Harmonizing Rural Road Development with Mountain Environment: Green Roads in Nepal

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Abstract

Conventional approach of road building with cut and throw practice has caused significant mass wasting and has created landslide of hill slope. For having the roads, any type of adverse environmental damage was acceptable to the implementers. Local people, with innocence and ignorance wanted roads and accepted all types of evil practice to have road in their village. They thought, perhaps to have the road, land degradation, landslide, side tipping of ruthless excavation with cut and throw is acceptable and this might be the only way to build road. Whereas, need to develop the road networks in the country is of paramount importance.

Soil loss is occurred in various stages of road building i.e. quantity of excavated mass, shear failure in downhill of the road due to additional load of tipped soil, landslide due to unstable slope created due to cut height in mountainside of road and soil erosion during operation of roads. This paper focuses to discuss the Green Roads practiced in Nepal for minimizing the magnitude of direct mass wasting due to excavation of hill roads comparing with the conventional cut-throw approach and balanced cut-fill method adopted in Green Roads approach and associated issues of Green Roads.

Keywords: Green Roads, mass wasting, landslide, know-how transfer, local capacity building.

1 Background

Conventionally, roads in Nepal have been built without sufficient attention given to the environmental aspects. Soil erosion is taking place in large quantity due to the roads being constructed without consideration of the fragile geological conditions and geo-complexities of the Himalayan ecosystem. Past studies have shown that road construction can have significant effects on slope stability, drainage, erosion and sediment supply to drainage networks. Studies from the Himalayas in Nepal and India indicate that cut slope failures after construction can generate an average of 500 m^3/km/year of debris, and that up to 2,000 m^3/km/year can be generated during single storms with 10-20 year recurrence intervals. Erosion rates in small catchments significantly affected by road construction can be at least 10 times those expected under natural conditions (TRL, *Overseas Road Note 16).* From the decade of 1980s environmental aspects have been taken care of in some strategic roads of Nepal but in rural road network this aspect is grossly neglected.

Development of rural road network in Nepal is constrained by its topography, geological condition of Himalayan region, scarce financial resources and lack of sufficient and experienced technical manpower in the districts. Conventional road building techniques without addressing properly the environmental issues have made the road building a costly endeavor and unsustainable. Another vivid aspect of Nepal's road construction is the resource depletion. There is situation of acute unemployed manpower at one hand and there is big resource depletion taking place through the conventional road building by means of fuel, machinery, materials used in construction. Next interesting factor in rural road construction in the developing countries is the appropriateness of labor-based technology. Adoption of labor-based construction technology in Nepal is suitable, where per day labor rate is about US$ 1.50.

Considering all these problems; low-cost, resource conservation oriented roads constructed with local resources and people's participation seems to be the viable alternative for the expansion of road network in Nepal to its rural corners. In Nepal, technological development of low-cost, environment friendly rural roads based on people's participation is taking place since mid 1980s.

Such roads are also called '*GREEN ROADS*' as this concept put emphasis on environment and resource conservation.

Local Road Improvement Programme (LRIP) supported by GTZ and Helvetas in Palpa District adopted the environment-friendly improvement and construction of 96 kilometers of road in 1986. GTZ supported the construction of environment-friendly road of 65 kilometers in Dhading District in 1987. Construction of these roads piloted the Green Roads Concept. Construction approach of these roads was widely accepted among the donor community. An article named as "*Green Roads for Rural Himalaya"* appeared in the Himal South Asia Jan/Feb, 1990. After publication of this article in the journal, this road is popularly known as **Green Roads**.

2 Basic Principle of Green Roads Concept

The Concept: The Green Road Concept is an approach. It refers to an environmentally sound, affordable (i.e. low-cost), participatory, technically appropriate, labor-based rural road or trail construction/maintenance methodology. The Green Road Concept focuses on conserving the delicate mountain ecology, in particular the protection of vegetation cover as means of soil conservation. In fact, Green Road is a low-cost, low-volume, fair-weather earthen road. They are usually village roads or district roads under the rural road network and not a new class of roads in itself. Greater emphasis is given to the selection of a smooth longitudinal alignment that allows for progressive upgrading as traffic increases. This approach is most appropriate for rural hill road construction having low traffic volume. But some aspect of Green Roads could be used in Feeder and Roads an Highways too.

Basic Principles

Participatory Rural Road Network Planning: District Transport Master Plan is to be prepared and roads are to be selected for the construction as envisaged in DTMP. A participatory methodology is developed and used for the preparation of the DTMP. Decisions are made by the concerned DDC on the basis of consensus, respecting the views of all the stakeholders.

Preservation of the Fragile Mountain Environment: The Green Road technology has been developed as an approach to build mountain roads with minimum environmental damages in order to reduce future risks of road destruction by recurrent landslides or increased soil and water erosion. The approach is preventative, rather than curative minimizing disruption of vegetation cover along the road corridor. Re-utilization of local material underlines the construction philosophy, in which excavated material is transformed into construction material. Mass balancing and controlled tipping is practiced. Blasting of rocks is avoided to the possible extent.

Optimization of Supportive Natural Processes: The approach calls for a phased construction method to, which avoids management of large excavated mass and natural compaction through the monsoon season. Vegetation cover prevents excessive soil erosion and is developed on barren earth slopes. Destructive natural forces are minimized. The approach aims at dispersed drainage system by providing the outward slope in road surface.

Appropriate Technology Promotion: Green Roads aim at finding an optimum balance of manual and mechanized work processes. Simplified construction techniques (dry stone wall, stone ditches etc.) are applied using local construction materials (excavated stone, chips, soil, plants, etc.) and locally produced tools and simple equipment (i.e. wheelbarrows.) are used. Simplified and standardized designs, drawings, and estimates and procedures are used to the maximum extent possible. In order to speed construction, "sectoral" management in several sections lets work proceed all along the alignment.

Labor-based Construction Methods: Labor-based methods are currently the suitable and economic in Nepal. Significant benefit of labor-based road construction methods is that they

generate massive local employment opportunities, and recycle financial resources at the local level. Green Roads projects are integrated into "poverty alleviation" programs. Experience has shown that the construction of a Green Road requires about 12,000 person days per kilometer.

Performance-based Work Management: Locally managed labor groups are employed. Rather than paying workers at a fixed daily rate, they are paid on the basis of the quantum of work they accomplish. This provides a major incentive to work more so that they earn more. Small contract work assignments are used for more structural works that require external construction material; mechanical equipment and specific skill e.g. cement works.

Decentralization: Nepal's decentralization evolution is supported with Green Roads approach. Ideally, they are built with a delegation of authority and responsibility from the center to the district or village level and managed by community locally.

Enhancing Local Capacity Building and Self-help Efforts: A self-help mentality and local skill development are two positive side benefits of Green Roads. Experience has shown that social mobilization support assist to develop a feeling of ownership and involvement. Through the construction process investments are made in training at various levels including district officials, local representatives, supervisors, group leaders, masons and workers. Many of Green Road projects have integrated savings and credit schemes into the project to make it a more holistic answer to the poverty alleviation efforts. They have been able to leverage their earnings from construction into more sustainable, long-term income generating activities.

Low cost: A high Benefit to Cost Ratio through improved road access by a large beneficiary population is achieved accepting a simpler design standard. While other conventionally constructed mid-hills rural roads cost considerably more.

Collective Financing and Transparency: Green Roads depend greatly on a high degree of local resource mobilization. Through experience, it has been found that the most effective way to use these resources is for several stakeholders to pool their contributions, and manage them as one fund. Public awareness on the utilization of funds is promoted through public audits and cost transparency. Labor payments are made in public and are based on work measurements.

Sustainable Maintenance: Maintenance is promoted through local resource generation. Transporters are charged a user service fee or toll with. VDC/DDC annual grant funds are also made available. Roads are generally closed during the monsoon to prevent excessive wear and tear of the road surface. Any earth road will degrade extremely fast if it is driven over in the rain. During the district transport master planning process, the size of the network is scaled to what the district can afford to maintain.

3 Green Roads Design Standard

Green Roads are constructed mainly for rural road. However its principle is being applied for higher standard of road under some donor funded projects too. Rural Access Programme funded by DFID has adopted to construct the strategic roads too.

Design standard and geometric design of Green Roads are similar to that of standard road engineering practice. Maximum gradient should not exceed 12% and special surface treatment and side drains are required in higher gradient sections. Minimum radius in horizontal curve is 12. 5-meters. Pavement surface is earthen with spot gravelling at places wherever required. Road can be upgraded to gravel road when AADT increases.

4 Organization and Management

4.1 Institutional Arrangement

District Level: Most of the Green Roads are implemented through DDCs. Thus at district level DDC or DRCC functions as the legislative body to make the decisions related with the implementation of the Green Roads. Receives the proposal from VDCs and makes the decisions. It makes the agreement with VDCs and the User Committee (UC).

VDC Level: VDCs forms the separate user committee of the users to manage the road woks at community level. It facilitates the committee to make the agreement with DDC, provides complementary cash wage in case of WFP supported projects. Monitors the work of UC. In case of Food for Work programme VDC provide additional cash amount to workers on top of the WFP's food contribution.

Community Level: User Committee (UC) is formed for the road section. If the road is longer passing along the more than two VDCs, VDC wise UC are also formed. According to the project specific requirement sub-committees are also formed to facilitate the management of work and the mobilization of the labour. UC makes the agreement with DDC and VDC. A tripartite agreement is made for the implementation of the project. UC take the major responsibility to implement the project, of course with sufficient technical and social mobilization support.

Road Building Group (RBGs): Labor groups are formed comprising of 16 workers (in most of the cases). Each RBGs are assigned of the work in certain stretches according to the work volume. Their work is measured in monthly basis. Each RGBs are headed by Naike (foreman), who receives the tools from the UC and is responsible and accountable for the tools they receives and keeps the record of the attendance of his group. RBGs also function as cooperative and operate their saving/credit schemes and income generating activities.

4.2 Technical and social mobilization support

For the successful implementation of Green Roads, technical and social mobilization support is very important. Technical and other manpower live in the field continuously with the community, guiding the UC to manage the project. Technical support is provided by hiring the local or outside consultancy firm or the NGOs according to the size of the projects. In the absence of technical support roads implementation do not take place according to the principle adopted.

Technical support includes:

- Preparation of the District Transport Master Plan (DTMP)
- Road alignment selection, survey, design and report.
- Preparation of training materials
- Training to User Committee members, local supervisors, foreman, masons and labor groups.
- Preparation of project schedule and planning.
- Construction supervision of the work
- Facilitating the site office and store management.
- Work measurement and valuation of the work done by the (RBGs) labor groups.
- Quality control of the work
- Progress reporting and monitoring
- Assess and implement the preventive maintenance of the road during construction period.

Social mobilization support includes:

- Initiating the dialogues and meeting with the VDC and community
- Facilitating the formation of user committees.
- Playing the catalytic role in maintaining the political balance and bringing the consensus.
- Conducting the training to user committee, RBG, record keeping training etc.
- Facilitating the UC to mobilize the RBGs and social welfare of the workers.
- Facilitation to the UC for the payment to the workers.

- Help UC to maintain the Project Book
- Guiding RBGs to operate the group saving schemes and income generating activities.

5 Construction Technique

5.1 Effect of Conventional Cut-Throw in Hills

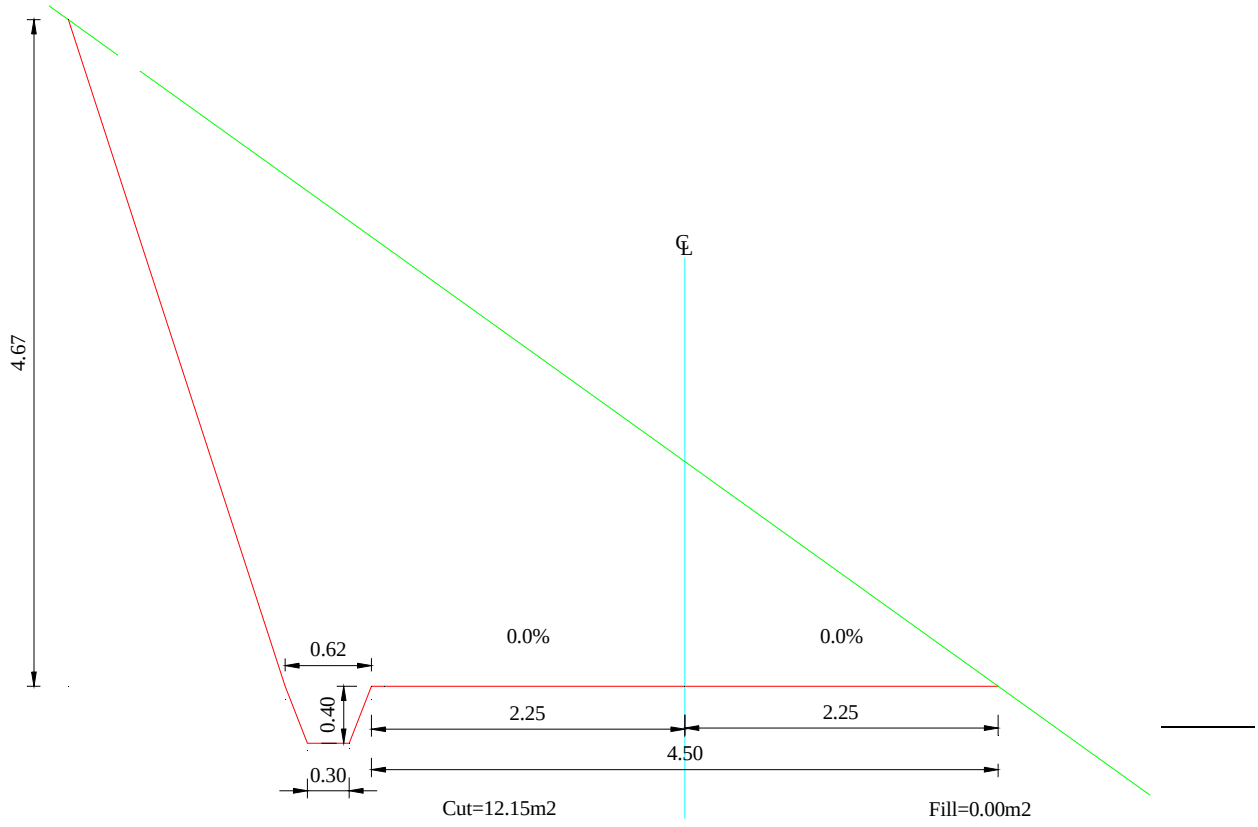
Loss of Agricultural and Forest Land: Excavated mass thrown down hill damages and covers the vegetation. It takes many years to reclaim the land to its original condition with vegetation growth. Area damaged by the thrown material is much higher than the area actually covered by the road, about three times more than the land occupied by the road.

Valley Side Shear Failure: Excavated mass thrown down hill in valley side of the road adds the surcharge load as the natural slope area. This additional load is further increased during monsoon with additional weight of wet soil mass. This mass will cause the landslide below the road due to shear failure caused by added load.

Contribution in Flood during Monsoon by Mass Wasting: The most studied effect of road building is hydro-geologic degradation, in the form of soil erosion, mass movement, sedimentation and altered stream flow. Materials throw downhill of road is washed out during monsoon rain and transported to the rivulets and rivers Sediment load increased in flood due to the mass wasting by road further adds to the damaging effect of the flood. It also plays a catalytic role to trigger landslide in valley side of road due to added load of excavated mass pulling down the original soil mass of hill slope, which was stable earlier.

Increased Occurrence of Post Construction Landslide: Cut-throw method increase significant cut height than cut fill method, which leads to the instability in the hill slope. Deuja (1994) estimates that 400-700 cubic meters of landslide occurs per kilometer per year along the mountain roads, and 3000 to 9000 cubic meters of landslide occurs per kilometer during the construction of mountain roads in Nepal.

Cut and throw system with side drainage (Cross Section of 35^0 hill slope)



5.2 Earthwork Excavation

Phased Construction Approach (Gradual widening): Gradual widening process is followed. The conventional practice is to cut the full width of road in one time. Hill slope is destabilized when full width and height of road is obtained at one time and need higher level of management to handle the larger mass excavated. Therefore cutting hill slope is done in phased manner. Normally, it takes three years to obtain full width and cut height. This mechanism allows time to help in adjusting hill slope with microbiological properties and simplified management. Phased road construction method adopted in Green Roads is as follows:

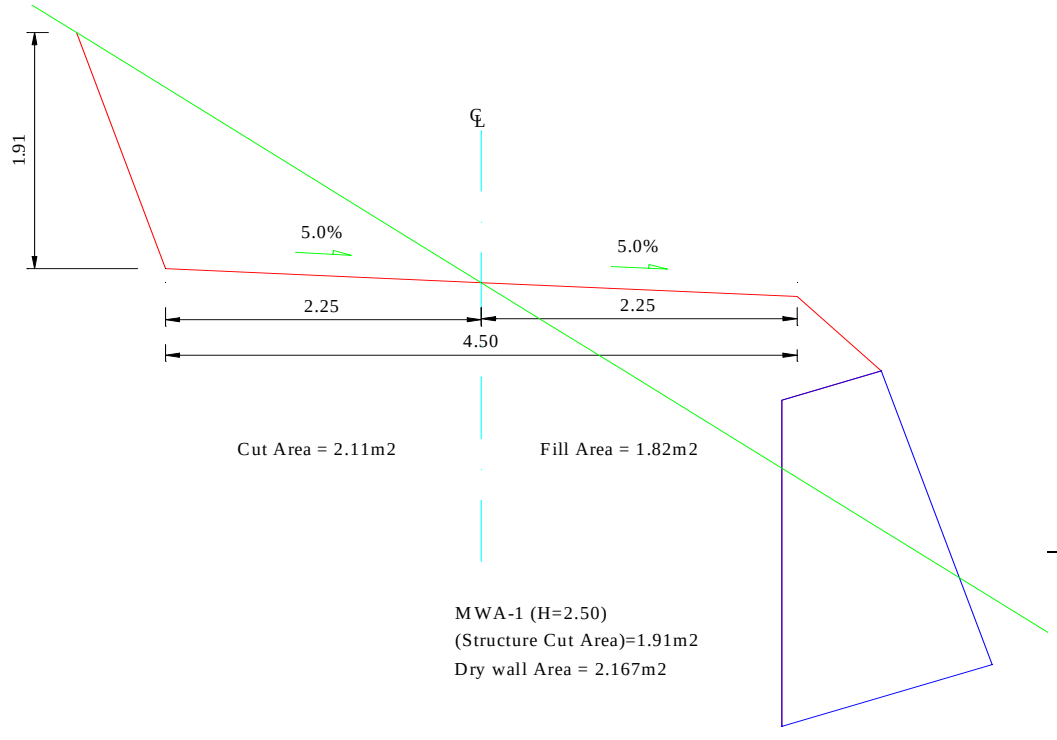
Phase I: A trail along the future road alignment (1.5 to 2 meter)
Phase II: A track created by the gradual widening of the trail. (3 to 3.5 meter)
Phase III: Full widening of road (4 to 4.5 meter)
Phase IV: Drainage structures, bypasses, natural compaction and bioengineering.

Mass Balanced Method of Excavation (Cut and fill): Conventional system of hill road construction is mass wasting, throwing down the excavated earth that accelerates the soil erosion. In mass balancing or cut-fill method of excavation, cut height is reduced drastically to that of conventional cut-throw method. Mass balancing is the most crucial as well as the most fundamental principle in the Green Road Concept of road building. Excavated mass is properly deposited in the valley side and part of road width is also obtained. Mass balancing cannot be obtained in all type of slope section. However longitudinal mass balancing alternative is to be sought and could be possible in many cases except in the steep rocky sections.

Minimization of Blasting for Rock Excavation: Careless blasting rock has disastrous effect in mountain environment. The tremor of blasting rocks affects the hill slope badly causing the destabilization. Due to vibration and tremor new micro-cracks are formed deep inside the remaining part of rock/earth surface. Water seeps along these cracks during rain. This may cause rock fall and landslide in future. Therefore use of explosives should be minimized.

Experience shows that some of the work groups are skilled and specialized during the road construction, such work groups very often are willing to do harder work with the motivation of some additional wage incentives to them. Very interestingly, it was revealed during the discussion with field supervision team that few specialized, skilled and courageous group of workers is available in most of the road. Existing Work Norms allows paying adequately to the group for such works.

Cut fill without side drain (Cross section of 35^0 hill slope)



In a study, it was found that 86% mass wasting could be saved (HRS 2003) compare to the cut throw approach. In addition to this, cut throw excavation approach will have following negative environmental impacts in the hills:

5.3 Retaining Structures/walls

Appropriate techniques are adopted while preparing design and estimate structures. Flexible types of soft engineering technique are adopted instead of conventional practice of rigid structures. Selecting type of structure depends upon cross slope of terrain and type of soil. As the cross slope increases structure height and thickness will also increases. As the Green road focus on low cost, environmentally friendly and labor based construction approach, most of retaining structure used is dry stonewall and gabion wall. Jute bag and bamboo terracing structure are used with Bioengineering works.

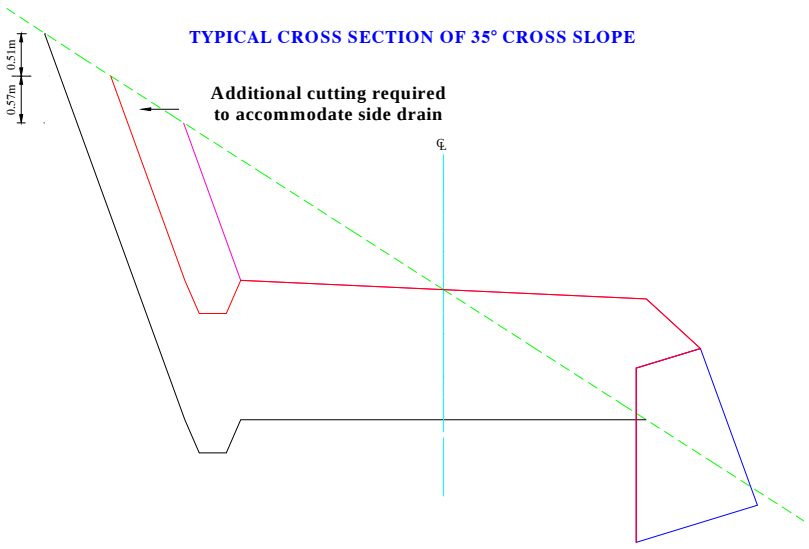
Dry Stone Wall: For the hill slope between 30 degree (58%) and 45 degree (100%), dry stonewall is used as retaining wall. Normally, height should not exceed 3.5 meter. Outer slope is kept to 3:1 slope. Top width should not be less than 70cm. Each stone are laid in 3:1 inclination. Bond stones are provided at frequent interval. 30cm filling is made on top of walls. Cuttings of plant on top of wall and trees saplings at the bottom are planted.

Gabion Wall: For the hill slope exceeding 45 degree (100%), gabion wall is used, where height of structure is normally more than 3.5 meter. Gabion walls are also provided in wet area. Outer inclination of wall is 1:4 slopes. All the process of dry wall construction should be followed for stone filling.Tie wires should be provided at 60cm interval.

Jute Bag Wall: If stone is not available for structure then jute bag wall is used in gentle slope. Outer slope is kept in 1:2 slopes. Topsoil is put on outer layer. Only two third of bag should be filled. Open end of bags should be kept inside. Plantation of hard woodcutting should be done all over the wall. This type of wall should be avoided on the seepage area.

5.4 Drainage Works

Optimizing the Drainage Requirement: Conventional practice in Nepal is to construct the side drain all along the road. This requires about one meter of extra cutting. If road width is 4.5 meter wide, 5.5 meters of width has to be excavated to accommodate the side drain. The additional cutting of 1 meter result in height increment of 1.5 meter to 45^0 hill slope according to hill slope as shown in figure below:



Additional cutting is required to accommodate side drain. Therefore it is recommended to optimize the actual required length of side drain to help in minimizing the excavation. It is true that side drain in all along the road cannot be avoided. But in the condition suitable for not providing the side drain, it should be avoided.

To facilitate the rainwater and surface run off, 5% outward slope in the road surface is provided. Often it is argued that after the operation of the vehicle in earth road two parallel guts are formed along the load exerted in the vehicle tyre. But even if the side drain is built along the side, surface run off flowing along the guts formed by tyre will not flow along the side drain provided. It could be managed only by regular maintenance of the road. Thus this problem is directly related with the maintenance. Therefore it is recommended to provide the side drains only in following conditions:

- At places where longitudinal gradient are more than 7%.
- Along the paddy field area, where irrigation water is often encountered along the road surface also.
- Along the built up and settlement area, where household water effluent is likely to run off along the road surface.

But it should be noted that each side drain should be managed with proper outlet of water flown in it. Cross drain should also be provided to provide the outlet to the water from side drain. Cascades and small check walls are to be built to drain down the water safely. Side drain without cross drain will further accelerate soil erosion and landslide due to accumulated water flow with more energy to damage. The idea of not providing the drainage in suitable places is to dissipate the damaging energy of water like in terraced agriculture farmland, where rainwater is drained in natural way in dispersed way.

Cross Drainage: The main function of cross drain is to remove surface water coming from side drain and river, streams etc. Some times the natural outlets for side drains are located at fairly long distances. As a result of this along certain stretches the standard side drain is unable to cope with the quantity of water coming to the drain. To cope with this situation there are two alternatives available. Either to increase the size of side drain, which would mean either reduction of the road width available for road, traffic a discharge the excess water down the hill by providing lateral outlets of water. The laterals of water are known as cross drains. By providing the cross drains at suitable intervals, the standard section of the road formation, including the size of the formation is maintained.

There are 4 types of cross-drain generally used in road works.

- Minor Ditches: Wooden ditch, dry stone ditch, pre-cast ditch, scupper
- Causeway: Dry stone causeway, PCC causeway, RCC causeway
- Culvert: RCC slab culvert, Concrete pipe culvert, Masonry Arch culvert
- Bridges

6 Bioengineering Works for Road Slope Stabilization

Bioengineering is the integral part of Green Roads Concept. It is the use of living vegetation, either alone or in conjunction with civil engineering structures and non-living plant material, to reduce shallow-seated instability and erosion on slopes. Positive mechanical and hydrological properties of the plants are utilized to obtain engineering purpose in controlling erosion and stabilizing the slope. Bioengineering solution can be adopted in many soil stabilization and erosion control situation from stream bank and lakeshore protection to upland gully restoration and slope stabilization. Vegetation is an essential part of every ecosystem.

Bioengineering is the important guideline for environment-friendly approach of road construction. Biological approach for slope protection with vegetation is most effective low-cost measures to contribute the long-term sustainability. Bioengineering is both curative and preventive measure to stabilize the hill slope of road. It can be applied in the failed zone of slope as a curative means and it can also be applied for reducing the risks of future slope failure as a preventive means of slope stabilization.

Advantages of bioengineering solutions are:

- Low-cost and lower long-term maintenance cost than traditional methods.
- Low maintenance of live plants after they are established.
- Environmental benefits of wildlife habitat water quality improvement and aesthetics.
- Improved strengths over time as root systems develop and increase structural stability and
- Compatible with environmentally sensitive sites or sites with limited access.

Bioengineering systems work in the same way as civil engineering systems and have the same functions. They are effective at depths of up to 500 mm below the surface.

7 Green Roads Completed and Under-construction in Nepal

After piloting the Green Roads Concept in Palpa and Dhading districts, this concept is widely adopted in various other districts by various donor funded projects. Later Rural Community Infrastructure Works (RCIW) programme known as Food for Work (FfW) supported by WFP, GTZ, and Government through Ministry of Local Development started in 1995 implemented in 20 districts of Nepal also adopted the Green Roads approach of rural road construction. Rural Access Programme (RAP) funded by DFID in 7 districts, District Road Support Programme (DRSP) funded by SDC, Upper Sagarmatha Agriculture Development Project (USADP) and Rural Infrastructure Development Project (RIDP) funded by ADB. INFRIN funded by USAID

Total rural roads in Nepal are more than 20000 kilometers, in which about 3000 kilometers of roads are constructed following the Green Roads approach.

8 Green Roads Myths and Misconception:

There are some misconceptions about Green Roads Concept. Some people thinks that all the rural roads implemented by DDCs and VDCs are Green Roads, irrespective of the construction process they adopted. But this is wrong. All the rural roads are not Green Roads.

People have the feeling that construction time is much longer in Green Roads than conventional approach as it follows the gradual widening approach. This is wrong. Gradual widening is followed in slope land which. It allows the complete construction of all the section of the road within 3 to 4 years. Major reason for delayed period of completion of construction is resource gap. Fund allocation pattern is major constrains for longer project period.

Another misconception is Green Roads stops the vehicle during monsoon, thus operation period is less, operated during fair weather of about 7 months only. But reality is it compromises with investment. Paved roads/bituminous roads are expensive, gravel road is also expensive. Paved roads are almost three times expensive and gravel roads are two times expensive than earthen road. Rural roads do not get priority for such investment. Obviously roads without paved surface are not suitable for operation of vehicle during rainy season and monsoon. Muddy earth roads are the common scene in Nepal. But Green Roads Concept articulately advocates that vehicle should be operated during monsoon/rainy season only when road surface is paved, otherwise it should be stopped to avoid the excessive damage and high vehicle and road operation and maintenance of roads.

9 Role of consultants in implementation of the concept:

Consultant's role is very crucial to effectively implement this approach. Most part of the works is carried out by user committee. User Committee comprises of rural hill people. They are to be guided properly. Supervising the construction works carried out by the qualified contractors and the user committee differs. Where technical supervision is inadequate, proper implementation can not take place. Many of the rural roads implemented by government fund and donor funded road projects have tried to adopt Green Roads Concept. But due to absence or inadequate technical supervision, these projects are not implemented with the concept and have created lots of slope stability problem.

10 Conclusion

Minimizing the mass wasting and to reduce the post construction landslides along the hill roads are very important to harmonize the road development with fragile hills of Nepal. Thus mass balanced method of hill road construction**,** selection of optimal alignment, labor-based implementation of construction, phased construction approach, optimization of width of the roads, re-use of excavated material as construction materials, optimizing the drainage requirement, minimization of blasting for rock excavation and bioengineering works for road slope stabilization are the major consideration to harmonize the road development in hills of Nepal.

Policy of planned undertaking of road construction with labor-based construction method, participatory management of road construction, social mobilization support and technical support is required. Training to local people for transfer of know-how and their capacity building at local level is very important. After the completion of construction appropriate operation and maintenance management mechanism is to be established and adherence is required for its sustained use.

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