CHAPTER – 4

Geology Of The Project Area

4.1 GEOLOGY OF SIKKIM

The preliminary geological survey of the locations of all the structures on the ground was carried out after site visits. The site-specific geological data were collected and utilized in the design of various component of the project. The survey of the nearby area was also carried out to co-relate the geology of the project area.

The engineering geological investigations are the most important basis for assuming the design considerations for the tunnel system. The geological conditions in the area are considered for the design of the tunnel system to find the best location, orientation, shape and dimension of the tunnel. The location and orientation has been selected after preliminary geological investigations. Geological investigation involved-

- Topo Map and Satellite Imaginary studies
    - Digitization of Topographic Maps
    - Land Use, Drainage and Landslides studies with the help of GIS work
- Geological Survey
    - Geological mapping for overall project area and detailed geological map of the tunnel portal with the help of handy GPS, DGPS, Total Station and Geological Instruments.

The Indian State of Sikkim is mainly located in the watershed of the Tista River .Through the foothills of the Himalaya, the Tista and its tributaries have deeply eroded the terrain. Landslide occurrences are quite common in the Sikkim Himalaya; the main reasons for this phenomenon are attributed to the geology of the area and the high intensity of rainfall. Apart from these reasons, recent development, particularly road and housing construction have aggravated the incidence of landslides and subsidence problems **(Mehrotra et al., 1996)**. Geologically, Precambrian rocks cover a major portion of the Sikkim Himalaya and are represented by the following four major rock formations, listed from youngest to oldest **(Raina and Srivastava, 1981)**:

- Everest Pelitic Formation
- Sikkim Group
- Chungthang Formation
- Kanchenjunga Gneiss Group

The Sikkim Group of rocks consists of low to medium grade metamorphic and meta sedimentary rocks. East Sikkim is mainly dominated by rocks of the lower metamorphic grades, mainly chlorite schist, sericite schist, and quartz schist. These rocks have a phyllitic appearance. The region of central and eastern Himalaya near the Tista River is characterised by large-scale thrust movements from the northwest towards the southeast. The East Sikkim Himalaya is mainly traversed by two thrusts called the Chungthang Thrust and the Main Central Thrust (MCT), both trending in a NW–SE direction **(Mehrotra et al., 1996)**. The MCT is a well-known tectonic boundary between sedimentary and crystalline rocks, separating the Lesser and Greater Himalaya. It is characterized by crushed rock and fracture zones. The Nepal–Sikkim Himalaya and adjacent foredeep area are dominated by conjugate strike–slip faults that face the wedges of the Indian shield. Rocks of this terrain are characterised by intense folding, metamorphism, and thrusting in a number of tectonostratigraphic units, which exhibit inversion in stratigraphic succession as well as in metamorphic grading.

The area lying on the Eastern Himalaya represents the Gorubathan Sub-group under the Daling Group of Middle to Late Proterozoic age, as per the mostly adopted stratigraphic classification based on the geological works of Ray (1989), Ravishankar et al (1989) and Acharyya et al (1989). It is represented by the lithounits of chlorite quartz schist, chlorite schist. / phyllite with or without sericite, quartz sericite schist, sericite quartz schist, slaty phyllite/slates and quartzite. It forms a part of the northern limb of the Rangpo-Chu antiform. The rocks have attained metamorphism up to lower green schist facies.

4.2 SOIL STRATIFICATION

The soils of this area is in general have derived from parent rocks such as Quartzite, Phyllite, Schist, Phyllitic quartzite and colluvial materials. Soils are generally acidic to very acidic. Occasional dark soils are found due to extensive existence of phyllitic and schists. The soil of this area can be classified mainly mixed sandy loam and loamy sandy soils, sometimes mixed with pebble size sliding particles of existing rocks.

The presence of phyllites makes the slopes of the region prone to erosion and weathering. The possibility of erosion of soil and the reduction of mineral content is increased by excessive rainfall. Such geology is susceptible to natural disasters like landslides. The kind of soil prevalent in the north-eastern state of Sikkim is suitable for deciduous and evergreen forests. The soil does not have a high content of organic matter. The soil is not rich in minerals. The presences of these kinds of rocks have turned the soil of these regions brown and clayey. Due to chemical and physical weathering the low to medium metamorphic rock some outcrops in the proposed area are highly disintegrated and weathered. This has resulted into soil formation on the top layers and the thickness of the loose top soil formation varies between 1 and 2 m at different localities. The soils are primarily silty sands with gravel and rock fragments. Occasionally, the top stratum is also bouldery. The immediate rock strata below the top soil cover, is also highly fractured and weathered. Several sets of joints are present due to which the rock mass slides at many places due to instability.

4.3 DETAILED GEOLOGY FOR SINKING AREA

Sinking and sliding is one of the major problems in hilly terrain like Sikkim. Landslides occur frequently in the Himalayan State of Sikkim, India. This is due to the high intensity of rainfall that not only contributes to rapid erosion and weathering of the rock mass, but also increases groundwater levels causing reduction in the stability of natural slopes. These factors, coupled with the increase in human activity associated with urban development, have contributed to increased instability of slopes in the region. Corrective and preventive measures to be adopted in a landslide or a landslide-prone area must be based on a detailed integrated geological and geotechnical investigation. In analyzing a landslide, it is important to determine what factors have controlled the formation of the rupture surface and the movement on that surface. This requires an engineering analysis of the stability of the landslide mass and analysis of the changes in geologic and meteorologic conditions that are correlated with landslide activity. This report describes only the geological investigations among the above said investigations for the case of sinking of Airport road, but geotechnical investigations needs to exact support of the stability of the road.

The Airport road from Ranipool to Pakyong consists of several smaller to larger sinking zone. They were having problems because of poor drainage. Due to this poor draining problems, water passes through the roads. The lithounits are mainly schist / phyllite. The rocks have attained metamorphism up to lower green schist facies.

The Airport roads sinking are characterized as composite rock / soil slide-debris flow, in which the slope movements were initiated by sliding on the bedding or schistosity of the rock mass followed by flow of the displaced material. The average slope of the landslide is varying from 25° to 36°. The Main sinking zone starts from CH-8.4 upto CH-10.7. Initially near to CH-8.4 the amount of slip is about 1.5 m with an average sink rate of 5 cm/yr, at CH-9.2 the sink rate is about 15 cm/yr and finally at CH-10.5 the area got maximum sink with an average sink rate of 35 cm/yr. This earth movement affects the surface which preserves by BROKEN BREAST WALL, ROAD DAMAGED, BENDING TREES and also Damage of local houses. Except this large sink/slide remaining smaller sink/slide can be protected by proper drainage and good protection work (like Gabion wall & Retaining wall down hill side & breast wall & catch water drain upstream side along with proper line channel of natural nallah), but this large sink can only protected after knowing the actual story behind it. So, without geotechnical investigation it will be difficult to design the protection work for this large sinking zone.

(Figures are attached bellow)

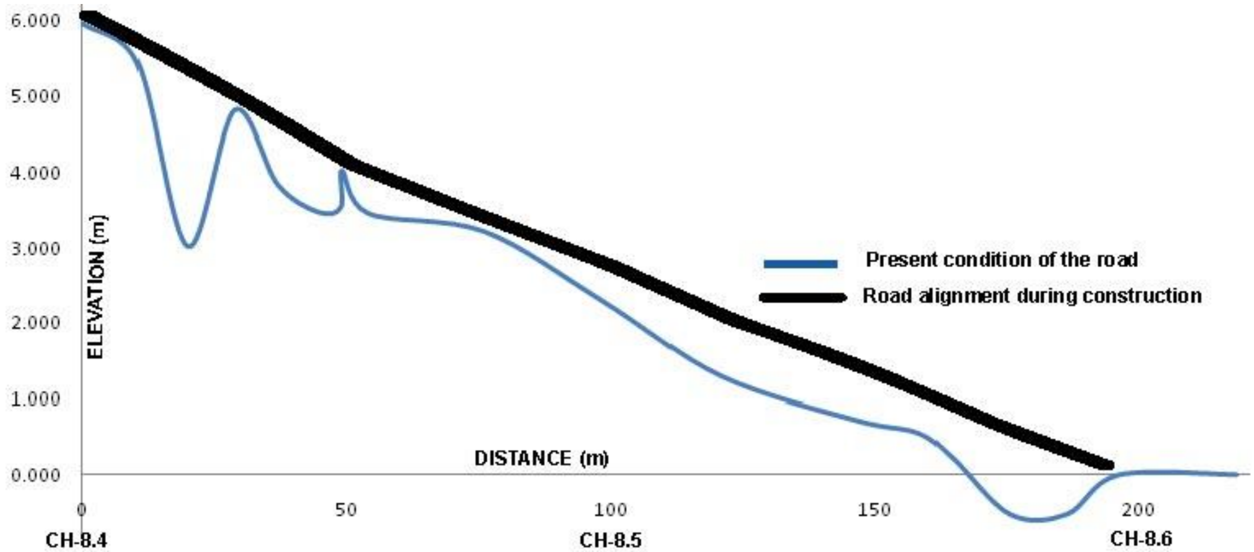

Fig: Surface topography of the Sinking zone at CH-8.4 showing the displacement of the road after sink

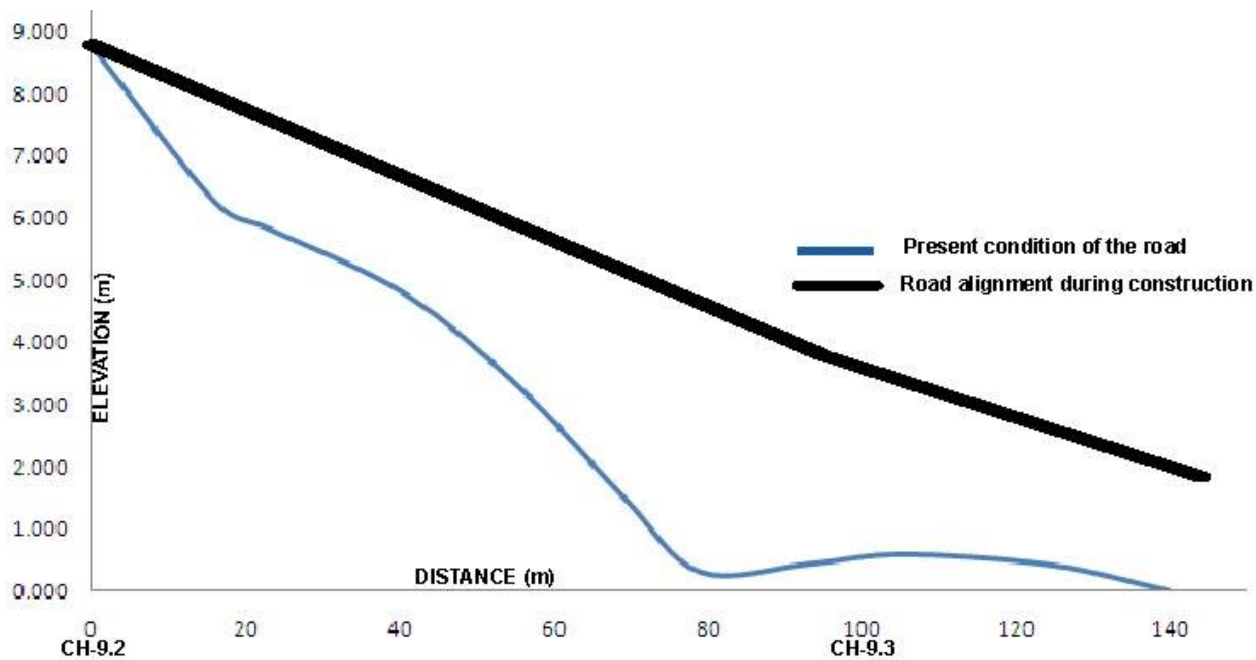

Fig: Surface topography of the Sinking zone at CH-9.2 showing the displacement of the road after sink.

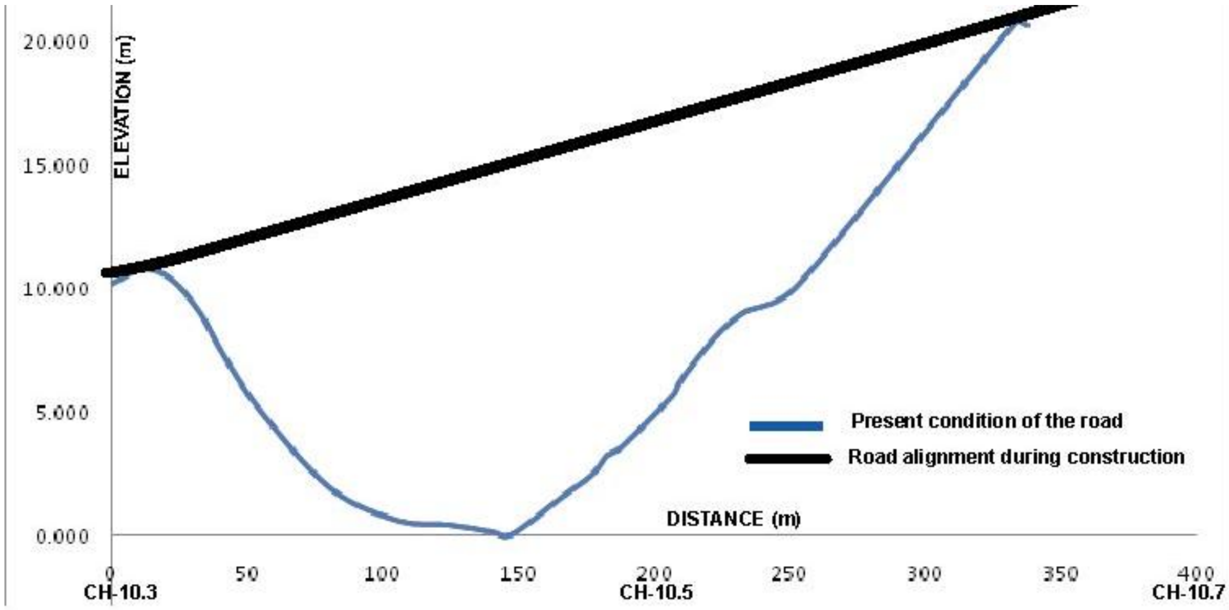

Fig: Surface topography of the Sinking zone at CH-10.3 showing the displacement of the road after sink.

4.4 PAST SEISMICITY OF THE AREA

Sikkim is located in zone IV according to seismic zoning map (**Fig: 3**). The state of Sikkim is spread on the Himalayan mountain range with the two main thrust faults, Main Boundary Thrust (MBT) and Main Central Thrust (MCT) crossing the state (Dasgupta et al. 2000). Due to continuous thrusting of Indo- Australian plate against the Eurasian plate, Sikkim has been a moderately active seismic region in the historical times (De and Kayal 2003; Nath et al. 2000). The significant earthquakes to have caused shaking in the region in the last 50 years include the 19 November 1980 Sikkim earthquake of Mb 6.0, and 21 August 1988 Bihar-Nepal earthquake of Mb 6.5 and February 14, 2006 (Mw 5.3) (*www.usgs.gov*).

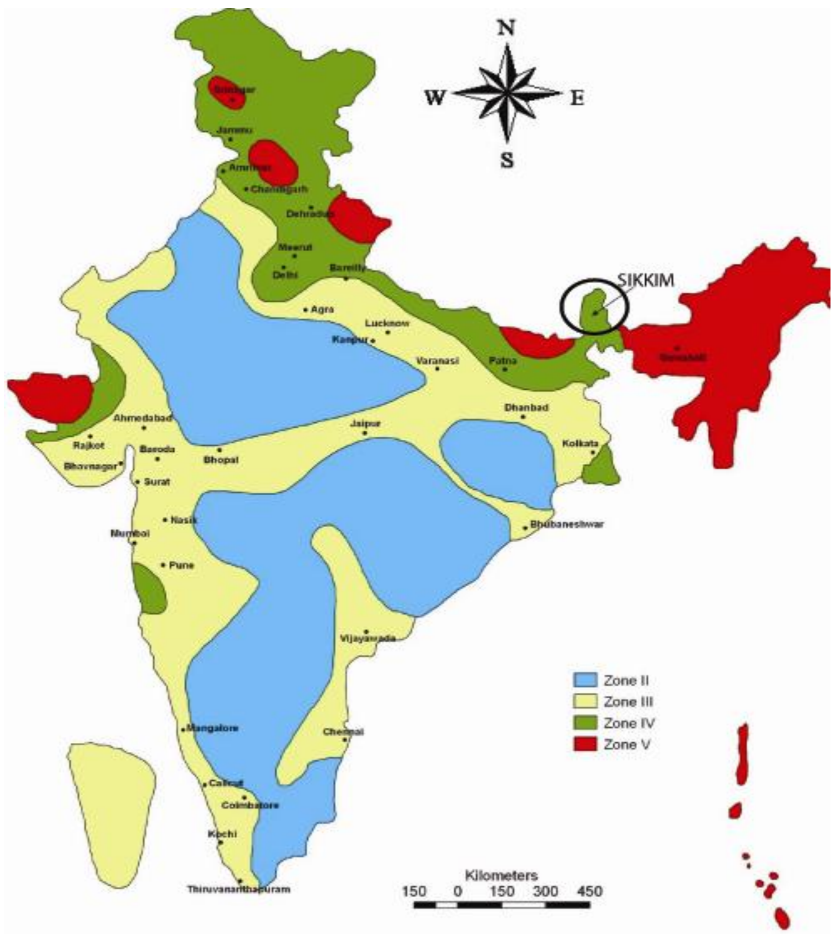

Fig-7: Seismic zoning map of India showing location of Sikkim in zone IV (BIS 2011, New Delhi)

The most recent earthquake (reported as Mw 5.3 by USGS and as ML 5.7 by IMD) occurred in the state of Sikkim on February 14, 2006 at 06:25:23 a.m. local time. The earthquake's epicenter and focal depth were reported from two different sources as, (i) at 27.35°N 88.35°E, near Ralang (South Sikkim), with a focal depth of 30 km (*www.usgs.gov*), and (ii) at 27.7°N 88.8°E, near Lachung (North Sikkim), with a focal depth of 33 km. Two Indian Army soldiers died in landslides after the ground shaking at Sherathang near Nathula in Sikkim; there were no reports of any other fatalities. The earthquake caused damage to heritage structures as well as modern buildings. Both masonry and reinforced concrete buildings showed poor performance. The damage seen in and around Gangtok was clearly disproportionate to the size of the earthquake, which was a moderate 5.7 on the Richter scale. This very clearly establishes the high level of seismic vulnerability of the region.

Considering the high seismic hazard in Sikkim, chances of moderate earthquakes will be possible in near future, it is evident that the project area is very close to seismically active zone in the vicinity of MCT. Therefore, it is essential to adopt suitable seismic coefficient in the design for various structures of the project. Suitable design for the tunnel can be withstand any future devastating earthquake.

Recently a strong earthquake of magnitude 6.8 on Richter scale was observed on 18.09.11 at 18:11 hrs. Its epicenter was noticed near Sikkim – Nepal border ,about 68Km north West of Gangtok.