Engineering Geological Studies along the Tinpiple Banchare Dada Road, Central Nepal

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Abstract

The Tinpiple-Banchare Dada road is located northwest of the Kathmandu valley. Since the area is a mountainous terrain consisting of varieties of slopes, development activities may be threatened by landslide related phenomena. Recently, Kathmandu Metropolitan City (KMC) and Ministry of Local Development are jointly constructing the access road (Tinpiple-Banchare Dada Road) for the mobilization of the solid wastes collected from the KMC. It is, therefore, desirable to have engineering geological studies along the road alignment. This paper describes the methodology used in preparing the engineering geological map along the road. The purpose of the present study was to prepare an engineering geological map along the road alignment and to determine the geotechnical properties for both rocks and soils. For these purposes, the required attributes for engineering geological studies were identified and are mapped in the field. Soil and rock samples were analyzed for different engineering parameters. Results reveal that the most part of the road is aligned through the completely weathered sandstone, its residual soil along with the gneisses. The result reveals that areas with 3-6 meter thick soil may be hazardous in terms of landslides and should be avoided, if possible.

1. Introduction

The construction of the Tinpiple- Banchare Dada road was started at the beginning of the 1990 by Kathmandu Metropolitan City. The road starts from Tinpiple on the Kathmandu-Tirshuli-Dhunche road and plan to reach Banchare Dada (Okharpauwa) through Simtar and Kagatigaun. It also crosses the Kalphu Khola at the Tallosiudanigaun (Fig. 1). The road is aligned through the southwestern slope of the ridge. The road has the very low gradient at the beginning but later while descending down to the Kalphu Khola the gradient increases. Since the road is planned for the transportation of solid waste of the Kathmandu Metropolitan City to the Okharpauwa landfill site, it is desirable to have a sound road that can be operated without blocked throughout the year. So it is essential

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to have engineering geological studies along the road alignment.

This paper first describes the general geology of the area followed by detailed methodology for the engineering geological mapping of the road alignment. Both the field method and laboratory test were performed for the engineering geological properties of the rock and soil. Detailed chainage wise description of the road alignment is also presented. Results of the laboratory test were also presented and analyzed.

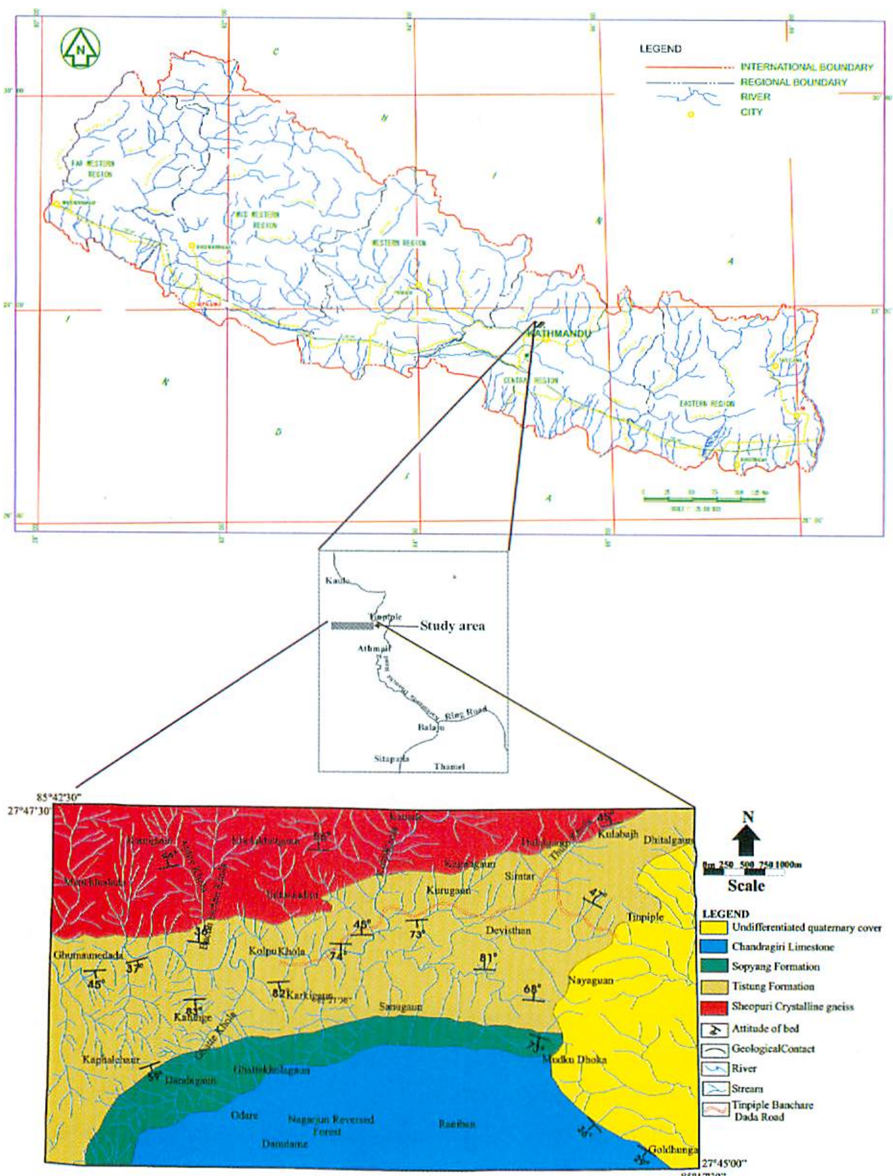

Figure 1. Location map and geological map of the study area

2. Geology of the area

The road passes through the Tistung Formation of Phulchuki Group of Kathmandu Complex, Lesser Himalaya (Stocklin and Bhattarai, 1977). It also passes through Sheopuri Gneisses, inter-fingered with the Tistung Formation (Fig. 1). This formation consists of metasandstones and siltstones with occasional presence of slate and phyllite. The Sheopuri Gneisses comprises muscovite, biotite, fine to coarse grain banded gneisses, ribbon gneisses and augen gneisses, which mainly consists of quartz and feldspar. Tourmaline-muscovite granite is also exposed.

3. Engineering Geological studies along the road alignment

The engineering geological studies were carried out along the Tinpiple-Banchare Dada Okharpauwa landfill site road between Km 0+000 and Km 8+300. The studies includes the detailed evaluation of engineering geological and geotechnical conditions of the road corridor. The engineering geological studies were based on the following technical parameters.

3.1 Slope angle

The stability of natural slope (either rock slope or soil) is mainly controlled by the slope angle. During the detailed field study the natural and cut slope of different location within the road section was measured and are shown on the engineering geological map (Figs. 2a, 2b, 2c).

3.2 Land use

Land use has greater influence on the soil slope than in rock slope. In forest water flow and infiltration is regulator whereas a cultivated land may undergo instability owing to the periodical soil cover saturation. The condition is worse for barren soils where sheet erosion is very active leading to progressive gully formations by sliding process. The land use around the studied road section is described as cultivated land, forest and shrub land (Figs. 2a, 2b, 2c).

3.3 Rock type

Different rocks have diverse affect on the stability of the slope. Thus, rock outcrops is studied in terms of texture, composition, structure, colour and thickness of layers. If the rock is covered by the thick layer (about 1m or more) colluvial or other soil types the properties of both bedrock and soils should be noted. The studied area consists of sandstone, quartzite and gneisses (Figs. 1, 2a, 2b, 2c).

3.4 Weathering

The weathering condition of the rock has a significant influence on the engineering properties of rock mass. The degree of weathering may differ in the rock mass depending upon various factors such as size and orientation of discontinuous and ground water movement. Weathering can also drastically reduce the rock strength and lead to weak foundation. The rock of the study area shows almost all range of weathering grades.

3.5 Rock structure

Measurement of the structure includes determination of attitude (direction and dip angle) of the discontinuities (bedding plane, joint, foliation, cleavage, shear zone and fault). It is important to know the relationship of the discontinuity with the slope. For this purpose, the discontinuities were plotted on a stereonet. Joints and bedding planes were studied for spacing, persistence, width, waviness and infilling material. The stereoplot of the discontinuities of the selected locations of the areas with cut slope are shown on the engineering geological map (Figs. 1, 2a, 2b, 2c).

3.6 Soil type

According to their origin, the soils are classified into, alluvial, till, eolian, residual and colluvial soils. Alluvial soils consist of rounded, well rounded, well sorted, occasionally well-graded fragments deposited by the stream or river. Till is a material deposited by a glacier and composed chiefly of a silty-clay or striated cobbles and boulders. The deposit from a wind is called eolian. Residual soil is a soil formed from the in situ weathering of rocks. Colluvium is made up of angular grains of poorly sorted cohesion less deposits found on the sides or bottom of slopes or cliffs and brought there by gravity. Colluvium is highly unstable mostly, when toe is under cut by stream, river, and road cutting. The study area consists mainly of residual and colluvial soil. Detailed soil type distribution is shown on the engineering geological map (Figs. 2a, 2b, 2c). The classification of the soil is based on Unified soil classification system (USC) Casagrande, 1948.

3.7 Hydrological Parameters

The intensity of gullies has to be observed because it is most important indicator of instability. All the gullies are described in terms of their types, influence area, nature (seasonal/perennial), gradient and sinuosity. The seasonally (perennial/ seasonal) and their types indicate the water table variation. Seepage and spring may also be localized in certain rock types especially in interbedded and fractured ones. The drainage of the study area around road section is shown on the engineering geological map (Figs. 1, 2a, 2b, 2c).

3.8 Geomorphologic Condition

Different types of terrain impose varying problems in the road engineering. Steep rocky slopes and cliffs pose a high hazard of rock fall, talus slides and wedge failure. In the moderately sloping hills debris flow and gully erosion are common. Steep colluvial slopes are affected by debris slide. So it is important to consider geomorphologic condition at the time of construction.

3.9 Soil depth

The depth of soil has a great influence on the stability of soil slope. The presence of soil vicinity to rock exposure indicates thin soil cover whereas the soil (colluvial) has greater depth at the foot rather than at the slope. The alluvial soil has almost uniform depth. Soil depth in each segments are described in chainage wise study.

3.10 Chainage wise study

3.10.1 Km 0+000 - Km 0+515

The alignment begins from the Tinpiple (Figs. 1, 2a). It is almost horizontal and runs towards west and passes through the middle slope of the hill. The natural slope lies between 20° and 30° (Fig. 2a). The cut slope in this section varies from 40° to 80° (Fig. 2a). The up slope area is predominantly covered by cultivated land and settlement with a few shrubs and the down slope is covered by cultivated land where there are a few rock exposures of highly weathered interbedded sandstone and gneiss at 0+250 km and 0+515 km. The attitude of sandstone is S43° W /41° NE. The sandstone is medium grained dark grey micaceous. The soil types found in the area are colluvial and residual. The soil found at the beginning of the road is classified as ML and the soil at the remaining section is classified as SM and depth is greater than 6m.The area is fairly dry and few seasonal gullies are encountered along the alignment, which are less active and of low gradient. The area is relatively stable and hazard level is low. One small landslide is activated due to high cut slope at about 0+420 km. No major problem is anticipated within this section in the future.

3.10.2 Km 0+515 - Km 1+000

This is an ascending section and runs through the middle slope of the hill following northwest trend. The natural slope angle ranges between 5° and15° (Fig. 2a). The cut slope of the section varies from 45° to 80°. The majority of the area is covered by cultivated land. The alignment runs towards west at the beginning and than towards north. The up slope area is covered by cultivated land and settlement. The down slope area is covered by cultivated land. The down slope is covered by colluvial soil (GP) and the up slope is covered by residual soil (SM). The soil in this area has thickness of greater than 6m. Between 0+800 km to 1+000 km sandstone and gneiss are interbedded. The attitude of bedding is N70° W / 60° NE. At chainage 0+563 km a 40 m x 20 m soil slide (B_1, Fig 2a) is present. Within the slide small gullies are developed (Fig. 3). This site can be stabilized by the use of jute netting and diagonal grass lines, a simple bioengineering technique (Koirala, 2005). Another small slide (B_2, Fig 2a) is present at chainage 0+860 km (Fig. 4). Contour grass lines or jute netting and randomly planted grass can be used as effective bioengineering measure for this site (Koirala, 2005). The joint analysis at chainage 0+880 km shows that the intersection between the joint 1 and 2 produce the wedge, which is in the opposite direction of the cut slope thus this location seems structurally safe considering any failure (JN_1, Fig 2a). At chainage 1+000 km a small landslide occurs (B_3, Figs 2a &5). Grass seeding, mulch and wide mess jute netting is considered as the effective bioengineering technique for this site (Koirala, 2005).

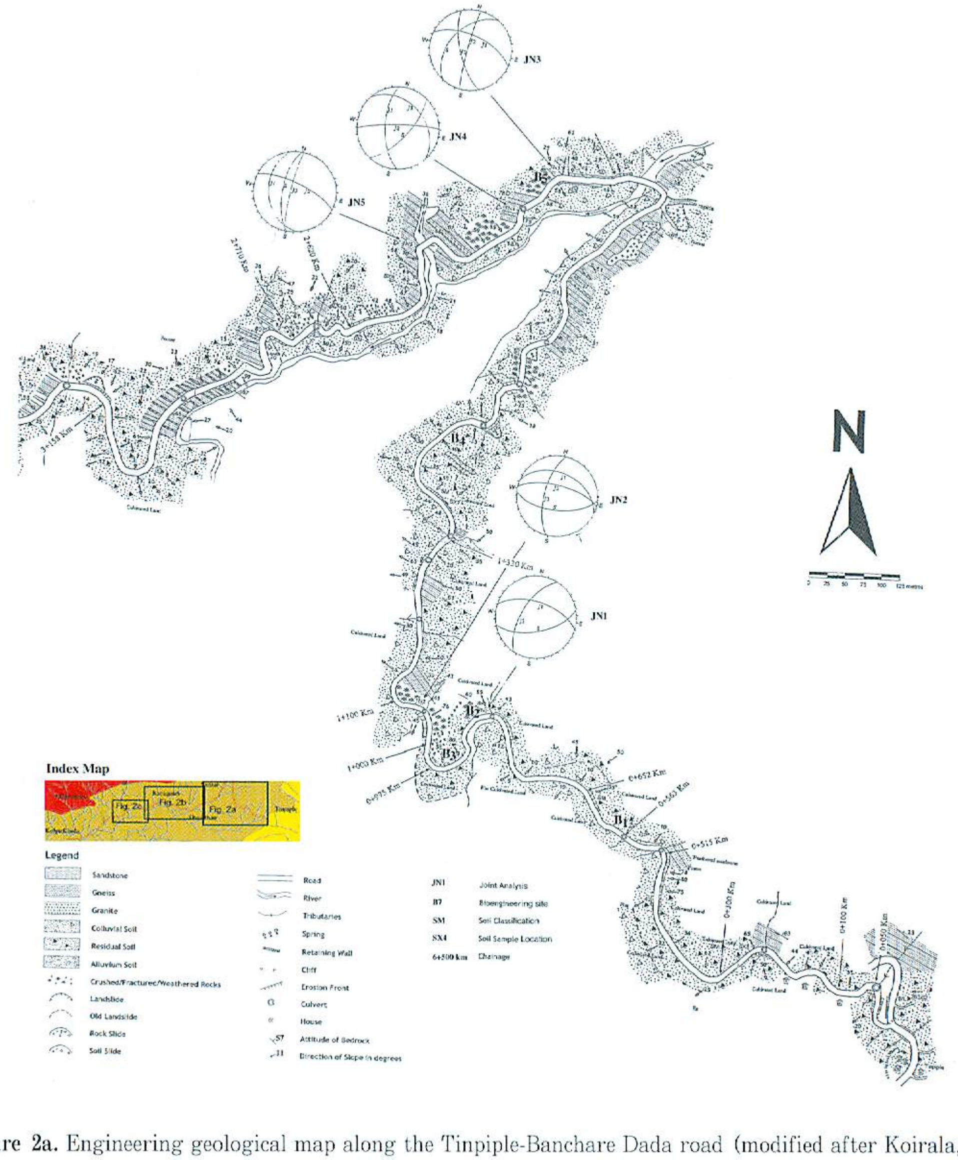

Figure 2a. Engineering geological map along the Tinpiple-Banchare Dada road (modified after Koirala, 2003)

3.10.3 Km 1+000 - Km 2+100

Almost all part of this section follows the northern trend. This is the descending section of the road. It has a sharp bend at about 2+000 km and crosses the Thulo Khola there with a bridge for the road to cross. The up slope consists of the residual soil and down slope consists of colluvial soil at the beginning of this section but both upslope and down slope through out the section consist of colluvial soil. The land is covered by cultivation and at the end of this section the land is covered by forest. The soil depth in this area reaches up to 3-6m. Occasionally beds of sandstone, augen gneiss and granite are well exposed in this section. The soil is classified as SM between 1+100 km to 1+800 km and GM between 1+900 km to 2+ 100 km. Joint analyses at chainage 1+060 km shows that both joints 1 and 2 are susceptible towards topples but the high dip value of joint 2 indicates the probability of toppling. Joint 1&2 produce lateral wedge, joint 1&3 and 2&3 produce central wedge but are structurally stable (JN_2, Fig 2a). The rocks exposed are highly weathered and fractured at 1+100 km and at the middle of the section. But at the end of the section the rocks are slightly weathered. The attitude of the bedding plane is S72° E/72° NE. Soil slide and gully erosion are present within this section. At about 1+530 km a soil slide occurs which consists of rill and gully erosions (B_4, Figs 2a & 6). Shrub and tree planting is the recommended bioengineering technique for this site (Koirala, 2005). Seepage and springs are also present in the middle part of the section. Rapids and falls are also present at the end of this section. At the end of this section between 2+100 km to 2+100 km at the opposite bank of the Thulo Khola rocks and soil slides are also present. The natural slope of the area varies from 18° to 45° and the cut slope of the area varies from 30° to 70°.

3.10.4 Km 2+100 - Km 3+158

This is the ascending section of the road and trends towards southwest. This section follows the trend of Thulo Khola and from 2+980 km it bends towards northwest. First 550m consists of colluvial soil (GM) on the both up hillside and the down hill side of the road. The remaining portion of the road consists of both residual (SM) as well as colluvial soil. The soil depth reaches up to 3-6m. Between 2+200 km to 3+000 km the up slope consists of rock exposures, the rock type is granite, sandstone and gneiss. The granite and gneiss are highly weathered and the sandstone is slightly weathered. The attitude of the bedding plane is N60W/63° NE. Joint analysis at chainage 2+115 km shows that joint 1&2, 2&3 and 1&3 produce the lateral wedge and the entire three wedge formed dips greater than the cut slope so they have probability of failure (JN_3, Fig 2a).

A soil slide is present at chainage 2+180 km (B_5, Figs 2a &7). It consists of completely weathered rocks. It is due to slope cutting. Direct seeding of shrub or small tree is an effective bioengineering method (Koirala, 2005). Joint analysis at chainage 2+210 km shows that joint 1&2, 1&3 produce the lateral wedge and 2&3 produce the central wedge. The wedge formed by 1&3 and 1&2 are stable as wedge formed dips opposite to the cut slope. The central wedge formed by the joint 2&3 is also stable as it dips less than the cut slope (JN_4, Fig 2a). Joint analysis at chainage 2+475 km shows that central wedge formed by the joint 2&3 is unstable and the central wedge formed by the joint 1&2 is stable. The lateral wedge formed by the joint 1&3 has probability of failure (JN_5, Fig 2a). The natural slope in this section varies from 23° to 60° and the cut slope varies from 27° to 68°. Retaining walls are constructed on the down hill side of the road where the cut slope more than 60°.

3.10.5 Km 3+158 - Km 4+500

The road in this section follows general trend of west with sharp bends at 3+200 km (towards south west), 3+800 km (towards north west), and at 4+000 km (towards west). This is the descending section of the road. The soil type in this section is classified as SM at the beginning of the section and SM - SC at the end of the section. Both the up slope and down slope is cultivated land and the soil depth is greater than 6m. Between 3+200 km to 3+300 km, 3+900 km to 4+120 km, 4+450 km to 4+500 km, sand stone, granite and gneiss are well exposed. Sandstone is slightly weathered and the gneiss and granite are highly weathered and fractured. The attitude of the bedding plane is S67° E/83° NE. The natural slope in this section varies from 13° to 28° and the cut slope varies from 38° to 71°. This portion of the road crosses many minor streams. A small soil slide is activated due to high cut slope at 3+450 km (Fig. 2b).

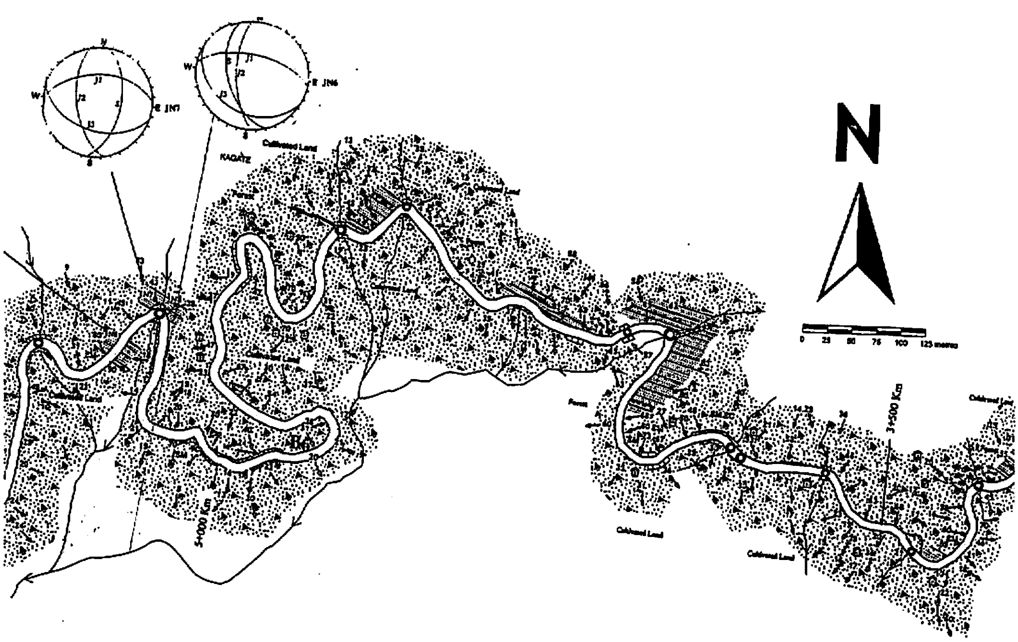

Figure 2b. Engineering geological map along the Tinpiple-Banchare Dada road (modified after Koirala, 2003)

3.10.6 Km 4+500- Km 6+000

The road in this section follows the general trend of southwest with sharp bend at 4+600 km towards northwest, 4+700 km towards south-east, 4+820 km towards west, 5+100 km towards north, 5+220 km towards southwest, 5+350 km towards south, 5+650 km towards northwest and after that it follows the north west trend. This is the descending section of the road. The soil type present in this section is residual soil on both up and down slope. The soil depth reaches up to 6m and the soil is classified as SM. At 4+500 km to 4+600 km weathered and fractured sandstone and gneiss are exposed. At 4+750 km to 5+100 km soil slides are present (B_6, Figs 2b & 8). The soil slide is characterized by the gully erosion and mudflow. Down slope grass lines or diagonal grass lines are the recommended bioengineering techniques (Koirala, 2005). Joint analysis of the location 5+125 km shows that Joint 2 has probability of plane failure. Lateral wedges are formed by the intersection of Joint 1&3, 2&3 and 1&3. The wedge formed by the joints 1&2 has probability of failure as it dips greater than the cut slope (JN_6, Fig 2b). Joint analysis at 5+ 175 km shows lateral wedges formed by the joint 1&2, 2&3 and 1&3 all are stable as they dip opposite to the cut slope (JN_7, Fig 2b). Joint analysis at 5 +230 km shows central wedge formed by the joint 1&2 has probability of failure as it dips greater than the cut slope. The lateral wedge formed by the joint 2&3 is stable as dips opposite to the cut slope (JN_8, Fig 2c). The down slope is cultivated land and up slope is covered by settlement and the forest. The natural slope of the area varies from 9° to 31° and the cut slope varies from 31° to 80°. The road in this section crosses three minor streams with culvert over them.

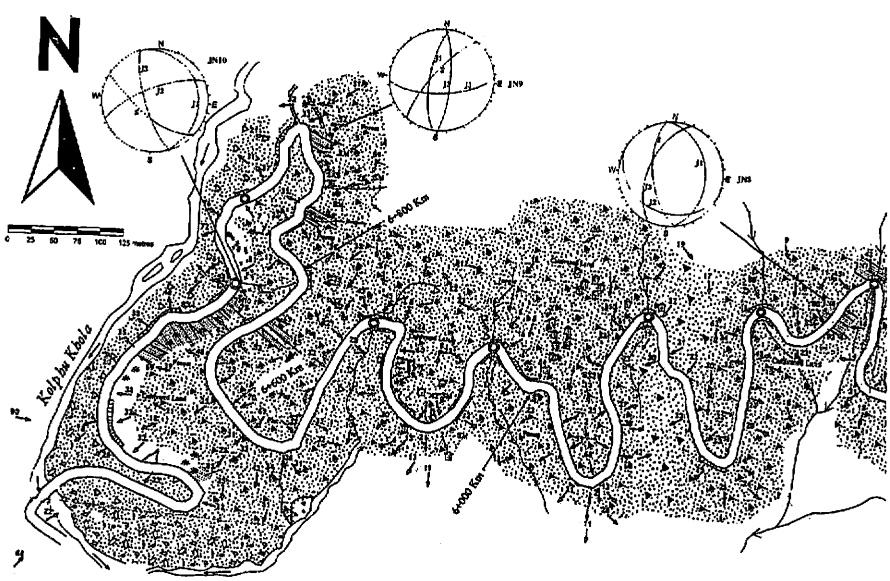

Figure 2c. Engineering geological map along the Tinpiple-Banchare Dada road (modified after Koirala, 2003)

3.10.7 Km 6+000- Km 7+000

This is the descending section of the road and follows the general trend of northwest with sharp bend at 6+100 km towards southwest, 6+450 km towards west, 6+520 km towards northwest and at 6+700 km towards north. This section of the road is aligned through the residual soil with occasional outcrops at 6+700 km, 6+850 km and 7+000 km. The rock exposed is slightly weathered sandstone. The attitude of the bedding plane is N27° W/85° NE. Many soil slide and gully erosion are present within this section. At 6+400 km the soil slide is characterized by the gully erosion and soil flow at the upper surface initiated due to cut slope (B_7, Fig. 2c & 9). Shrub or small tree planting (after it becomes dry) is an effective bioengineering technique (Koirala, 2005). The soil of this section is classified as SM and the soil depth is greater than 6m. The natural slope of the area varies from 11° to 28° and the cut slope varies from 32° to 68°. The road crosses two minor streams with culverts over them. Both up slope and down slope near the road is cultivated land and the up slope above this is covered by settlements and forest.

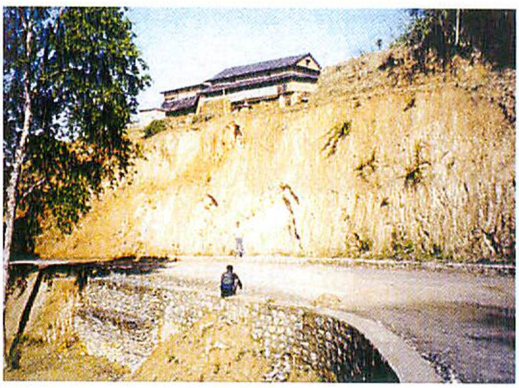

Fig. 3 Bioengineering site B1 at chainage 0+563 km view towards northwest

Fig. 4 Bioengineering site B2 at chainage 0+860 km, view towards northwest

Fig. 5 Bioengineering site B3 at chainage 1+000 km, view towards north

Fig. 6 Bioengineering site B4 at chainage 1+530 km view towards east

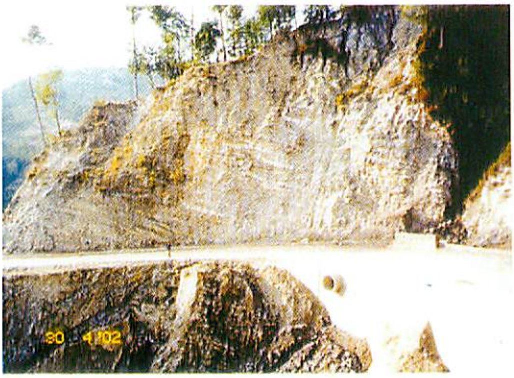

Fig. 7 Bioengineering site B5 at chainage 2+180 km view towards northwest

Fig. 9 Bioengineering site B1 at 6+400 km view towards east

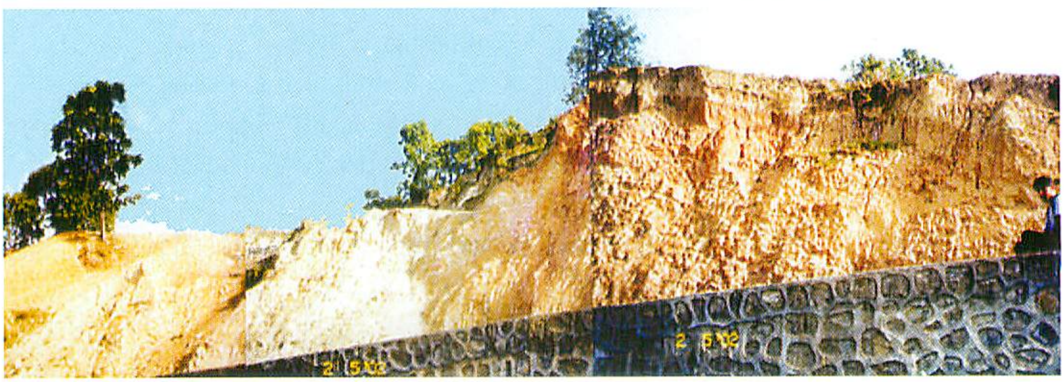

Fig. 8 Bioengineering site B6 at 4+750 km to 5+100 km view towards north

3.10.8 Km 7+000- Km 8+300

This is the descending section up to Kolphu Khola at 8+200 km and after that the section is ascending and follows the general trend of southwest with the sharp bend at 7+600 km towards west. The down slope up to 7+600 km consists of the residual soil and the up slope consists of the colluvial soil. The residual soil is classified as SM and the colluvial soil is classified as GM. The remaining section of the road consists of alluvial soil and is classified as GM. Between 7+300 km to 7+400 km the slightly weathered sandstone beds are well exposed. The attitude of the bedding plane is S86° E/62° NE. Joint analysis at chainage 7+220 km shows, 2 central wedges are formed by the intersection of the joint 1&3 and 2&3, and the wedge formed by joint 1&3 has probability of failure as it has same dip amount to the cut slope. The lateral wedge formed by the intersection of the joint 1&2 is stable (JN_9, Fig. 2c). The joint analysis at chainage 7+525 km shows that central wedge formed by the intersection of joint 2&3 has high dip but its direction is in the other direction thus it is rather safe. The lateral wedge formed by the intersection of the joint 1&2 has low dip thus it is also structurally safe (JN_{10}, Fig. 2c). Highly weathered and fractured rocks are also exposed between 7+400 km to 7+600 km. Soil slide with erosion front is present at 7+650 km and is characterized by gully erosion and debris flow. The natural slope varies from 0° to 22° and the cut slope varies from 20° to 61°. The road crosses the Kolphu Khola at 8+200Km with a bridge over it.

4. Conclusion

Engineering geological studies along the Tinpiple Banchare Dada road was carried out. The results of the investigation suggest that the small landslides along the road were mainly initiated by the road cutting. All the slides are in the up slope area. Simple bioengineering techniques are sufficient to control instability. The slides are also initiated where the soil depth is 3-6 m. The result of the joint analysis reveals that chainage 2+ 115, 2+475, 5+125 to 5+ 175 and 7+220 km has probability of lateral, lateral & central, central and central wedge failure respectively. As the investigation was focused only along the road with limited up slope and down slope information, far mass movement hazard and other aspects are not considered. Therefore, further study is recommended.

Acknowledgements

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