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Final Report

Final Report

on

Assessment of soil bioengineering and conventional methods used in road side slope stabilisation work in Nepal

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Austrian Academy of Sciences (OeAW)
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Content:

1 Summary

Since twenty years of the slope stabilisation works the technique of soil bioengineering has developed and now established as an alternative and additional engineering discipline beside the conventional geotechnical or civil engineering in Nepal. Living plants and auxiliary materials are used as construction material. From the point of view of sustainability, environmental impact, and socioeconomic aspects these “living” soil bioengineering systems provide a lot of advantages. The research work was focussed on field investigations to develop technical standards of soil bioengineering systems. For the implementation of the research project works, several sites were selected (Kusunti, Lalitpur; Kali Khola, Pokhara; Pulchowk campus, Kathmandu; Sarangkot-Road, Pokhara). The local people have been involved in the practical construction work, whereby the public awareness could be increased in the different applications of soil bioengineering techniques. A vegetated bamboo crib wall was compared with a conventional slope stabilisation method (gabion) by means of different parameters, which results that this kind of system is a suitable alternative for solving slope stability problems or for road embankment protection in Nepal from a technical as well ecological and economical point of view. A direct arrangement shows that a bioengineering system (crib wall made of bamboos) is 4-times cheaper than a conventional civil engineering structure (gabion) and offers the same factor of technical safety. In addition a training program and a workshop was organised for the technicians and civil engineering experts working in the field of soil bioengineering to impart the knowledge of using soil bioengineering systems for slope stabilisation work.

2 Project background

Infrastructure development is important for social and economical progress. For a mountainous country like Nepal, road transport is only one viable means of transportation of peoples and goods within the country. There are about 25.000 km of roads including village roads in Nepal. Two third of these road networks are in fragile mountains and hills. The construction and maintenance of roads in Nepal is very difficult and costly due to frequent slope failures. There are more than 6000 roadside slope failures every year, which causes road closures and make the delivery of basic services redundant for a few days to even months depending upon the nature of slope failure. With the increasing demand of road infrastructure, the problems associated with its maintenance are becoming more critical. Therefore, Nepal needs to develop sustainable techniques in road side slope management.

On searching an appropriate technique for sustainable slope management over the last two decades, soil bioengineering has emerged as an alternative and additional engineering discipline to the conventional geotechnical or civil engineering. Soil bioengineering is a technique using plant materials, living or dead, and auxiliary material for geotechnical problems such as landslide, eroding slopes and riverbank protection. Independent of living or dead the whole construction material is local available, which is quite different and can be considered as an alternative to the use of steel and concrete. Therefore these “living” soil bioengineering systems provide a lot of advantages from the point of view of sustainability, environmental impact and socioeconomic aspects. Although different techniques of soil bioengineering have been practised successfully in the past, there are still missing technical standards. Research work is therefore required for technical standardisation of soil bioengineering techniques.

In a previous research project in Nepal a new soil bioengineering technique called vegetated bamboo crib walls were tested for the first time. The following benefits were observed:

- Bamboo and the vegetative cuttings used in construction are locally available renewable resources
- These types of wall look like invisible construction
- Plants add the aesthetic beauty and improve the environment
- The construction technique of such wall is simple and fast
- The construction requires no qualified technical manpower

- The construction can be accomplished by local labours

Initial results and benefits showed that this technique seems to be quite useful for developing countries like Nepal. The new technique should now be tested for its performance in several conditions. This project is proposed to analyse the technical and economic justification of the new technique to use in practice. In addition to this applied research, the demonstration of the project and the training activities will aware the local community to use appropriate techniques in the form of different soil bioengineering systems and their capacity developments.

3 Project objectives

Over the past decade, considerable know-how has been acquired in the application and assessment of soil bioengineering systems in Europe, which can also be applied in developing countries. The project will establish an academic and development co-operation to transfer this knowledge and experience as a contribution to sustainable economic development and poverty reduction in Nepal. The specific objectives of the project are:

- To compare a vegetated crib wall with a gabion wall
- To test the technical and economical feasibility of such construction technique
- To transfer, share and exchange the technology to its stakeholders
- To disseminate knowledge and experience ("best practice") in soil bioengineering.

4 Project activities

After the approval of the project from the Commission for Development Studies at the Austrian Academy of Science (kef), the project works were officially started on **1st September 2006**. In the first months of the project conceptional considerations (literature review, pre-assessment for the selection of potential construction sites and the procedure of field investigations) were discussed among the project partners. In October 2006 the first construction site was selected and in November the implementation work at this site was carried out. The 2nd construction site was done in June 2007 in Pokhara. The third and fourth constructions works were carried out in December 2007 and January 2008 in Kathmandu and in Pokhara. A detailed description of major project works (selection and location of the project sites, implementation steps, analysis and results as well as

dissemination activities) carried out in the framework of this project are presented in the following sections.

5 Test sites in Nepal

Among the various activities planned under this project, the construction of the test sites is an important project activity to demonstrate the technique and assess the suitability to solve the slope stability problems associated with road infrastructure development in Nepal. Under this activity, test constructions at four different sites were carried out. Before construction, it is important to select a suitable construction site and also to select the mode of construction (using a contractor or with user groups). After site selection and mode of construction, the sites were surveyed and detail designs were carried out. Finally the constructions works at each of these sites were completed and monitored.

5.1 Selection of the sites

For the implementation of the research project works, several sites were visited. Some of the sites are located in the rural hilly and mountainous areas, far from Kathmandu. Actually, the sites are good, but they are far and it will be unmanageable from Kathmandu in the long run. The resources available were not sufficient to run such projects in such areas. There are other sites in the Kathmandu valley itself. Some were very big and some were on the no man's land, which are not in the interest area of the local people. Considering various other aspects related to local needs, financial constraints, accessibility to the site, management of construction works and site monitoring, we decided following four construction sites:

- **Kusunti, Lalitpur**

The site is located at Kusunti, in Lalitpur district within Kathmandu Valley. There was a serious and humble request from one of the communities in Lalitpur Municipality, where the community people were planning to construct a local road. There was an extreme need of a retaining structure along a newly built community road. The site was inspected and dialogue was held with the local people. It is a new settlement where people from more than 20 districts of the country have resettled. They were very interested to know the new technology for slope stabilization. Actually, it was realized that such types of projects can broaden the knowledge of the people and they can share the experiences with their native fellows in the countryside. So the site was accepted as the most appropriate. The

characteristics of the site are: the size of the site is within the capacity of the project, it is a people driven project, the experiences can be shared with the people of several districts at once and it is manageable in the process of research.

- **Kali Khola suspension bridge, Pokhara**

This site was selected as a demonstration site for the engineering technicians of Kadoorie Agricultural Aid Association (KAAA), a NGO working in the rural areas of Nepal. The site was selected for hands-on practical works during training on the use of soil bioengineering techniques in slope stabilisation organised by the NGO. The training course content was result of consultations and meetings with the Chief of the technical department of KAAA and the trainers involved in this project. The participants had to plan, survey, design, and implement the vegetative crib technology on the site. So it is totally a participatory and non-formal approach of training in contrast to the conventional lecture type trainings.

- **Pulchowk campus, Kathmandu**

After the construction of the site at Kusunti in Lalitpur and Kali Khola in Pokhara, a third site was selected at the premises of Tribhuvan University, Pulchowk Campus. The main objective of the construction site was to make the students and academician aware of the advantages and benefits of vegetative crib techniques. This site was directly supervised by the students and academics working in this field.

- **Sarangkot-Road, Pokhara**

The fourth site was selected at the Sarangkot road section in Pokhara. This was the result of the visit of the Austrian partner to Nepal in October 2007. As there was a big necessity to repair the damaged gabion wall and protect the landslide as early as possible, we decided to construct this site. This site was constructed by the division road office of the department of roads, a government authority.

5.2 Mode of constructions

Depending upon the geographical location of the sites and the interest of the local people, the mode of constructions works were selected. In the Kusunti site, there was an involvement of User Committee, who was directly responsible for the supervision of construction works, aftercare and maintenance works. In this site there were also involvements of students.

In the site at Kali Khola, Pokhara, there is a direct involvement of a NGO (KAAA) and trainees of a soil bioengineering training program. The NGO is responsible for aftercare

and maintenance of this site. In the third site within the premises of Pulchowk Campus, the construction works were carried out under direct supervision of academic staffs and the maintenance works will also be carried out by the students. The site at the Sarangkot, Pokhara was constructed by the local divisional office of the department of roads, a government authority.

5.3 Formation of user group at Kusunti site

The local people had requested to assist them for the construction of a retaining structure on the valley side of a local road. It was necessary that the local people should be responsible for and take care after its construction. In this connection, a mass meeting of the local people was organized and a user group was formed. The name of the group is “Kailash Tol Sudhar Samiti”, i.e. Committee for Kailash community development. There was a significant presence of women, Janajatis, Dalits i.e. Nationalities (Low cast people) and under privileged groups of people.

Figure 1:Meeting of user groups and instruction by Nepalese partner

The mass meeting has formed a working committee for this “User Group”. The committee comprises the following people (Table 1):

Table 1: Register of the User Group

Name	function
Mr Hari Prasad Dulal	Chairperson of the committee
Mr Manoj K.C.	Advisor
Mr Sadhuram Neupane	Advisor
Mr. BalaKrishna Sherchan	Secretary
Mrs. Meena Rai	Member

Mrs. Tumla Devi G.C.	Implementation
Mrs. Radhika Sharma	Implementation
Mrs. Sushila Dangal	Implementation
Mrs. Goma Kumari Dangal	Implementation
Mrs. Sanu Maya	Implementation
Mrs. Radhika Dulal	Implementation
Mrs. Devi Garbuja	Implementation
Mr. Kul Bahadur Alemagar	Implementation
Mr. Bal Bahadur Pun	Implementation
Mr. Om Kumar Thapa	Implementation

Commitment of the users' committee

The committee has committed to:

- be involved in the research process so that new knowledge can be acquired
- participate in the implementation process
- aftercare of the site after its implementation
- not to disturb the site for at least two years
- be ready to explain and demonstrate the construction method of the bamboo crib wall to the visitors and
- to serve as an instructor for the extension of such projects in other parts of the country.

5.4 Site survey and design

After the final selection of each site, it was surveyed in detail. Levelling or theodolite surveys were conducted to prepare the cross section, plan and slope profile. With the data obtained from the survey, contour maps were generated. The plans of the structure with cross-sections at different chainage were plotted in the contour map.

At the Kusunti site, it was designed that half portion of the site was treated with the gabion retaining wall and half with the bamboo crib wall to compare two retaining wall systems from a technical as well as an economical point of view. One layer of gabion retaining wall was constructed for the whole stretch as a base. The total designed height of the wall is 3m.

At the Kali Khola site, the construction work was carried out just for practical works during a training program. Therefore there was no detail design prepared. A sketch was prepared by the trainers and the construction works was carried out as per direction of the trainers. At the Pulchowk Campus site, survey was done by the students and the drawings were prepared and the site was constructed as per design.

At the Sarangkot site in Pokhara, a detail survey was carried out and the cross sections were prepared. Afterwards a detailed design was prepared by the project team and finally the construction works were carried out.

5.5 Construction arrangements

As the different sites are selected for different objectives, the modes of construction at these sites are also different. The volumes of works at most of these sites are too small for the big contractors. Local contractors will not be interested to work in such projects. Therefore, construction works should be managed by the researchers working in the project. In this connection, the materials were purchased and the workers hired. Gabion boxes, stones bamboos and other required materials were purchased from the local markets or local people and the construction works were carried out. The construction details of each site are presented below.

- **Kusunti, Lalitpur**

The actual construction work at this site was started on 11th of November 2006 and ended on 23rd of November 2006. A supervisor was appointed to control the quality of the work. Students from the Pulchowk Campus and one student from Switzerland (University of Applied Sciences Wädenswil (HsW)) were also directly involved in this work. The designed cross section of the wall is shown in figure 2. The before and after construction photographs are presented in the figures 3 and 4. The other details about this site can be found in the report prepared by Jonathan Sury as his foreign practicum work.

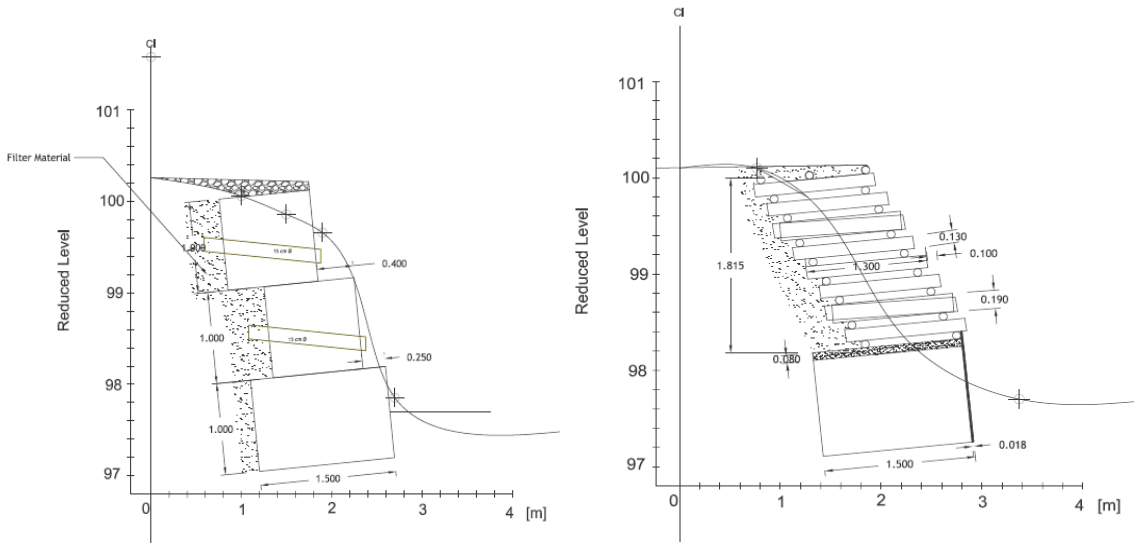

Figure 2: Cross sections of retaining wall (Gabion and crib) constructed at Kusunti, Lalitpur

Figure 3: Before and after construction photographs, Kusunti, Lalitpur (November 2007)

Figure 4: The vegetated bamboo crib wall just after construction (November 2006) and after one year of construction (Kusunti, Lalitpur, November, 2007)

- Kali Khola, Pokhara

The construction work at this site was carried out during a training course organised by a local NGO. The training was conducted by Mr. Padma Khadka. The site was constructed under his direct supervision. Preliminary drawings were prepared by the NGO technicians. Before and after photographs of the site are shown in figure 5. About 1.75 m high and 15 m long vegetated bamboo crib wall was constructed and about 20 m x 15 m slope grid with bush and tree plantation inside the grid was also installed on the slope.

Figure 5: Before and after construction photographs, Kali Khola, Pokhara (June 2007)

- Pulchowk campus premises, Lalitpur

After the visit of the Austrian partner to Nepal, it was decided to construct at this site for demonstration purpose to the students and academics. At this site about 2 m high and 10 m long wall is constructed under direct supervision of Nepalese partner. The maintenance of the site will be carried out by the campus itself. The photographs of the site before and after construction are shown in the figure 5.

Figure 6: Before and after construction photographs, Pulchowk Campus, Lalitpur (December, 2007)

- The landslide site at Sarangkot-Road, Pokhara

This site was selected also after the visit of the Austrian partner to Nepal. The 7 km long Pokhara-Sarangkot road sector was constructed in 1995. At that time, there was no use of any soil bioengineering techniques. All of the retaining structures were made of either gabion or masonry construction.

During the monsoon in July 2007, a big landslide was occurred. About 20 m length of road section was damaged. In this section, gabion retaining wall was constructed before. The length of slide is about 250 m, average width is about 25m and the height difference is

about 100 m. Now the land slide is stabilised using series of vegetated bamboo crib walls. It is planned to stabilise the slope between two crib walls with hedge brush layers. The surface water coming along road and from the top of hill is diverted to the side drain. Bushy vegetations will be planted on the slope during monsoon season.

The site was surveyed and a technical drawing was prepared. Then the construction works were started in January 2008. The main construction works were completed within a month. The photos of landslide before and after the construction are shown in figure 7.

Figure 7: Before and after construction photographs, Sarangkot landslide, Pokhara (January, 2008)

5.6 Involvement of students in construction and monitoring

The students of Master's Programme in Geotechnical Engineering have participated in all activities of the research project. They were very enthusiastic and eager to get new knowledge and skill from the project. Likewise a student from Switzerland, Jonathan Surry was also involved from the very beginning during the construction at Kusunti Lalitpur. He worked very actively and enthusiastically at this site and completed his 3 months practicum on this project. It is expected that the students involved in the different project activities have gained a valuable experience as well as practical knowledge of vegetated bamboo crib wall construction techniques.

5.7 Measurements and monitoring of sites / Future arrangements

There are two types of activities in the research process: aftercare and maintenance of the site and monitoring the site to study its performance. Depending upon the physical location and basic objective of the construction, monitoring and maintenance of the sites are being carried out.

The site at the Kusunti is mainly for research purposes, where the construction of conventional gabion wall is also carried out. The basic objective of this construction site is

to evaluate the performance of the bamboo crib wall in comparison with the gabion retaining structure. For this purpose a change of the slope parameters are studied. The central material testing laboratory of the Pulchowk Campus, the partner institute in Nepal was assigned to conduct the soil tests and other measurements each month. Soil samples of the site have been taken and the soil has been tested in the laboratory. The strength characteristics have been determined from the direct shear test of an undisturbed sample, whereas other index properties have been determined with the disturbed soil samples collected from the site. The results are analysed and performance of both walls are evaluated. Scientific monitoring of the site are being carried out by the researchers and technical persons assigned by the researcher. At this site, the user group along with the local community will take care of the general maintenance works.

The purpose of construction works at other three sites is mainly for demonstration. The main objective of construction at these sites is to disseminate the idea about the vegetative crib walls and increase the awareness of the people for soil bioengineering solutions. Therefore, there will be general site maintenance work by the respective authorities involved in the project. The site at Pulchowk campus will be maintained by the Campus itself. The site at Kali Khola, Pokhara will be monitored and maintained by the local NGO, KAAA. The site at the Sarangkot will be maintained and monitored by the Division Road Office Pokhara.

6 Critical Study on the use of vegetative crib walls

Regarding this activity, both partners have prepared a report on the use of different soil bioengineering methods used in Austria and Nepal. During the technical visit of Nepalese partner in Austria, both the partners presented their reports and discussed about the advantages and disadvantages and also limitations of various methods to be used in different context and geographical locations. Based on the outcome of this study, the training programme was prepared and the agenda for the workshop in Kathmandu was finalised. The details of this study are reflected in the training manual prepared and distributed to the trainees in Kathmandu.

7 Technical visit to Austria

The technical visit of the Nepalese partner was organised from 27 May to 11 June 2007. The Nepalese partner, Associate Prof. Mr. Padma Khadka visited Vienna. The complete visit programme has been presented in the annex. During his visit, Mr Khadka visited various soil bioengineering sites in Austria and also in South Tyrol, Italy. He had several meetings and discussions with Austrian partners and other academic personnel of BOKU. Mr Khadka also delivered a lecture to Mountain Risk Engineering Student at BOKU.

8 Field measurement and monitoring

In order to compare the construction techniques, some field measurements and monitoring of construction sites has been carried out. The changes in ground water conditions, ground settlements, growth of plants and future developments of construction sites are being monitored. Soil samples from the field are taken and tested in the laboratory to know the soil characteristics. The construction site will be continuously monitored in future also depending upon the research outcome and interest of Nepalese partner. Some measured data are presented in the field report submitted by Jonathan Sury. In order to judge the usefulness of the proposed soil bioengineering technique, a comparative study has been carried out jointly by Austrian and Nepalese partner. The analysis was on its technical and economic feasibility. The study also analysed its strength, weaknesses, opportunities and threats for the development of infrastructure. Both partners tried to involve students into this research work. A typical result of cost analysis is present in Table 2 and 3.

Table 2: A typical cost analysis for the construction of a vegetated bamboo crib wall

Materials for L= 30.5 m, B=1.2 m, and H=1.5 m, vegetated bamboo crib wall	Unit	Quantity	Rate [NRs]	Total amount in NRs
Bamboos	m	673.20	30	20196.00
Binding wire	kg	4.00	50	200.00
Total labour used for construction including cutting collection	Nos.	24.00	180	4320.00
Total cost				24716.00
Cost per m³				450.20

The cost analysis presented in Table 2 is based on the actual expenses made on the construction of a vegetated bamboos crib wall. The costs of similar wall made of stone masonry, concrete or gabion to perform same function are given in Table 3. The Table 3 shows that the unit cost of bamboo crib wall is much less than that of other retaining wall types, which proves that it is a cost effective solution for a wall height up to 2 metres.

Table 3: Cost analysis of different construction types

Wall Type	Width of wall required/used in practice in metres	Unit	Quantity	Rate [NRs]	Total amount [NRs]	Cost per running metre [NRs]
Vegetated bamboo crib wall, L=30.5 m	1.2 m	m^3	54.90	450.20	24716.0	810.36
Stone masonry (L=30.5; B= 0.7; H=1.5)	0.5m at top; 0.6 H at bottom	m^3	32.02	1800.00	57636.0	1889.70
Gabion wall (30.5 m)	1 m	m^3	45.75	1200.00	54900.0	1800.00
Dry stone masonry (L=30.5, B= (0.5+1.12)/2, H=1.5)	0.5 m at top 0.75 H at bottom	m^3	36.45	800.00	29160.0	972.00
Cost saving per running metre (compared to gabion wall)						989.63

9 Dissemination activities

On the basis of the critical study and comparative study of the different soil bioengineering techniques used in slope stabilisation in Austria and Nepal, the required training need was assessed and the training material was developed jointly. The target group of the training was the village and district level technicians working in different infrastructure development projects in Nepal. Emphasis was given to the female participants and those from most deprived community but there was only one women participant in the training.

The training material developed under this project was distributed to the trainees as training manual.

9.1 Organization of workshop and training program in Nepal

There was also a workshop organised for academics and policy makers in Nepal to share the knowledge and experiences. There were 50 participants in the workshop, who are the professionals working in soil bioengineering fields.

In addition to the workshop, there was a 5-days training program for the local technician which was organized from 1st to 5th October 2007. This training was intended to develop skills and capacity of local technicians in the use of soil bioengineering techniques. There were 22 participants from different districts and working in different infrastructure development projects in Nepal. The detail program of the training is presented in the Table 4 and the training participants are listed in Table 5. The workshop program and participants' list are presented in Table 6 and Table 7 respectively.

Figure 8: Participants of the soil bioengineering training program (October, 2007)

Table 4: Training Program on Soil Bioengineering Techniques for Mid level technicians

Date/ Time	8:30 – 9:30	9:30-9:40	9:40 – 10:40	10:40 11:00	11:00 – 12:00	12:00 13:00	13:00-14:00	14:00 14:10	14:10 – 15:10	15:10 15:30	15:30 – 16:00
30.09.07	Opening ceremony and Introduction to course (1)	Break	Introduction to soil bioengineering (2)			Lunch Break	Attitudinal behaviour and barriers to implementation (3)	Break	Slope instability analysis(4)		
01.10.07	Causes and mechanism of failure (5)		Runoff and related hazard (6)	Break	Site investigations techniques (7)		Field work on site investigation (8)				
02.10.07	Small scale civil engineering structures (9)		Vegetative systems (10)				Field work on civil engineering systems (11)				
03.10.07	Selection of bioengineering plant species (12)		Interaction between civil and vegetative system (13)	Break	Bioengineering programming work (14)		Field work on vegetative systems(15)				
04.10.07	Introduction to Norms and specification (16)		Maintenance and care of young plants (17)	Break	Bioengineering extension works and community participation (18)		Project presentation (19)			Break	evaluation and closing (20)

Table 5: List of participants in Training

S.No.	Name	Organisation
1	Ram Bahadur Ghalan	Swechchha Bioengineering consultant
2	Ramesh Dimdung	Swechchha Bioengineering consultant
3	Rajiv Ranabhat	Concept Development Pvt. Ltd.
4	Ranjit Basnet	Bajra Guru Company
5	Shiva Khadka	Malikhola Hydropower Company
6	Jayaram Maharjan	Institute of Engineering, Pulchowk Campus
7	Maheshwor Khadka	QST Pvt. Ltd.
8	Anant Raj Ghimire	Institute of Engineering, Thapathali Campus
9	Om Shanta Maharjan	Institute of Engineering, Thapathali Campus
10	Chinikaji Maharjan	Institute of Engineering, Thapathali Campus
11	Shovitman Kafle	District Technical Office Kathamndu
12	Shyam Sharan Shrestha	District Technical Office Lalitpur
13	Iswar Prasad Shrestha	District Technical Office Bhaktapur
14	Laba Karki	District Technical Office Lalitpur
15	Bed Raj Regmi	District Technical Office Bhaktapur
16	Raj Bhai Maharjan	DOLIDAR (Department of Local Infrastructure and Agricultural Roads)
17	Siddheshwor Shrestha	DOLIDAR
18	Dilli Sher Rai	ERMC Consultancy
19	Sajana Adhikari	K.L. Consultancy, Kuleswor
20	Prakash Man Singh	District Technical Office Kathamndu
21	Bishomber Pahari	DOLIDAR
22	Birendra Kumar Shrestha	DOLIDAR

Table 6: Workshop program, Yak Palace Pulchowk, Lalitpur, 7th October, 2007

Sunday, 7 October 2007	Venue	Person
9:00 – 9:30	Registration	
9:30 – 9:45	Inauguration	
9:45 – 10:30	Keynote speeches	Director General, Department of Roads
		Director General, Department of Agricultural Roads
10:30 – 11:00	Hi Tea	
11:00 – 12:30	Paper presentation	Dr Hans Peter Rauch BOKU, Vienna
		Dr. M.S Acharya, BOKU, Vienna
		Prof. N.M. Shakya, IOE, Kathmandu
		Mr. Padma Khadka, IOE, Kathmandu
12:30 – 13:30	Lunch	
13:30 – 15:00	discussion on papers	Discussions on four different groups
15:00 – 15:30	concluding session	Presentation of the results of groups
15:30 – 16:00	closing session	Closing remarks

Table 7: List of participants in workshop program

S. No.	Name	Organisation
1	Badri Prasad Sharma	Department of Roads
2	Binod Prasad Sapkota	Department of Roads
3	Madan Raj Joshi	DOLIDAR
4	Sudhir Pradhananga	STUPA Consultant
5	Nahendra Pradhan	SASCON
6	Prof.Dr. Siddhibir Karmacharya	Trichandra Campus
7	Tej Raj Thapa	Institute of Engineering, Pulchowk Campus
8	Kedar Nath Dhakal	Institute of Engineering, Pulchowk Campus
9	Surya Bahadur Bhat	Division Road Office, Kathmandu
10	Sharad Manandhar	District Technical Office, Bhaktapur
11	Sushil Adhikari	Institute of Engineering, Pulchowk Campus
12	Ram Babu Poudyal	Rural Access Engineering Consultant
13	Dinesh Aryal	Department of Roads
14	Rasi Kumar Gautam	ACME Engineering College
15	Mitra Shrestha	IDRS Pvt. Ltd.
16	Dilli Raj Niraula	Department of Roads
17	Bharat Mandal	Institute of Engineering, Pulchowk Campus
18	Tulasi Sitaula	Department of Roads
19	Mira Shrestha	ITECO Nepal Pvt. Ltd.
20	Ranjan Kumar Dahal	Trichandra Campus
21	Khagendra Dahal	District Technical Office, Kathmandu
22	Dinesh Pathak	Trichandra Campus
23	Kedar Sharma	District Technical Office, Lalitpur
24	Ramesh Prasad Pandey	Institute of Engineering, Pulchowk Campus
25	Roshan Khadka	Department of Irrigation, Lalitpur
26	Santosh Shrestha	Institute of Engineering, Pulchowk Campus
27	Hem Nidhi Sharma	EMRC
28	Hans Peter Rauch	BOKU
29	Madhu Sudan Acharya	DOR/BOKU
30	Laxman B. D. Shrestha	INFRIN, Sanepa
31	Surendra Joshi	Department of Irrigation, Lalitpur
32	Shekher Raj Paudel	Institute of Engineering, Pulchowk Campus
33	Brahma Dhoj Gurung	NSCFP
34	Ram Prasad Thapaliya	Q.S. Tech. Pvt. Ltd.
35	Naresh Man Shakya	DOR

36	Iswar Man Amatya	Institute of Engineering, Pulchowk Campus
37	Bhim Kumar Dahi	Q.S. Tech. Pvt. Ltd.
38	Rabindra Nath Shrestha	Institute of Engineering, Pulchowk Campus
39	Shanti Nath Shrestha	Kantipur Engineering College
40	Suman Vaidya	Institute of Engineering, Pulchowk Campus
41	Madhav Sharma	Tribhuvan University
42	Bhupendra Bahadur Basnet	CIAA
42	Achyuta Nanda Bhandary	ICES
43	Akal Bahadur Singh	Rt. IOE Pulchowk
44	Shaligram Regmi	DOR
45	Arpan Bahadur Singh	Nepal Electricity Authority
46	Ram Prasad Pathak	DOR
47	Prem Chandra Jha	Institute of Engineering, Pulchowk Campus
48	Yog Bahadur Chand	GEC Pulchowk
49	Narendra Man Shakya	Institute of Engineering, Pulchowk Campus
50	Padma Bahadur Khadka	Institute of Engineering, Pulchowk Campus

9.2 Technical visit in Nepal

The first technical visit in Nepal was conducted in November 2006 during the construction of the first site. The purpose of this visit was to provide technical assistance in site selection, survey, design and construction of vegetated crib wall. The next technical visit to Nepal was on September/October 2007. During this visit, the training and workshop program were also organised and there was also a few days' field trip to various landslide sites in Nepal. The field visit has provided an insight especially to the Austrian partner into the special conditions of slope stability problems in Nepal.

10 Financial summary

The following table gives an overview about the planned budget and the actual expenses.

Table 8: Planned and actual cost of the project

Major cost headings	Planned budget	Actual expenses
Staff costs	€ 9.400,00	8544,66
Travel and subsistence	€ 10.360,00	12454,03
Material expenses and capital equipment	€ 6.500,00	4625,20
Documentation, research and public relations	€ 350,00	200,00
Miscellaneous	€ 3150,00	4234,96
TOTAL	€ 29.760,00	30.058,85

11 Conclusions and future recommendations

The project work was initiated in the active and enthusiastic manner. All the stakeholders are fully satisfied and the project is completed successfully in time. From the various project activities and critical study and monitoring of project sites the following general conclusions on the use of soil bioengineering techniques can be made.

- The costs of soil bioengineering (SB) techniques are lower than conventional civil engineering techniques, especially in the long term.
- Soil bioengineering techniques requires less maintenance cost, only labour forces will be required for maintenance, where labour is cheap, the maintenance cost will also be low.
- The strength of SB techniques usually increases with time. The mechanical effects on slope stability develop as the plant community matures. Living plants can adapt to changes in the microenvironment.
- SB techniques will be very helpful in environment protection in hills and mountains of Nepal SB techniques are compatible with the environment in terms of conserving biodiversity, ecological integrity and scenic beauty
- SB techniques are more acceptable to local people, more participatory involving local co-operation/user groups which improve social harmony.

- Use of locally available materials (bamboos, cuttings), will motivate local people to explore their own sources of income.
- These techniques are easy, fast, weather independent construction techniques
- Use of unskilled labours will be an advantage to employment generation for rural poor

In addition to the above general conclusions made from the comparative study on use of soil bioengineering techniques, the following specific conclusions can be made in case of use of bamboo crib walls in Nepal.

- Vegetative crib walls are comparatively cheaper than gabion or stone masonry wall (const. costs only ¼ of gabion and 1/5 of masonry wall)
- Although there is more vertical settlement in case of vegetative crib wall, compared to gabion/masonry walls, vegetative crib walls have better attachment with the slope
- Vegetative crib walls keeps minimum soil moisture, avoids cracks on soil, provides better interception during rainfall
- More stability through increased cohesion and soil reinforcement in case of vegetative crib walls
- The vegetative crib wall made of wood or bamboos is more suitable (also sustainable and environmental friendly) alternative for solving slope stability problems or for road embankment protection in Nepal.

Considering the outcome of the present project the following recommendations for future research/implementations are suggested for road side slope maintenance works in Nepal.

- Prepare standard specifications, norms and standard drawings for vegetated crib wall techniques.
- Make a database of all soil bio-engineered slopes and prepare maintenance and monitoring guidelines.
- Prepare a strategy to intervene and take preliminary measures within a week after the occurrence of any slope failure event.
- Prepare a classification and category for slope failures based on some scoring criteria (dimensions, geology, risk, socio-economic loss, environmental aspects etc.) and make a table for immediate action, short term and long term action plan
- Prepare off road maintenance plan for soil bioengineering works

- Organise soil bioengineering refresher training courses/workshops
- Involve community participation, user groups in monitoring and maintenance works

12 Project publications

Acharya M.S., Rauch H.P. (2008): The use of soil bioengineering techniques in roadside slope stabilisation- a practical approach at the landslide of Pokhara–Sarangkot in Nepal In: European Geoscience Union, Geophysical Research Abstracts, Vol. 10, 2008, EGU General Assembly 2008, 13.-18.04.2008, Wien

Acharya M.S., Rauch H.P. (2007): Sustainable Management of Road Side Slopes in Nepal In: Institute of Engineering, Tribhuvan University, Kathmandu, Nepal, Workshop on Soil Bioengineering Experiences and Practices - Challenges to Implementation , Workshop proceedings, Workshop on Soil Bioengineering Experiences and Practices - Challenges to Implementation, 8.10.2007, Kathmandu

Rauch H.P., Acharya M.S. (2007): Soil bioengineering examples and experiences in Central Europe In: Institute of Engineering, Tribhuvan University, Kathmandu, Workshop on Soil Bioengineering Experiences and Practices - Challenges to Implementation , Workshop proceedings, Workshop on Soil Bioengineering Experiences and Practices - Challenges to Implementation, 8.10.2007, Kathmandu

Acharya M.S., Rauch H.P. (2007): Attitudinal behaviour towards solving slope stability problems Training on Soil Bioengineering for Mid Level Technicians, 1.10.2007, Kathmandu

Acharya M.S., Rauch H.P. (2007): Sustainable Management of Road Side Slopes in Nepal Workshop on Soil Bioengineering Experiences and Practices - Challenges to Implementation, 8.10.2007, Kathmandu

Rauch H.P., Acharya M.S., Khadka P. (2007): Construction of soil bioengineering and conventional methods used in road side slope stabilisation works in Nepal (Poster) European Geoscience Union Assembly, 19.4.2007, Vienna [Poster]

Rauch H.P., Acharya M.S. (2007): Introduction to Soil Bioengineering Training on Soil Bioengineering for Mid Level Technicians , 1.10.2007, Kathmandu

Rauch H.P., Acharya M.S. (2007): Soil bioengineering examples and experiences in Central Europe Workshop on Soil Bioengineering Experiences and Practices - Challenges to Implementation, 8.10.2007, Kathmandu

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