Capacity Enhancement in Rock and Tunnel Engineering in Nepal

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ABSTRACT

In the recent past, infrastructure development activities have gained momentum in Nepal. Many roads are being and will be upgraded to enhance transport efficiency. The hydropower development activities are in full momentum. However, frequently occurring natural hazards caused by monsoon rain and large-scale earthquakes are major challenges to Nepal's endeavors of infrastructure and hydropower development. Developing an efficient transport network functioning in all-weather conditions and resilient hydropower is not possible without the construction of tunnels. The experience indicates that the construction cost for tunnels is considerably higher due to insufficient capacity and knowledge base within Nepal and dependency on foreign agencies who have limited knowledge on the Himalayan geological condition. It is important to build capacity through specialized high-level education and research within Rock and Tunnel Engineering both at MSc and Ph.D. levels. This paper discusses a new curriculum developed for MSc education in Rock and Tunnel Engineering for the Institute of Engineering (IoE) of Tribhuvan University with the support of the Norwegian University of Science and Technology (NTNU). It has started the MSc program and first batch of students has been enrolled for the academic year 2020/2021 at IoE-WRC Pokhara. NTNU collaborates with IoE through a research grant NORHED II Project 70141 6; Capacity Enhancement in Rock and Tunnel Engineering in Nepal received from the Norwegian Agency for Development Aid (NORAD).

Keywords: Himalayan rock mass, Rock and tunnel engineering, Capacity enhancement, Infrastructure development

1. INTRODUCTION

Road and railway tunnels, tunnels and caverns for hydropower and other utility use, tunnels for irrigation, and water supply are becoming inevitable in the development of sustainable Nepal (Panthi 2004). Finding innovative solutions in underground construction is a key issue where cost reductions can be achieved to improve financial viability. The tunnel design and construction technology used until today in Nepal proven to be time-consuming, causing a delay in construction and substantial variation and cost overruns (Panthi & Nilsen 2007). This is due to the extensive use of imported expertise and methods that are not user-friendly to address challenges associated with Himalayan rock mass. Innovative solutions are needed to increase reliability and cost-effectiveness in this sector. Emphasis must be given to enhance local resources and methodologies, which is only possible through higher-level education (MSc and Ph.D. levels) within rock and tunnel engineering. The GoN has started planning and implementing tunnels for highway networks, which is a start of a new era in infrastructure development. An example is the construction start of Nagdhunga – Naubise road tunnel. There are over 10 road tunnel projects under planning and design phases.

The use of underground space (tunnels and caverns) started from ancient time by developing caves (example: caves house in upper Mustang and mining caves scattered around the country). The first modern road tunnel (Churiamai) was built over 100 years ago at the Siwalik Mountain by Nepalese engineers and the workforce (NTA 2019). Unfortunately, no further tunnels were constructed to develop infrastructure until the present, except 250 km of tunnels and some underground powerhouse caverns for hydropower projects, irrigation, and water supply. Extensive exploitation of water resources available in Nepal to produce hydropower energy needs construction of over 1500 km long tunnel. Tunnels are needed to transfer water from one basin to another for irrigation and water supply, for the development of high speed, reliable and sustainable road networks, and the development of Metro systems in urban areas. Underground storage caverns are needed to store Oil, Gas, and food products. This manuscript describes the typical characteristics of Himalayan rock mass, the development of the MSc curriculum for the Institute of Engineering (IoE), Tribhuvan University (TU), and capacity enhancement within rock and tunnel engineering at IoE-WRC NTNU through financial support received from NORAD under NORHED II Project 70141 6; Capacity Enhancement in Rock and Tunnel Engineering in Nepal.

2. CHARACTERISTICS OF HIMALAYAN ROCK MASS

The advancement made in rock and tunnel engineering and rock support technologies must be fully used. The planning and design of tunnels and underground caverns are made optimally-effective, and long-term sustainable (Panthi 2014). Some challenges hinder achieving this goal due to insufficient engineering research covering engineering characteristics of the Himalayan rock mass. The Himalayan range has a complex geological set-up, and there is a significant tectonic influence on the overall rock mass quality condition. The engineering characteristics of Himalayan rock mass vary greatly. The major areas of challenges concerning engineering behavior of the rock mass and stability of underground structures in the region are summarized (Panthi 2006; Panthi 2014).

2.1 Schistosity

The rock mass in the Himalayan region has undergone intense deformation due to the under-thrusting of the Indian plate under the

Euro-Asian plate. The degree of schistosity is intense and is a common phenomenon. Among the most distinct inherent properties of the Himalaya rock mass is strength anisotropy caused by the preferred orientations of mineral grains or directional stress history. The bedding and foliation in the sedimentary and metamorphic rocks of the Himalayas have made them highly directional concerning strength and deformability (Fig. 1).

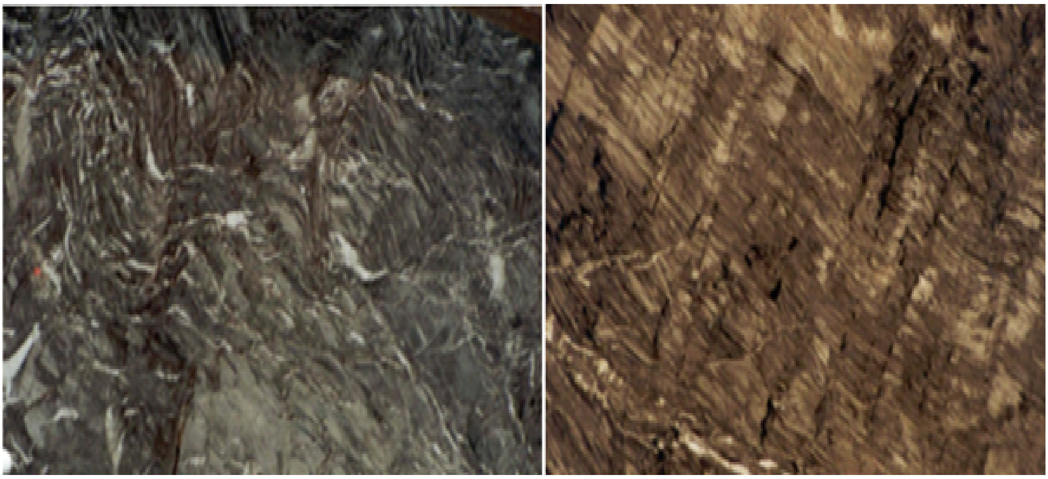

Fig. 1. Highly Folded (left) and Thinly Foliated (right) Rock Mass.

As a result of this directional behavior in strength and deformability, some rocks in the region are weak and have reduced self-supporting capability. The rocks such as mudstone, shale, slate, phyllite, schist, and micaceous gneiss that are dominant on the Siwalik and Lesser Himalayan mountains show such directional behavior. Another major feature of the highly deformed rock mass of the Himalayas is frequent intercalation between different rocks and shear bands. Such intercalation is observed at an interval of even less than 50 centimeters (Fig. 2).

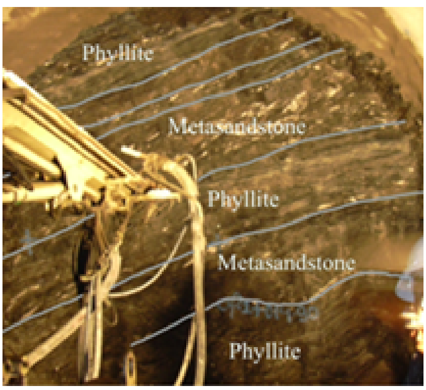

Fig. 2. Typically, mixed face condition with phyllite and meta-sandstone bands.

On many occasions, thin bands of very weak and highly deformed rocks such as slate, phyllite, schists, and sheared myloniteare intercalated within the bands of strong and brittle rocks such as gneiss, quartzite, and dolomite which are dominantly found in Nepal. These small bands of weak rock mass are squeezed and highly sheared within these stronger layers of rock mass (Panthi 2006), i.e., typical mixed face conditions.

2.2 Faulting and Weathering

The intense compressional tectonic movement results in the rock mass to fault, fold, shear, and fracture. This is especially the case in areas near large-scale tectonic faults and their splays. In addition, the monsoon contributes to deep weathering in the rock mass (Fig. 3). The fracture and fault zones are generally permeable, and rock mass weathering is a key factor for ground water-induced instability in tunnels (Panthi 2014). During rock mass quality evaluation at planning and implementation stages, tunneling in such an environment needs to be well addressed.

Fig. 3. Deep weathering (left) and fractured (right) rock mass at a steep slope.

There are two main effects of rock weathering and fracturing concerning tunnel stability. The first one is immediate tunnel collapse during excavation and the second one is very limited capacity to self-sustain even for a very short period (low stand-up time).

Since fractured and weathered rock mass and fault zones are highly permeable, tunneling through such zones always represents great difficulties and challenges (Panthi 2004; Panthi 2009). Severe water inflow into the tunnel after excavation and water leakage from the tunnel after excavation completion, Fig. 4, must be considered while planning, designing, and constructing tunnels.

Fig. 4. Water inflow in the tunnel (left) and leakage from the tunnel (right) after water filling.

The severity of inflow and leakage are huge, and on many occasions, several weeks and months and a huge number of resources were spent to control if it is not visualized in advance.

2.3 Stress-Induced Instability

Another major stability challenge faced during tunneling in the Himalayan region is related to in-situ stress conditions (Fig. 5). If the tunnels and underground caverns are not properly placed during planning and design, the risk for meeting stressed induced instability increases.

Fig. 5. Squeezing at a depth of about 80m (left) and brittle rock-burst failure at about 650m (right).

Mentioned stability challenges should be well addressed while tunnelling through the Himalayan rock mass. If no proper and well-thought solutions are applied, each tunnelling project faces construction delays, cost overruns, and contractual conflicts. Hence, the behavior of Himalayan rock mass is studied innovative, and cost-effective solutions are developed, so that tunneling projects become competitive and worthy of investment.

3. TUNNEL EXCAVATION

Both Drill and Blast (D&B) and Tunnel Boring Machine (TBM) are two tunneling methods relevant in the Himalayan region. Of course, the most dominating method is D&B, which is flexible in dealing with difficult geological conditions such as crossing through weakness and fault zones and dealing with fractured and weak rock mass. Today's available TBM tunneling technology has not been very successful in the region (Panthi 2009), excluding TBM excavation used at Bheri-Babahi Multi Diversion Project. The D&B method of excavation has not also proven excellent. The average weekly tunnel advance rate has been less than 15 meters from each tunnel face. The tunneling technology available today, especially the D&B method in combination with flexible rock support consisting of systematic bolting and systematic use of sprayed concrete with robotic machines, can cope with very difficult ground conditions efficiently and produce weekly excavation progress exceeding 25 meters from a single face. The slow progress and cost overruns in tunneling in Nepal is mainly due to a lack of proper education and training.

4. NEED FOR MSC IN ROCK AND TUNNEL ENGINEERING

Nepal lacks proper education within rock and tunnel engineering, which directly influences the adoption of advanced tunneling technology with due consideration of Himalayan rock mass and development of tunneling practices suitable for Nepal. It is only possible if the MSc study program that produces rock and tunnel engineers capable of developing tunnel design and construction methodologies suitable to Nepal started. With this view in mind, the author discussed the need for Rock and Tunnel Engineering education in Nepal with the leadership IoE for about a decade. The discussion was intensified in 2018 after IoE leadership became active to get help from the Norwegian University of Science and Technology (NTNU). A meeting was held between the leadership of IoE, NTNU Rector with delegates and NORAD representative Ms Viveke Sørumin in May 2019. In the meeting NORAD informed that there exists possibility for NTNU and IoE to apply funding in the upcoming NORHED II program with a clear aim of capacity enhancement within this field. IoE-WRC organized a workshop in Pokhara in November 2019 to develop a preliminary MSc curriculum for "Rock and Tunnel Engineering".

5. DEVELOPMENT OF CURRICULUM FOR MSC IN ROCK AND TUNNEL ENGINEERING

In the curriculum workshop, Professor Krishna Panthi of NTNU presented a framework sketch of the curriculum. This preliminary sketch was comprehensively discussed and adjusted by the participants of the workshop (see acknowledgement) to fit IoE MSc curricula. A high-level meeting was held in Kathmandu to adjust the developed curriculum. Further detailing of each course was partly completed in early February 2020 in Kathmandu and was approved by the Tribhuvan University (TU) board. The curriculum will be further enhanced, and more curriculum workshops will be organized in the coming years.

5.1 Review on the Status of Faculties

For the success of any regular MSc and Ph.D. level programs in rock and tunnel engineering, permanent faculties within the field are required, which IoE lacks. A capacity enhancement is therefore needed.

5.2 Field and Laboratory Facilities

The MSc program within rock and tunnel engineering seeks extensive involvement of the students in field investigation, mapping, and experiment at the laboratory. At present, no such facilities are available at IoE. It is, therefore, necessary to acquire field-based and laboratory-based equipment.

5.3 Responsibility of Government of Nepal

The Government should prioritize funding and enhancement of an education system suitable to produce engineers capable in planning and design of tunnels through Himalayan rock mass. The Government has realized this gap; especially the Gandaki provincial government has emphasized the need for knowledge enhancement in rock and tunnel engineering. Gandaki Provincial Government has financially supported Paschimanchal Campus, Institute of Engineering (IoE-WRC) to develop the curriculum and promised to allocate funds for the development of minimum infrastructure needed at IoE-WRC.

6. INVOLVEMENT OF NTNU THROUGH NORHED II PROGRAM

IoE closely collaborates with Norwegian University of Science and Technology (NTNU) through financial support from Norwegian Agency for Development Aid (NORAD) since 1990s. In June 2020, NTNU and IoE applied to NORAD under the NORHED II program seeking financial support for the "capacity enhancement within rock and tunnel engineering" at IoE-WRC" through NTNU professors are/will be engaged for teaching and capacity enhancement of IoE-WRC faculties through Ph.D.research at NTNU (Panthi 2020). NORAD positively responded to this initiative. NTNU has signed an agreement with NORAD within the NORHED II program, which will support Ph.D. research by IoE-WRC faculties at NTNU and to produce over 90 MSc fellows from IoE-WRC in "Rock and Tunnel Engineering in six years period.

7. IMPACT OF NORHED II PROGRAM

The approved NORHED II funding is oriented to implement a high-quality graduate education program within rock and tunnel engineering at IoE-WRC. The funding aims to make IoE-WRC capable of running MSc education and Ph.D. research in a long-term sustainable way through the enhancement of its ability by providing Ph.D. research support to IoE-WRC's faculties at NTNU, establishing state-of-art rock and tunnel engineering laboratory and training by NTNU faculty members in teaching. Upon the success of this graduate study program at IoE-WRC, IoE should aim to expand this program in other IoE campuses, particularly at IoE-Pulchowk (Kathmandu) and IoE-Dharan (Eastern City Dharan). The possibility of internalization of this course is very high due to its relevancy to the neighboring countries in the Himalayan region (Bhutan and India) and adjacent countries like Myanmar and Sri Lanka. It is likely that IoE may become a regional center for high-quality education and research within this field. Building upon the base through NORHED II grant project, it is expected that the graduate program will become self-sustainable. Since IoE-TU is a government-owned public education entity like NTNU, the basic cost-related to salary to faculties, administrative and scientific staff, and minimum operational cost is covered by the Government of Nepal, which provides a solid base and ascertains for the continuation of graduate education and research within this field for many decades to come. NTNU and IoE aim to continue to collaborate through research projects applied in the future for mutual benefits. Research, faculty, and student exchange will continue in many years to come.

8. CONCLUSION

The MSc program in Rock and Tunnel Engineering is the need of the day for a mountainous country like Nepal, where topographic and geological conditions are unique. The start of MSc education at IoE-WRC and capacity enhancement through the NORHED II program will bring positive results in the sustainable development of Nepal. Completed Ph.D. research by four internal faculties of IoE and advanced laboratory facilities will enhance the capacity of IoE-WRC. It is hoped that the Government of Nepal will continue to allocate appropriate funding to IoE. In addition, IoE will be active in seeking collaboration with international universities like NTNU so that further research at both MSc and Ph.D. levels are continued. The developed MSc program is unique for Nepal, and it will enhance capacity within Rock and Tunnel Engineering, which will help develop innovative solutions suitable to Himalayan topography and geological conditions.

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