Mainstreaming stabilisation trials to strengthen slope management practices in Lao PDR

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Abstract
Landslides pose a hazard to many parts of the Laos road network. These landslides are brought about by steep slopes, seasonally heavy rainfall and tectonically disturbed and weathered underlying rocks. Road construction has tended to aggravate this instability through the creation of cut slopes and spoil dumps. A study carried out between 2006 and 2009 established 13 low cost slope stabilisation trial sites using bio-engineering and geotechnical measures, and has been able to demonstrate that positive outcomes can be achieved using low cost methods. Paramount to achieving these results, however, is the definition of the extent and depth of ground movement and the interpretation of site geology. Close control on the practices of the contractor is also paramount, particularly with regard to quality control and adherence to specification. A slope maintenance handbook and manual were prepared following the outcome of the trials, and these have been distributed widely amongst Lao road sector practitioners. They have been used as the basis for mainstreaming project outputs through training of trainers at the National University of Laos. A practitioner training programme was devised and implemented, combining fieldwork and classroom training, to enhance roadside slope management amongst road maintenance engineers from central and provincial level in Laos. The basis has, therefore, been established for future training and strengthening in the slope management sector.

Introduction
Those authorities responsible for constructing and maintaining roads through hilly or mountain terrain often have insufficient resources with which to employ a 'total engineering' approach to landslide and slope management. Insufficient resources, in this case, usually combine to yield the following constraints:

- Limited information on ground conditions and the pattern of rainfall and slope drainage with which to plan pro-active measures in advance and to respond most effectively in a reactive way when landslides and other geo-hazards take place.
- A very small number of geo-professionals within their organisations who are capable of interpreting ground conditions, taking the most appropriate technical and risk management decisions and developing designs accordingly.
- Very limited funds to undertake slope stabilisation and protection measures, either in a reactive or proactive way.

The extent to which these constraints come together to create the worst case set of circumstances varies from country to country. Furthermore, the hazard posed by landslides and road earthworks failures also varies widely, from region to region according to topography, underlying geology, climate and land use. For example, in Nepal, these factors combine to create some of the highest hazard slope stability conditions found anywhere in the world. Fortunately, in Nepal there has been over 30 years of investment in the assessment and management of these hazards (Hearn 2002) and there is a large body of data and a wide skills base that has been established to address and manage these hazards. In Laos, by contrast, much of the landscape remains forested, slopes are generally not as steep and the incidence of landslides and road earthworks failures is less. However, engineering geology in Laos is still in its infancy and the situation is such that road maintenance units suffer from all three constraints listed above.

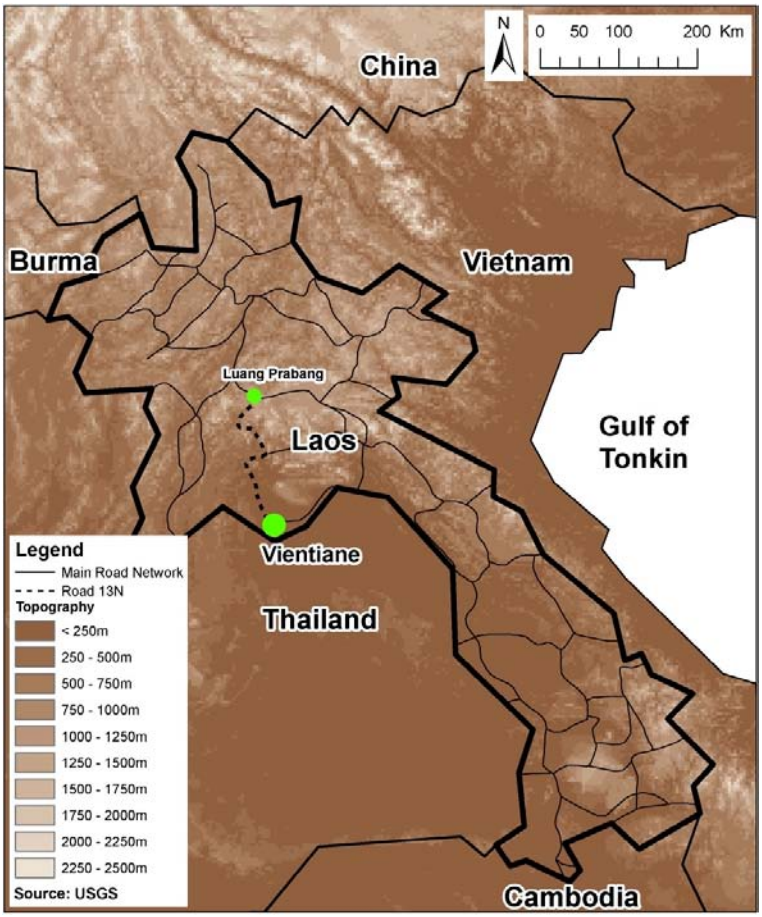
In 2006 a programme of study was commenced in Laos to examine methods of slope stabilisation and protection to assist in the management of the hill road network. The study comprised the implementation of slope trials over a two-year period and was followed by a programme of

dissemination and mainstreaming of project outputs in 2008 and 2009. The principal beneficiary of this mainstreaming has been the Lao PDR Ministry of Public Works and Transport (MPWT) and its provincial departments and related organisations. However, the mainstreaming has also included the consulting sector and has involved the National University of Laos (NUoL) through a trainer training programme.

Slope hazard along the Laos road network

Laos occupies an area of 237,000km^2 and has a population of 6.5 million. It is landlocked between Burma, China, Vietnam, Cambodia and Thailand (Figure 1) and is a predominantly (75%) hilly or mountainous country. Forest occupies over half of the territory, and is the main land use in the upland areas. The climate is humid sub-tropical, and is monsoonal. Heavy rains fall during the summer months and in some areas the annual average rainfall exceeds 4500mm. Sedimentary, metamorphic and igneous rocks form the complex geological outcrop pattern (Workman 1977), though metamorphic rocks, principally phyllite and schist, occupy large parts of the hilly areas. These rocks especially have been affected by a geological history of folding and shearing, and their strength and stability at the slope surface has been reduced significantly by these processes (Figure 2). Tropical weathering has resulted in the development of deep soils in places and has weakened slope materials still further. These factors combine to create conditions favourable to the development of slope instability, especially where slopes are disturbed by land use change and road construction.

Figure 1 Geography of Laos



Landsliding has formed an important process in the development of the topography, and deep-seated slope failures are often identifiable on valley sides, both in terms of back scarps and landslide deposits (Figure 3). The road network is approximately 7,000 km in length and approximately half of this is located in steep terrain. An inventory carried out by Hearn et al (2008) identified 150 landslides affecting approximately 1,500km of road. This equates to one landslide every 1km on average, but does not include the numerous small failures that occur in roadside cuttings that are quickly removed by road maintenance operations. Following a period of heavy rainfall in 2008 for example, the authors recorded a total of 47 cut slope failures along a length of 100 km of mountain road. Data provided by the Ministry of Public Works and Transport (MPWT) suggests that between 50% and 80% of emergency maintenance expenditure is directed towards landslide clearance and road repairs (Figure 4).

Figure 2 Typical rock condition exposed in roadside cuttings

Figure 3 Landslide scarp and failed debris occupy many slopes crossed by the road network

Figure 4 Typical slope failure leading to partial loss of road formation

The SEACAP 21 project

Through the South East Asia Community Access Programme (SEACAP), the Department for International Development (DFID) of the United Kingdom has funded a programme of transport sector initiatives in Cambodia, Laos and Vietnam, aimed at supporting each country's poverty reduction and growth strategies. The SEACAP 21 project in Laos formed part of this programme and commenced in October 2006 (Hearn 2007), initially to undertake a series of slope

stabilisation trials on Roads 13N and 7, working with the MPWT. Road 13N is one of the principal roads in Laos, linking the capital Vientiane in the centre (Figure 1) with the mountainous interior of the country and Luang Prabang to the north. The construction of the trials was financed under the Transport Sector Project of the World Bank, which is assisting the MPWT to move to a sector-wide approach in the planning and management of transport infrastructure. The trials were used to test low cost approaches to slope stabilisation and protection, maximising the use of locally available materials as a means of promoting sustainability. The experience gained and lessons learnt from the trials were used to develop slope management and maintenance manuals which formed key elements of training and mainstreaming activities under later phases of the SEACAP 21 project.

Slope Stabilisation Trials

Following a selection process based mainly on risk assessment, 13 landslide sites (out of a shortlist of 22) were originally selected along Roads 13N and 7. Of these, three sites were chosen to be treated using bio-engineering techniques (Figure 5) and the remaining ten stabilised predominantly by low cost geotechnical engineering techniques. These comprised mainly masonry and gabion retaining walls (Figure 6) and slope drainage, but a reinforced concrete surface covering was also applied to stabilise closely jointed and weathered rock masses (Figure 7). At two locations it was decided that total stabilisation was outside the funding limits of the project, and localised improvements and slope monitoring was put in place accordingly. Engineering geological mapping and ground investigation, comprising trial pits and boreholes, were used to determine the extent and depth of ground movements. This formed the basis of decision making over slope management approach and the design of remedial works and road reinstatement. It is important to note that the total funds expended on the capital works was US$245,000, which excluding the monitoring sites amounted to an average of $22,000 per site.

Figure 5 Bio-engineering methods used to protect slopes against shallow failures and erosion

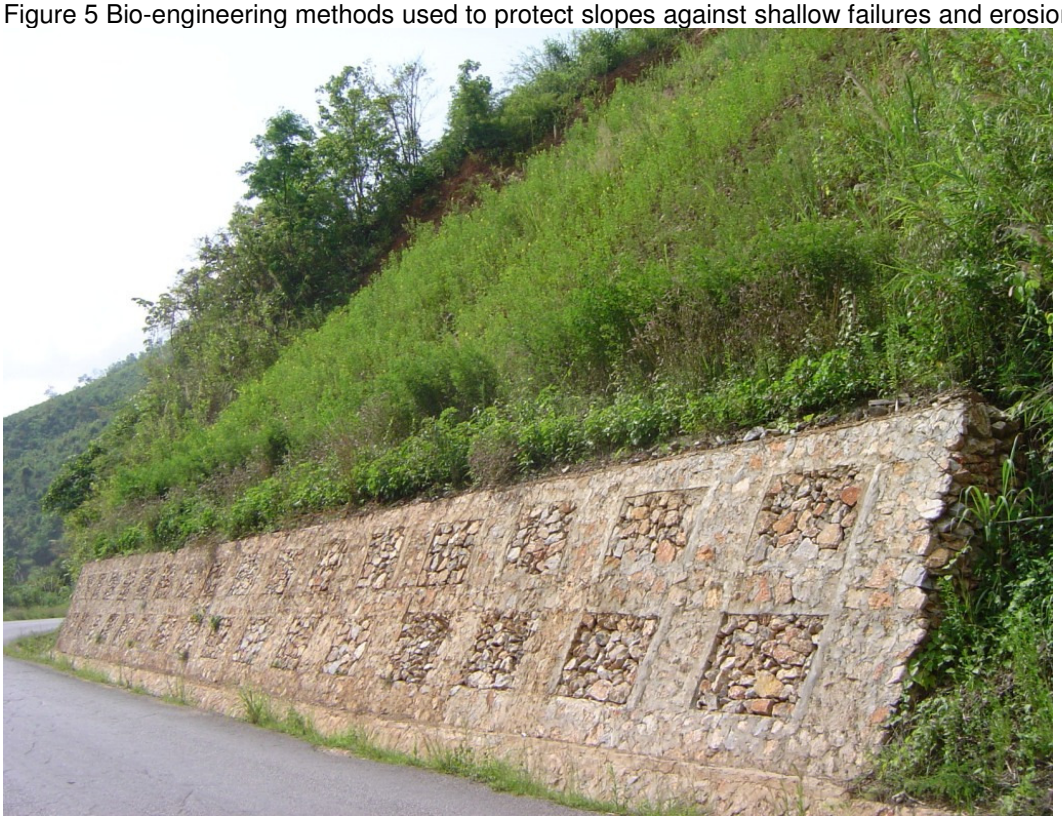


Figure 6 Masonry retaining walls to support the road formation and provide protection from landslides and ground movement on the slopes below

Figure 7 Use of hand-applied reinforced concrete surfacing to stabilise jointed rock masses

With local road maintenance contractors engaged using competitive tendering procedures, the bioengineering works were completed early into the 2007 wet season, whilst the geotechnical engineering works were completed prior to the 2008 rains. The contractors' workforce had to be carefully trained to carry out bio-engineering planting. Site labourers were unused to handling sensitive plants and re-planting was necessary for some sites. The timing of the planting was also critical, relying on sufficient rainfall in the early part of the wet season, but not too much to cause

significant surface erosion before the plants had become established. With regard to the geotechnical works, the contractor required constant supervision to ensure that the workmanship matched the specification – particularly in respect of retaining wall construction and compaction of backfill. The winning bid for the geotechnical works was significantly below the engineering estimate, with the result that the contractor was always looking for ways to reduce costs, and this highlighted the need for close supervision. Although there should have been a significant contingency sum built into the contracts to allow for the inevitable variations – e.g. length and depth of walls varied to suit actual ground conditions, the standard road maintenance contract in Laos does not easily permit such variations. Fortuitously, however, most variations could be accommodated within the overall Bill of Quantities.

Many slope instability problems along mountain roads are triggered or aggravated by spoil disposal. The dumping of spoil material adds additional load to the slopes below, and it is recommended policy to select stable slopes upon which this material can be placed and compacted. For the Laos trials the contractors were required to haul surplus spoil to safe disposal sites, and provision was made in the contract documents to fulfil this.

Feasibility study for a slope stability management programme
Towards the end of the construction period for the stabilisation trials, a feasibility study was carried out to assess the scope and practicality of strengthening slope stability management in Laos. This study required extensive discussions with the MPWT and related road construction and maintenance organisations, both at central and provincial level. It also involved the collection of a landslide inventory, prioritisation of sites based on a risk assessment, and the economic analysis of the costs and benefits to be accrued. This study is described in Hearn (2008) and led to the preparation of a shortlist of landslide locations requiring attention and the development of recommendations for training and institutional strengthening.

Mainstreaming of project outputs
Following the completion of the slope stabilisation trials, the mainstreaming of the outputs commenced with the preparation of a Slope Maintenance Manual and a Slope Maintenance Site Handbook, both translated into Lao. Early demonstration activities commenced with a field workshop that involved road maintenance engineers from the MPWT provinces and used the Road 13N and Road 7 trial sites as illustration. In order to help demonstrate the application of the manuals, a further six landslide sites were identified along Road 13N. These were mapped and investigated by trial pitting and boreholes and preliminary engineering designs for stabilisation and road reinstatement were developed. These were then discussed on site with MPWT road maintenance engineers and a set of recommendations was then submitted to the MPWT for consideration and implementation.

One of the key areas identified in the future strengthening of slope engineering in the road sector was the provision of teaching and training facilities offered by the National University of Laos (NUoL) in Vientiane. A review was undertaken of the course curricula offered in the Civil Engineering and Forestry Faculties, and it was concluded that the University would benefit if it could be used as a means of training road maintenance practitioners in the take-up of the SEACAP 21 manuals. Although it was clear that the Provincial road maintenance engineers had been carrying out generally successful slope stabilisation works before SEACAP 21, there were gaps in their knowledge and an overall lack of a logical approach, sometimes leading to very inefficient designs. The training of university trainers was identified as a possible means of bridging these gaps in a sustainable way.

In total, five university staff were selected for the trainer training. Their backgrounds varied and ranged from forestry and bio-engineering, through geology and geotechnical engineering to structural and civil engineering. In addition, a road maintenance engineer from MPWT, who had been seconded to the SEACAP 21 project, was also included in the trainer training in order to provide the important perspective of site practice.

The developed trainer training curriculum comprised the following themes:

- Types of slope instability affecting the Laos road network
- Factors influencing slope stability in Laos
- Introduction to slope stability management
- Slope and roadside inspections and assessments
- Slope instability hazard and risk assessment
- Engineering geological assessments
- Remedial measures: Selection of options
- Remedial measures: Design
- Remedial measures: Construction
- Bio-engineering techniques of slope protection
- Integrated slope stability management

The trainers were examined prior to the training and again after the training period in order to establish the extent to which they had absorbed the training materials. The results demonstrated an overall significant improvement in their knowledge. A theme champion was identified among the trainers for each training theme, and this person became responsible for developing and delivering the training materials to road sector practitioners.

The road sector practitioner training took place over a period of two weeks, commencing with a visit to the slope stabilisation trials on Roads 13N and 7. This was followed by intense classroom training in NUoL, Vientiane. The practitioner training was undertaken entirely in Lao and comprised presentations, demonstrations, discussion sessions and examinations. A total of 23 practitioners attended the training. They were drawn from the central and provincial MPWT and the consulting sector. The pre- and post-examinations revealed that the practitioners had been able to strengthen their knowledge significantly as a result of the training. Each was asked to complete a questionnaire giving comments on the quality and content of the training programme. These comments were mostly very positive, although it became apparent that some of the practitioners would have benefited from more hands-on practical training and demonstration in road maintenance practices.

Discussion

The SEACAP 21 study has involved a combination of field surveys and investigations, together with discussion and liaison with the MPWT and related organisations, to establish the nature and extent of landslides impacting the road network and the procedures and resources in place for dealing with them. Although, by Asian standards, the scale of landsliding in Laos can only be described as moderate, there is limited knowledge of ground conditions and limited documented guidance on procedures to be adopted to avoid or mitigate landslide impacts. The manuals developed as part of this study go some way towards bridging that gap, and the NUoL training materials can be used in a sustainable way in the future to strengthen road sector practitioners' knowledge and know-how in the slope management sector. From the experience gained under the SEACAP 21 practitioner training, this strengthening would benefit from a greater focus on site conditions, and in particular on the field recognition and management of landslide features in relation to construction and maintenance practices.

The slope stabilisation trials developed under SEACAP 21 generally proved successful and demonstrate that it is possible to achieve favourable outcomes using low cost approaches. However, it is important to point out that these approaches must be properly planned, designed and executed, with adequate attention being paid to geological and geotechnical detail, and with close control of the workmanship quality of the contractor.

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