Engineering Aspect, Design for Local Road Network in Nepal
Let’s analyses few photos of roads with water and landslides
<table>
<thead>
<tr>
<th>Occurred: 2nd of August 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casualties: 155</td>
</tr>
<tr>
<td>Physical damage:</td>
</tr>
<tr>
<td>120 houses (completely)</td>
</tr>
<tr>
<td>37 houses (partially)</td>
</tr>
<tr>
<td>1 km Anuiko highway washed off (Reopened November 2014)</td>
</tr>
<tr>
<td>Unstable when Ground water table is at surface and pga is 0.1 g</td>
</tr>
<tr>
<td>1989 small landslide and cliff present</td>
</tr>
<tr>
<td>Minor slide visible adjoining the crown at 12/7/2017 (Google earth image) which could have triggered by extreme precipitation observed in June 28 2017</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Maximum Cut Slope Ratio (h:v)</th>
<th>Low groundwater (below bottom of excavation)</th>
<th>High groundwater [1] (see page from entire scope)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>loose [2]</td>
<td>loose</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dense [3]</td>
<td>dense</td>
</tr>
<tr>
<td>GW, GP</td>
<td></td>
<td>1.5 : 1</td>
<td>3 : 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>85 : 1</td>
<td>1.75 : 1</td>
</tr>
<tr>
<td>SW</td>
<td></td>
<td>1.6 : 1</td>
<td>3.2 : 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1:1</td>
<td>2 : 1</td>
</tr>
<tr>
<td>GM, SP, SM</td>
<td></td>
<td>2 : 1</td>
<td>4 : 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5 : 1</td>
<td>3 : 1</td>
</tr>
<tr>
<td>Rock type</td>
<td>Maximum Cut Slope Ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>-------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Igneous (granite, trap, basalt, and volcanic tuff)</td>
<td>0.25:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.50:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedimentary (massive sandstone and limestone;</td>
<td>0.25:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>interbedded sandstone, shale, and limestone;</td>
<td>0.50:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>massive claystone and siltstone)</td>
<td>0.75:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>metamorphic (gneiss, schist, and marble;</td>
<td>1:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>slate);</td>
<td>0.50:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(serpentine)</td>
<td>0.75:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Special investigation</td>
<td></td>
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</tbody>
</table>

BASIC REQUIREMENTS TO MAKE ROAD NETWORK ALL WEATHER

- Roads Upgrading
- Roads and Bridges Maintenance
- New Bridges Construction
- Management of Roads and Bridges

Primary modes of potentially damaging mass movements caused by informal road cut excavation material stored on the downslope side of the road; (II) deeper seated landslides which include regolith (IIa), and freeze-thaw (IIb); (III) shallow failures close to the road caused by oversteepened road cuts that include potentially stabilizing roots from vegetation and oversteepening by road cuts that may include bedrock.
Geometric Design of Roads

- Design standards
- Design criteria
- Engineering designing includes the elements of:
  - Highway alignment
  - Highway cross-section
  - Adjacent roadside environment
**Road Standards**

1. Geometric design practices of roads & streets are not entirely uniform for different roads. Each country/roads has their own standards for geometric design.
2. Reasons behind this is:
   - Regional factor such as **terrain, weather conditions, availability of construction materials, financial abilities etc.**
3. Nepal Rural/Road Standards, IRC series, AASHTO British codes/TRL Road Notes
Design Controls & Criteria

- Traffic safety considerations
- Functional classification of roadway
- Projected traffic volume and composition
- Required Design Speed
- **Multimodal** needs of the community
- Topography of the surrounding land
- Capital costs for construction
- Agency funding mechanism
- Human sensory capabilities
- Vehicle size & performance characteristics
- Public involvement, review and comment
- **Environmental considerations**
- Right of way impact and costs
Design speeds (km/h)

- **National roads:**
  - Level terrain: 120 km/h
  - Rolling Terrain: 80 km/h
  - Mountainous: 50 km/h
  - Steep: 40 km/h

- **Feeder roads:**
  - Level terrain: 100 km/h
  - Rolling Terrain: 60 km/h
  - Mountainous: 40 km/h
  - Steep: 30 km/h

- **District roads:**
  - Level terrain: 60 km/h
  - Rolling Terrain: 40 km/h
  - Mountainous: 30 km/h
  - Steep: 25 km/h
Cross Section Elements

• Traffic/travel lane
  – Single lane, two lane, three lane, four lane or wider, divided highways.

• Limited Access highway:
  – Multi-lane, access control improve capacity, increase safety, high speed.
Cross slope/Camber/Pavement Crown

- Slope provided in the transverse direction to pavement.
- It depends on:
  - Type of the surface
  - Amount of the rainfall 1600mm avg, 3345 Pokhara 300 Mustang
- Importance:
  - Prevent the entry of water from pavement
  - To remove water from the pavement surface quickly.
  - **NRS Recommended values:** Pavement type and Camber %
    - Bituminous pavement: 2% - 1.7% 2.5
    - Water bound Macadam: 2.5 – 2.0% -
    - Earth pavement: 4.0% - 3.0% 5.0
    - Gravel 4.0
    - Cement concrete 1.5-2.0
Width of the pavement

Double lane pavement

Single pavement
Fig. 4.4: Cross Section Details

(a). In Embankment

(b). In Cutting
Kerb & Footpath are provided for urban roads. They may be of different shapes and size. They separate physically the carriageway and footpath or may be provided for separating directional traffic flow.
• Depending upon the site drainage ditches may be provided on one or both side of the road.
• Shape and location should not create hazardous to traffic.
• In urban areas they are generally covered.
Right-of-way

• Area of land acquired for the road along its alignment.

• Nepal Road standard:
  – National highway 25 m on either side of the road center line.
  – Feeder roads: 15 m on either side of the road center line.
  – District roads: 10 m on either side of the road center line.
Superelevation

• To encounter the effect of centrifugal force and to reduce the tendency of the overturn or skid the outer edge of the pavement is raised with respect to the inner edge.

• Superelevation/cant/banking is the transverse slope at the horizontal curve.
Transition Curve

Circular Curve

Extra Widening

Transition Curve

Transition Curve
Gradient Standard

• Maximum gradient for trunk road:
  – Mountainous 8%
  – Rolling 6%
  – Plain 5%

• Maximum gradient for feeder roads
  – Mountainous 10%
  – Rolling 8%
  – Plain 7%

• Maximum gradient for District roads
  – Mountainous 12%
  – Rolling 10%
  – Plain 7%
Typical slope failures

Common slump and slide failures in irrigated lands
Slope Management on roads

- Toe wall slope retention at cut face
- Minimise cut in steep / weathered rock cliffs – instead opt for road-side structure
- Allow nature to work on unstable or unsafe-to-work slopes (site dependent)
- Provide sub-surface drains in slopes
- Use check walls for safe spoil disposal
- Maximise bio-engineering treatment on select cut faces and downslopes
Slope treatment measures -

Toe protection wall
To maintain original slope angles (slope material and terrain dependent)
Constraint: Land-take and budgets
Water management

- Lined side drains more effective in loops and on high gradient
- Stone soling of road in ‘khets lands’ and side drains
- Subsurface and catchment drains to divert run-off from slide prone slopes
- Rigid structure in unstable plane?
Vegetative structures practiced on roadside slopes of Nepal

<table>
<thead>
<tr>
<th>1. Grass seeding or broadcasting</th>
<th>2. Palisades</th>
<th>3. Shrub planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Diagonal lines of grass planting</td>
<td>5. Tree planting</td>
<td>6. Vegetated riprap</td>
</tr>
<tr>
<td>13. Herringbone lines of grass planting</td>
<td>14. Live check dam</td>
<td>15. Horizontal lines of grass planting</td>
</tr>
<tr>
<td>16. Random pattern of grass planting</td>
<td></td>
<td></td>
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</tbody>
</table>
A take home message
Development, Climate Change Adaptation and Environment Management MUST GO TOGETHER
THANK YOU
So much!