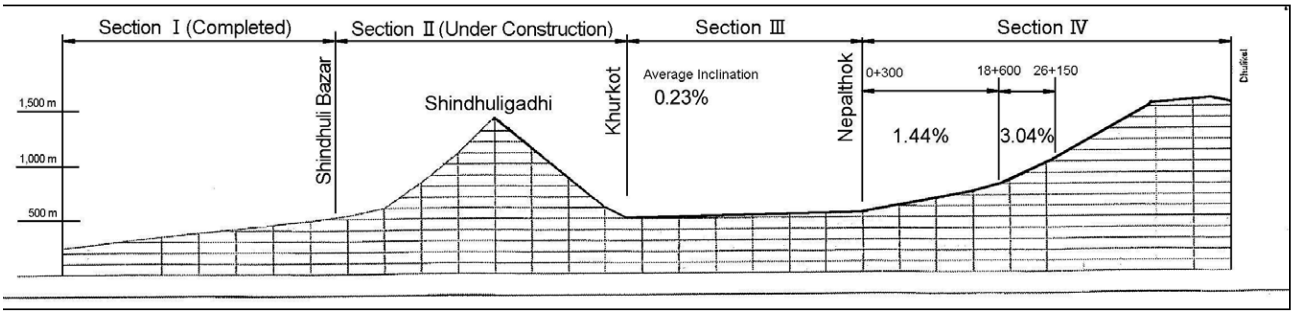
∴Q=2,500m3/sec, To be the estimated value.

2. Velocity of Sunkoshi River at Sec. 3

Flow section is assumed to be rectangular.

	Velocity (Manning's formula)			Sec. 4	Refer to the result of
	Case 1	Case 2	Case 3	down-stream	non-uniform flow
Inclination Ie=Ib=	**0.23%**			**1.44%**	Analysis at Section 4
Coeff. of roughness n=	0.035				(Use 51 River Cross sec.)
Estimated discharge	2,500 m3／sec				1,344 m3/sec
Channel Width (m)	200	300	400		Avrg. W = 93 m
Calculated Velocity	**3.34**	**2.82**	**2.53**		**Avrg, v = 5.39** m/sec
Water Depth (m)	3.80	2.95	2.50		Avrg. D = 2.68 m
sub or super critical	sub-critical flow	sub-critical flow	sub-critical flow		Super-critical flow
Stable River Bed Material Dia.	10.5cm	8.2cm	6.9cm		~~(40cm)~~ Avrg. I =1.44%

Inclination of riverbed ≒ Inclination energy　　Steep Inc. River　Ib＞0.6～2.5% →Super-critical Flow



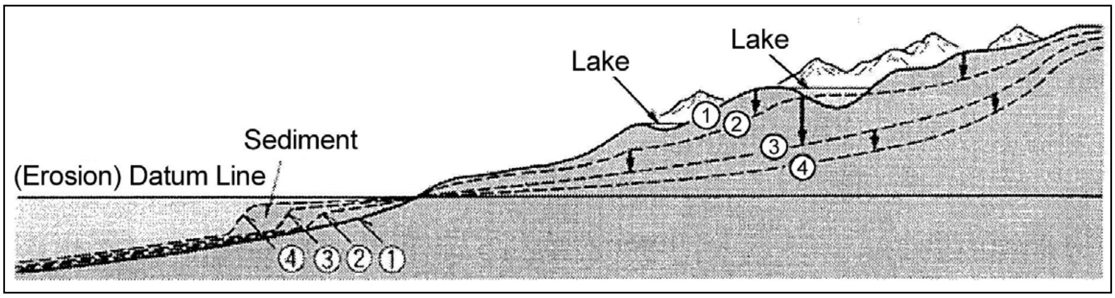
Longitudinal Section of Shindhuli Road

3. Reference

3. 1 Function of River

The River Erosin is is in proportion to the square of flow velocity, and the conveyance action of River is almost in proportion to flow velocity.

The River Profile develops as shown on the Illustration due to the erosive and conveyance action of River.



Development of River Profile

River Profile develops with ①②③④.

At first, River Profile is similar to the configuration of the ground, then develops with ③, ④ and reaches to the equilibrium condition.

3. 2 Rapid Flow River

At the flood of Rapid Flow River, water does not always flow in parallel with levee. There is a case that flow collides agains levee at right angle in localized area. Comparing gentle flow river, higher levee freeboard may be applied for rapid flow river

3. 3 Trees in the Flood Plain

Trees in the Flood Plain shows there was no sever flood for long time.

資料３　主要面談者リスト

主要面談者リスト

（１） 公共事業計画省（MOPPW）
Mr. Durga Prasad K.C.,　Director General
Mr. Dhruba Raj Regmi,　Deputy Director General
Mr. Bindu Shamsher Rana,　Project Manager
Mr. Shiva Raj Adhikari,　Engineer
Mr. Bed Kantha Yogol,　Senior Divisional Engineer
田島　専門家

（２） 環境科学技術省（MESC）
Mr.Batu Krishna Uprety.,　Chief, Environmental Assessment Section

（３） 森林・国土保全省（MFSC）
伊藤　専門家

（４） 在ネパール日本国大使館
吉野　二等書記官

（５） JICA ネパール事務所
吉浦　所長
福田　次長
徳田　職員
津守　職員
Mr.Sourab Rana,　Program Officer

（６） 日本工営株式会社
片桐　所長

（７） HAZAMA TAISEI JOINT VENTURE
村田　所長
鈴木　次長

（８） GEOCE Consultants (P) Ltd.
Mr.Subarna Bahadur Joshi.,　Managing Director

資料４　収集資料リスト

収集資料リスト

調査名：ネパール国　シンズリ道路建設計画（第三工区）予備調査

番号	名　　称	形態 図書･ビデオ 地図･写真	オリジナル･ コピー	発行機関	発行年
1	The DoR Strategy	データ		DOR	1995
2	Environmental Management Guidelines	データ		DOR	1999
3	Road Maintenance Manual	データ		DOR	
4	Guideline for Inspection and Maintenance of Bridge Volume 1	データ		DOR	
5	Environmental Assessment in the Road Sector of Nepal	データ		DOR	2000
6	National Transport Policy	データ		MPPW	2001/2002
7	20 Year Road Plan	データ		DOR	2002
8	Reference Manual for Envoronmental and Social Aspects of I	データ		DOR	2003
9	Statistics of Strategic Road Network (SSRN)	図書	オリジナル	DOR	2004
10	Master Plan for Strategic Road Network	データ		DOR	2005
11	DOR Budget Data	データ		DOR	2006
12	Banepa-Sindhuli-Bardibas Road Project, Section III Nepalthok - Khurkot Section, Stakeholders Meeting	図書	コピー	DOR	2007

資料５　土工数量計算

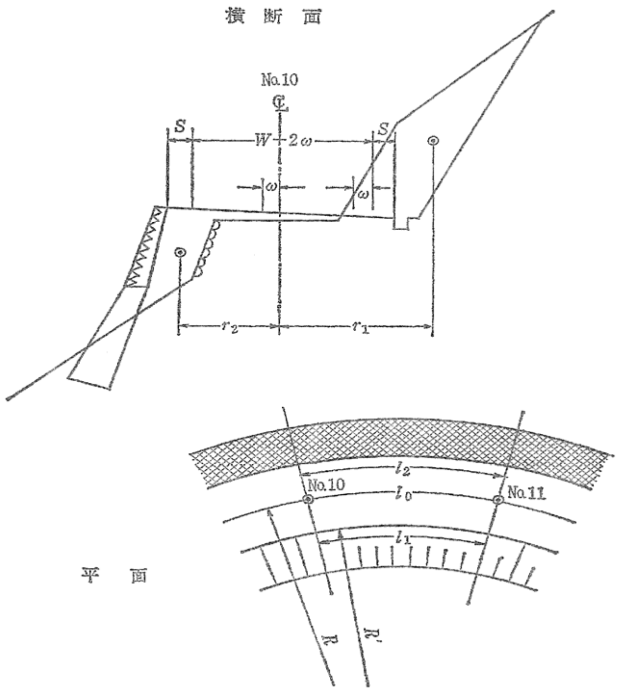
特殊な土工量

(A)　小さな曲線部の工事量

道路の横断設計は、一般に 20m ごとの測点・平面線形の変異点および地形の変化のいちじるしい点で行われる。

土量の積算には一般に平均断面法が用いられる。すなわち、2 測点間の土量は、両断面積の平均値に測点間の距離を乗じたもので表される。この方法は簡易でありながらある程度の精度をもつ実用的なものとされている。

この方法による計算土量の誤差は、曲線部であっても平地であれば大したものでないが、山地部で曲線半径の小さいところでは大きい。すなわち、凸部では切土量が過大に、盛土量が過小に積算されることになる。その影響は地山の傾斜角に比例し曲線半径の大きさに反比例する、このような曲線部で工事量を補正しようとするときは、測点間距離にかえて、切・盛土毎に断面の図心間距離を用いて計算するのがよい。



断面図心間距離（Ｒ＝60m）

測点	距離 l	右側				左側			
		r_1	平均 r_1	$1-r_1/R$	l_1	r_2	平均r_2	$1+r_2/R$	l_2
No.9	20.0	6.1	5.20	0.913	18.26	5.0	5.10	1.085	21.70
No.10	20.0	6.5	6.30	0.895	17.90	4.1	4.55	1.076	21.52
No.11	20.0	6.3	6.40	0.893	17.86	4.2	4.15	1.069	21.38
No.12	20.0	4.8	5.55	0.907	18.14	4.7	4.45	1.074	21.48

図 3-5-1　曲線部の土工量計算

山地部道路の横断面は、一般に図 3-5-1 にみるような形である。

断面図心問の距離は、式(6.1)から計算できる。

$$l' = l \times 2\pi R' \div 2\pi R$$
$$= l \times (1 \pm r/R) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

ここに、$l' = l_1$、l_2：図心間距離

l：道路中心線の区間距離

R：道路中心線の半径

R'：図心の半径

r：道路中心線半径と図心半径の差

ここに用いるｒは、断面図形の上で判断してプロットした概略の図心と、道路中心線との関係をスケールで読みとって、その平均値を求めれば十分である。

図 3-5-1 の表は R＝60m の曲線部における補正計算の一例で、両側拡幅の場合である。

しかし、この補正は地形と線形の曲がり方向の組み合わせによって相殺されたり、影響が小さくなる場合もあるから、その補正の要否は横断設計の結果によって判断すればよい。

擁壁、側溝等の構造物の数量にも、同様な影響がある。

(B)　大きな沢の埋め土量

山地部道路の土工は一般に、切・盛土量のバランスのうえで捨土が生ずる場合が多い。したがって、捨土のためから路線上で大きな沢の埋土を計画したり、捨土場所を別に求める必要が生ずる。

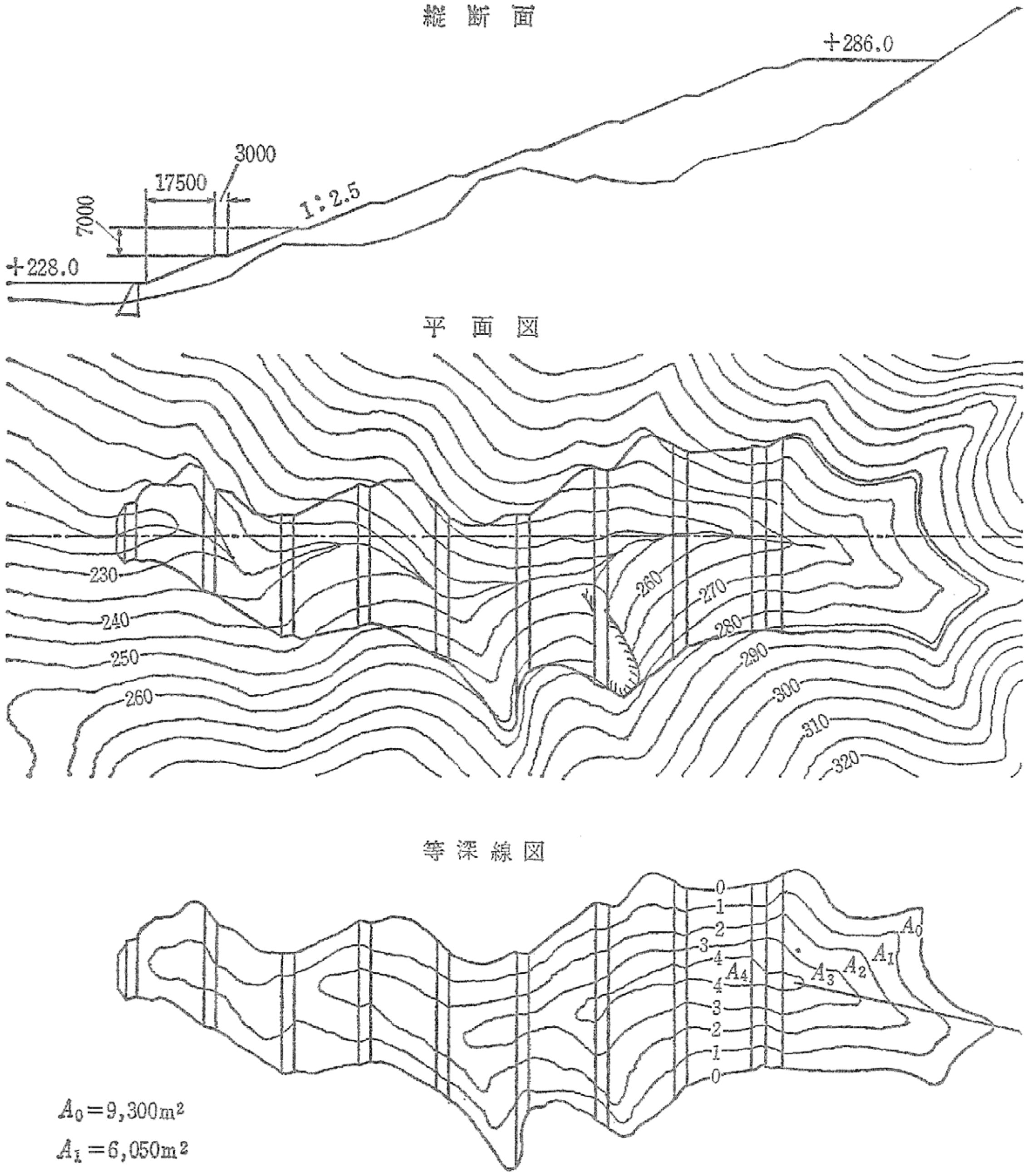
沢の地形が複雑なときの埋土量の積算は、平均断面法では断面の数を増しても、誤差が大きくなって実用的でない。

このような場合の土量Ｖは、図 3-5-2 にみえるように埋土計画を立てた地形図を用い、盛土ノリ面が地山と交わる面をA_0とし、A_0ノリ面から一定深さＨの面が地山と交わる面をA_1、同様に逐次深さＨの面をA_2、A_3……とし、各Ａの面積をプラニメーターで測って、式(2)で計算できる。

$$V = H/3\{A_0 + 4(A_1 + A_3 + A_5 \cdots\cdots) + 2(A_2 + A_4 + A_6 \cdots\cdots)\} \cdots\cdots\cdots\cdots\cdots (2)$$

（シンプソンの第２公式）

図 3-5-2 におけるＡの等深線図は、埋土計画を入れた地形図の縮尺が 1:1000 であれば、小段に平行した 1m の等高線を入れ、それが地形図の等高線と交わる点を結べば作成できる。



$A_0 = 9{,}300\text{m}^2$

$A_1 = 6{,}050\text{m}^2$

$A_2 = 3{,}350\text{m}^2$

$A_3 = 1{,}370\text{m}^2$

$A_4 = 300\text{m}^2$

$H = 7\text{m}$

$$V = \frac{7}{3} \times \{9{,}300 + (6{,}050 + 1{,}370) \times 4 + (3{,}350 + 300) \times 2\} \fallingdotseq 108{,}000\text{m}^3$$

図 3-5-2　埋土計画例

資料６　代替案検討箇所の線形図