CHALLENGES TO CONSULTANTS AND CONTACTORS IN BRIDGING NEPAL RIVERS

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INTRODUCTION

- 80% of total area of Nepal are hills & mountain with have more than 6000 no. of rivers and rivulets.
- For rapid development of the country, basic infrastructures like road and bridges in hill and mountain regions are unavoidable
- Design and construction of bridges have always challenged Nepalese Engineers & Contractors not only due to varied problems
- Bridge design, construction & maintenance in Himalayan condition need a different approach.
- High mountain and their rivers in different climatic zones tend to look and behave somewhat differently requiring variations in engineering approach to design and construction
- We have our own unique set of geological & environmental factors which influence the response of a bridge structure. The same will be discussed in this presentation

OBJECTIVES

- To focus the attention on the environmental issues relating to bridge design & construction under Himalayan condition
- Discuss different engineering problems that arises in bridging Nepal rivers in high mountains. Design a bridge to a standard that are in sympathy with the environment and costs, and are affordable to current development ethic of the country
- Design a bridge that can be maintained to a good standard

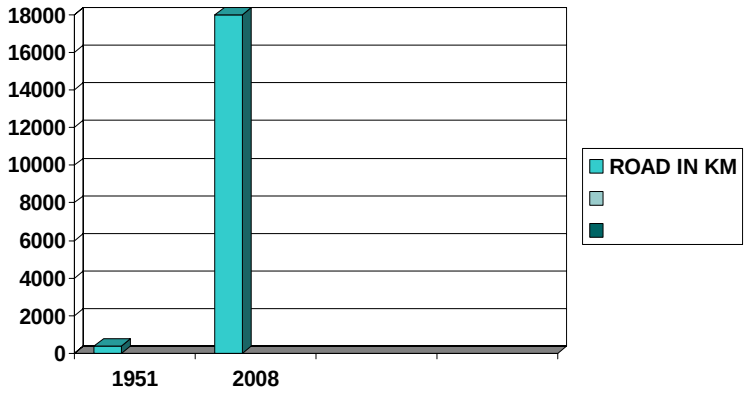
INTRODUCTION cont...

Water related bridge failures have been highlighted in recent years by the collapses of several bridges in Nepal

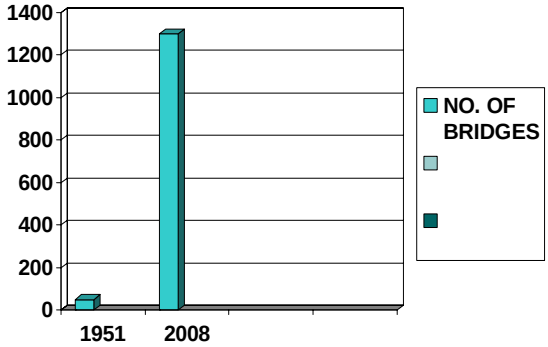
Study conducted by the author on bridge collapses indicates: flood & foundation movement were responsible for almost 90 % of 40 occurrences recorded

- Main problems to cause such events include: intense and prolonged rainfall, landsliding , erosion, river flooding & periodic seismicity

HISTORICAL BACKGROUND OF ROAD DEVELOPMENT IN NEPAL



HISTORICAL BACKGROUND cont…



BRIDGE CONSTRUCTION

Majorities of these bridges constructed during mid-60s to 80s by different donors country/agencies as per their own construction practices.

Some bridges have remained in place due to costly investment in construction, other have succeed because they are models of sympathetic engineering design . And several others have suffered such instability that they damaged and collapsed & have become impassable for long period.

- **Bridge design under Himalayan condition is relatively little explored**
- **The principal lesson learnt from the past failures is "applied design/const. practices were unable to respond to the problem posed within Himalayan condition"**
- **The bridge designers in Himalayan condition should be aware of full range of potential problem that arises in this region**

GEOGRAPHICAL SETTING OF HIMALAYA

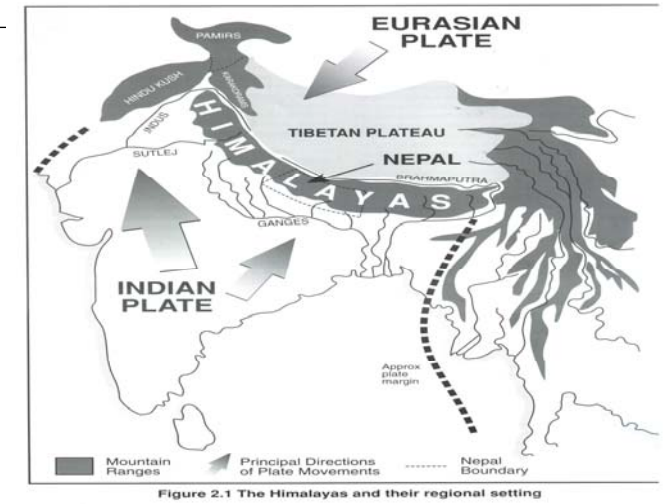


Figure 2.1 The Himalayas and their regional setting

GEOGRAPHICAL SETTING cont…

Himalaya formed due to collision of Indian sub-continent with Eurasian/Tibetian plates

These young fold mountains, especially experiences humid climates with seasonally intense rain are the most steep and unstable slopes in the world

- They are most difficult areas to construct roads and bridges
- Topography, slope stability, flood hazards & erosion potential are likely to be the most significant controls on the choice of the most optimal site and type of bridges
- Bridge type, its foundation, protection measures etc. must be designed so as to cause least impact on stability of bridge structure
- Behavior of river flowing beneath is another factor to concentrate

PRINCIPAL HIMALAYAN ZONES

Nepal is divided into 5- Phisiographical Zones. These include:

- **Gangetic Plain (Terai); up to 500m from msl**
- **Siwalik Hills (Churiya); 500 – 1000m from msl**
- **Mahabharat Lekh; up to 1200m from msl**
- **Middle Himalaya; up to 4500m from msl and**
- **High Himalaya; up to approximately 8,300m from msl**

GEOGRAPHY OF NEPAL
(Principal Himalayan Zones)

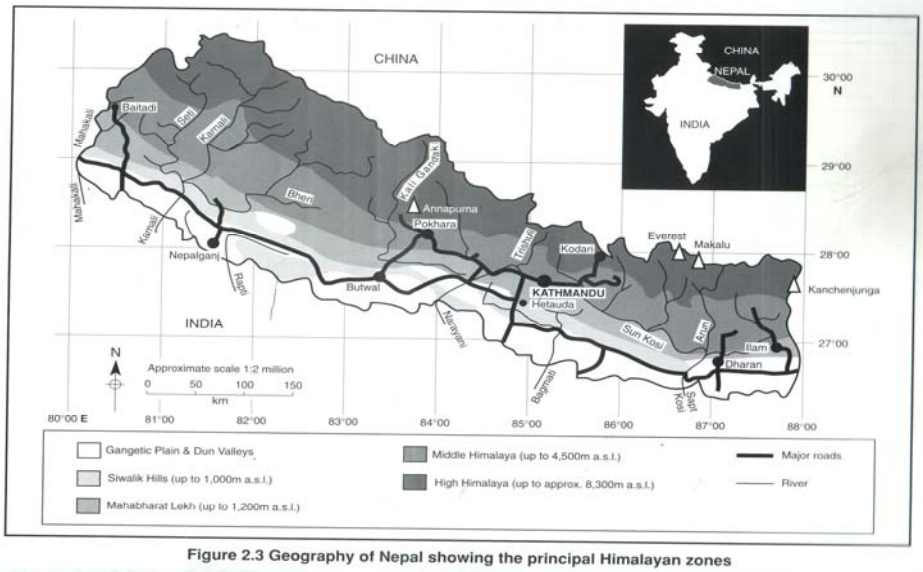


Figure 2.3 Geography of Nepal showing the principal Himalayan zones

GEOLIGY

Siwalik Hills

- **Rises from 500m and are formed from debris derived from rising Himalaya to the north. It mostly comprises:**
  - **Soft Sandstones, Mudstones & Siltstones**
- **Slope instability and erosion during intense rain is the main problem**
- **The granular material are easily eroded upon weathering & removal of vegetation cover**
- **They are eroded in the form of gravel and silty material and during heavy storms**

GEOLOGY cont…

Mahabharat Lekh

- ML forms a steeper and more rugged ridge system to that of Siwalik.
- It composed of a sequence of Limestones, Shales, Quartzite's and Phylites
- Vast quantities of water and sediments are transported in a seasonal basis by the rivers
- Problem of instability, sediment lower valley side of river-side locations
- The bridge structures in these region have to resist scour and transmit debris every year

GEOLOGY cont…

Middle Himalaya

- Elevation rises from 2000 – and up to 4500m
- The rocks of MH are predominantly Schist's and Gneisses
- Generally MH is more stable than the zones to the south, because landscape is less steep and the intensity of rainfall less extreme
- The majority of seismic activities are occurring in this regions because of the presence of fault and thrust
- Along the main rivers, steep valley sides are often subject to rock falls and rock slide

GEOLOGY cont…

High Himalaya

- **~~The HH comprises great peaks that rises to~~ more than 8000m above the sea level**
- **Road/Bridge engineering in this zone is less explored. However, the rocks of HH are mostly high grade metamorphic gneisses and intrude granites, and the climate is pereglacial and glacial**
- **These regions are characterised by snow fields, drifting snow and snow avalanches, glaciers, scree slopes, rock falls, rock slide, rock avalanches, melt-water flooding etc.**

MODEL FOR YONG FOLD MOUNTAINS

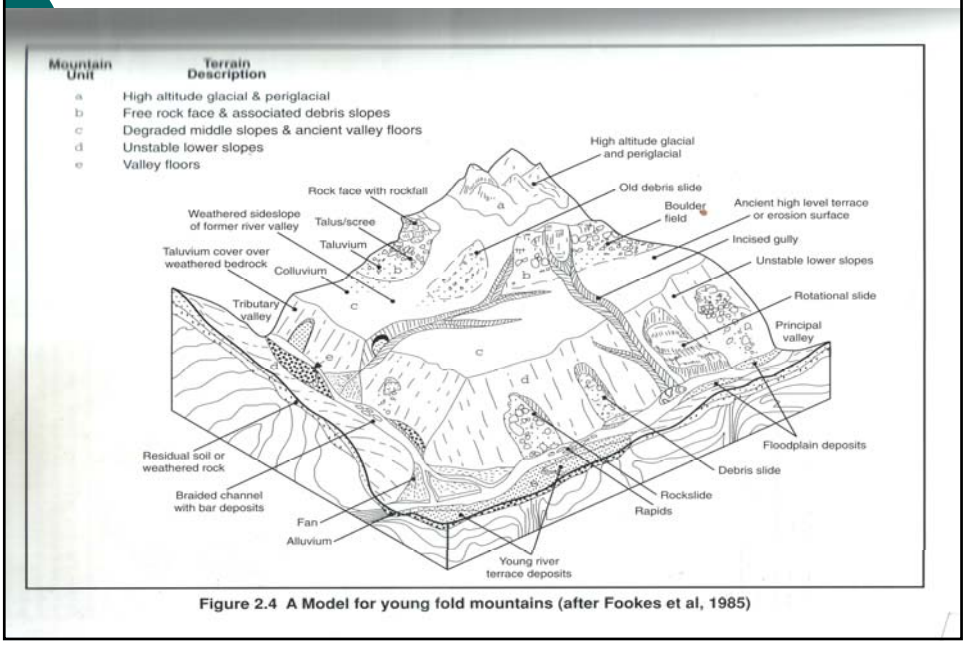


Figure 2.4 A Model for young fold mountains (after Fookes et al, 1985)

TERRAIN HAZARDS

Landslides

- In young fold mountain areas, instability of slope is ever present hazard, and rain water is always instrumental in causing slope failure.
- Soil falls, rock-falls and rock-slides are quite common in Himalayan condition
- Bridge abutment on fractured rock is always vulnerable
- Shallow Rotational slide on colluvial soil may collapse bridge abutments
- There are cases of bridge collapses due to landslides (Tinao Bridge in 1981)

TERRAIN HAZARDS cont…

Stream erosion

- The erosion effect of large storms and associated slope failures have remained visible even today in several streams. The frequency of these events appears to be highest in the Low Himalaya. The scour depth 3-5m during these storms are not uncommon in this zones
- During storm erosion the X-sectional areas increases drastically (2- 4 times)
- Undermining of pier and abutment due to bed and bank erosion is the main problem

TERRAIN HAZARD cont…

Sediment Transport & Flood Plain Scour

- Sediment tend to move in pulses through the drainage system, in response to the intense storm runoff, or the burst of a landslide dam or Glacial Lake Outburst Flood (GOLF).
- As the water subsides, the sediment rapidly & unevenly deposited.
- Deposited sediment can bury a bridge structures and can block the outlets and washout the superstructures
- There are several cases where the bridge decks have been lifted off their bearings by the combined effects of surcharge & entrapped floating debris & have deposited several meters D/S

TERRAIN HAZARD cont…

River Flooding

- River Flooding have the following effects on a bridge structure built on vulnerable locations:
  - Washout of the bridge structures
  - Overtopping & associated scour of the Abutment and Pier foundations
  - Creation of temporary head and condition of instability behind abutments
  - Temporary submergence of bridge structure
  - Blockage of waterway by sediment and floating debris
  - Impact damage of bridge soffit
  - Undercutting of the lower valley side and creating instability of Abutment
  - Damage to the bridge protection work etc.
- Severe flooding can be either rainfall-generated or triggered by failure of landslide dam or GLOF. Although spring snow melt can increase significantly the river water levels.

TERRAIN HAZARD cont…

LANDSLIDE DAMS

On certain occasion slope failure can be large enough to temporary block river courses. The following are the effects:

- The river level U/S of landslide dam rises rapidly, resulting in inundation, sedimentation & disturbance of hill slope around the temporary lake
- Flood occurs due to sudden breach of the dam by over-topping and bursting
- The flood will turned into debris flow super-charged with sediments and capable of transporting large boulders and may damage the bridge structures

TERRAIN HAZARD cont…

- Glacier Lake Outburst Floods (GLOF)
  - These are located in Himalaya above 3,000 – 5,000m above sea level
  - Breaching of the dam/lake can occur when:
    - Heavy rainfall causes the lake to overtop
    - A sudden rise of lake level occur, due to an ice fall or landslide into it
    - The lake/dam raptures due to melting of an ice lens in the core, or an EQ
    - These occurs without warning and can cause great destructions to bridge structures.
  - Examples of GLOF:
    - Arun river created GLOF in 1969 (10m high above normal level)
    - Bhote Koshi and Sun Koshi in 1981 which destroyed 20 km of Arniko Highway

TERRAIN HAZARD cont…

- Earthquake
  - EQ and ground tremors are quite common in Nepal
  - The Majority of epi-centers are located close to active thrusts and faults
  - It may not be practicable to design mountain road/bridge to avoid these active zones and hence, recommended to give consideration to the potential effect of seismic shakings while designing a bridge structures.

GEOLOGY OF NEPAL

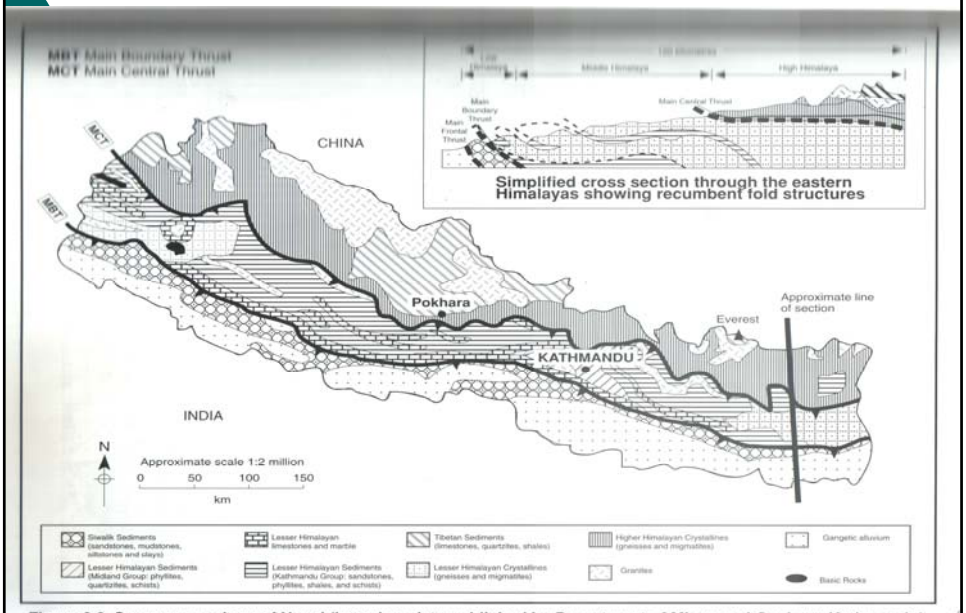


Figure 2.2 Summary geology of Nepal (based on data published by Department of Mines and Geology, Kathmandu)

SUMMASION

As discussed in various slides:

- **Most of the catchments of Himalaya rivers are prone to geo-dynamical phenomena such as landslide, mudflows/debris flows and torrents**
- **Erosion trend is quite strong and bed load especially high**
- **Their water carry a high percentage of solid particles during high floods, the rivers are able to convey big boulders of size up to 5 cubic meter**
- **The floods are sudden and extreme and scour heavily parts of the banks which are not rocky**
- **The bridge crossings in these areas have to resist scour and debris impact of big boulders, & failure to accept or resist those impacts or scour will damage or destroy Bridge Structures more effectively than hydraulic surcharge.**

ENGINEERING PROBLEMS

As discussed in various slides of physical environment, there are a range of difficulties and hazards that requires careful consideration these include:

- Choice of practical bridge site Stable rock for abutment and unyielding base for piers
- Straight & constant reach of river channel to reduce the possibility of natural scour
- Minimum backing-up of water from D/S due to tributaries and valley constriction
- Minimum intrusion of bridge structure into channel flow
- Seismic design of bridges
- Avoid piers as far as practicable

CONCLUSION

Main Problems in bridging Hills & mountains of Nepal are:

- Deep gorges in the upper mountainous reaches
- Boulder and deep beds with high sediment loads in sub-mountainous reaches
- Difficult founding condition
- Deep water with high velocity of flow
- Deep bed scours
- Channel instability
- Structural durability
- Environmental quality &
- Social demands

CONCLUSION cont…

Optimal solution under the parameters discussed will be:

- **Simplest approach is often the best**
- **Design should be robust to suit the difficult & unpredictable environment**
- **In the unstable mountainous environment, there is no substitute for practical experience.**
- **The first rule of bridge design in Himalayan condition is to recognize the prevalent mode of failure and design for it**

- **Bridge design, construction in unpredictable env. stems directly from its geology and climate. The climate particularly the rainfall dictates the way in which slope system and drainage system acts & destruction occurs. Any design that does not addresses the ever-changing environment may doomed to failure**
- **Bridge Engineers must take all the risks (as discussed) seriously. The engineer who does overlook the water running under the bridge may well find the bridge under water**