Journal of Nepal Geological Society, 2000, Vol. 22, pp. 205–210

Importance of tunnelling for infrastructure development in Nepal

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ABSTRACT

Tunnel and underground works of smaller dimensions were introduced in Nepal by the early miners during the 19th century. They applied their traditional technology to mine the ores of copper, iron, lead, cobalt, and nickel. But, their activity virtually came to an end when these metals were easily available in the local market through the supply from India.

Tunnelling for the 1 MW Tinau Hydropower Project done by Nepalese technician through the Siwalik rocks was a pioneering activity to convince the concerned institutions and technicians that tunnelling through hills and mountains of Nepal is technically feasible. There were fourteen operational tunnels and eleven test adits (36.16 km in total length) driven through different rocks and geological conditions in Nepal up to 1999. They have successfully dissected the Siwaliks, Midlands, and the Higher Himalaya irrespective of their geological conditions and rock types. At present, seven tunnel projects are under construction, which will augment an additional length of 28.436 km by the year 2000.

Today, hydropower development without perception of a tunnel component is virtually impossible. It is also true for the supply of irrigation water in a year-round basis to the agricultural land of the *Terai*.

A demand for tunnel works in the improvement of water supply system and road network is also emerging in urban areas like Kathmandu. The need of a 28 km long tunnel is identified in the Kathmandu-Melamchi Water Supply Project, which will be the first tunnel to supply drinking water in Nepal. Similarly, the Kathmandu-Hetaunda Direct Link Project will be the first of its kind to use tunnels of 3.8 km to 7.5 km in length.

INTRODUCTION

Nepal occupies the central portion of the Himalayan arc. About 83% of the total area of the country lies in the hills and mountains. Owing to steep topography, tunnelling and underground works play an important role in the development of infrastructure and mineral resources.

Early miners introduced tunnels and underground works in Nepal during the 19th century who applied the traditional technology for this purpose. They opened relatively small (though some openings were as large as today's powerhouse caverns) underground works to mine the ores of copper, iron, lead, cobalt, and nickel. This activity virtually came to an end at the beginning of the 20th century when mining for metal declined owing to easily available copper, iron, and lead in the local market through the supply from India. Many such underground works still remain intact without any roof or wall supports.

Tunnelling for the 1 MW Tinau Hydropower Project done by Nepalese technician through the Siwalik rocks with the assistance of United Mission to Nepal during 1970s with the formation of the Butwal Power Company (BPC) was a pioneering activity to convince the concerned institutions and technicians that tunnelling through hills and mountains of Nepal is technically feasible (WECS 1998). The underground works carried out to explore and develop lead and zinc deposits in the Ganesh Himal Region by the Nepal Metal Company were equally important in the history of modern tunnelling. Both these activities contributed significantly to build up strong confidence among the Nepalese technicians in the field of tunnelling. Subsequently, two private companies (namely the Himal Hydro and General Construction Company Ltd. and Khumbu Construction Company) emerged to undertake tunnelling works in Nepal. In a parallel activity, the Nepal Electricity Authority also initiated the underground works. It has driven many test adits for the development of potential hydropower projects.

IMPORTANCE OF TUNNELLING IN INFRASTRUCTURE DEVELOPMENT

In Nepal, construction of tunnels should be preferred in road, hydropower, irrigation, and water supply projects. The reason is the vulnerability of surface works in terms of landslides, debris flows, soil erosion, and other mass wasting phenomena that prevail owing to fragile geology, poorly protected soil cover, and high-intensity monsoon rainfall.

In the past, the infrastructure development activities regarding construction of the road, hydropower, irrigation, and water supply projects were implemented in preference to those projects that did not require tunnels. Today, under changed situation, the hydropower and irrigation development projects without tunnel are practically not available. Similarly, sustained year-round irrigation facilities required to boost agricultural production in the country are not practically possible without trans-valley tunnel projects based on major rivers (such as the Tamur, Sun Koshi, Kali Gandaki, Bheri, Sharda, and Babai).

Shortcut tunnel road construction is the only alternative to save fuel, wear and tear, distance and time, and foreign currency. It is also a must make for an efficient transportation. In the urban areas like Kathmandu, where intrinsic surface and groundwater are not sufficient to fulfil the present actual needs and foreseeable demand, tunnelling for diversion of water from other higher watersheds can be the only alternative solution.

TUNNEL PROJECTS

As of data up to 1999, altogether 25 underground works involving 14 tunnels and 11 test adits of a total length of 36.18 km exist in different parts of the country (WECS 1998) (Fig. 1 and Table 1, 2, 3, and 4). The tunnels dissect the Siwaliks, Midlands, and Higher Himalayan regions irrespective of widely varied geological condition, rock type and depth of overburden (from 110 to 670 m). Medium to strong phyllite, quartzite, slate, shale, limestone, schist, gneiss, and granite are the main rocks through which tunnels are driven in the Lesser and Higher Himalaya, whereas weak to moderately strong sandstone, siltstone, and mudstone predominate in the Siwaliks.

The hydropower development activity in Nepal leads a top position in the tunnelling industry whose role will remain virtually unchanged in the future as well (Table 1). Out of the total 14 existing tunnels, 11 tunnels constructed for the hydropower development have 4 to 7 m^2 cross-section area and a total of 29.169 km length. The other three tunnels, two of which were driven for the mineral development (from 2.5 to 6.5 m in diameter) and one for irrigation purposes (4 m^2 in cross-section), represent smaller length of 3.12 km (Tables 2 and 3). Out of the 11 other various underground works (Table 4), seven of them were driven specifically for the hydropower development, and the remaining four had multipurpose objectives (three of them were designated for the hydropower and irrigation, and one was for water supply and hydropower). They constitute a total length of 3.891 km with cross-section of 4 to 9 m^2.

There are seven tunnels under construction in Nepal (Table 5). They will supplement a total length of 28.436 km by the year 2000 in the history of tunnelling. Among them, six tunnels are opened for the generation of 280 MW of hydropower and the remaining one for the diversion of the polluted water of the Bagmati River from the Pashupati Region.

There are about 134 identified future tunnel projects totalling to 915 km in length by various feasibility studies for the development of hydropower, irrigation, water supply, and road in the country (Table 6). Future hydropower development activities will involve solely 132 such tunnel projects. Identified nine tunnel projects will facilitate irrigation systems, and the remaining two will improve water supply and road network, respectively.

CONTRIBUTION OF LOCAL AND FOREIGN CONTRACTORS

Subsequent to the emergence of the Tinau Hydropower Project in 1970s, the role of tunnelling in hydropower development has become increasingly important. In the history of tunnelling between 1970 and 1999, the contribution of the local and foreign contractors was almost equally significant, though the foreign companies were found entrusted to the bigger-scale jobs like the Devighat Hydroelectric Project, the Kulekhani –I and II Hydropower Projects, and the Marsyangdi Hydropower Project (WECS 1998).

The completion of the 5.1 MW Andhi Khola and 12 MW Jhimruk Khola Hydroelectric Projects with the tunnel length of 2.4 km and 1.1 km, respectively by the Himal Hydro and General Construction Company was the major breakthrough in capability building among local companies. In addition, current involvement of the local contractor the Himal Hydro and General Construction Company in the two of the six under-construction tunnel projects, namely the Modi Khola Hydroelectric Project and Lower Khimti Hydroelectric Project, has further substantiated the local capability in tunnelling.

On the other hand, one can believe that some of the national companies have developed an appreciable capability to undertake tunnelling works in the country. However, there will a need to rely on foreign companies when many tunnel projects come up in the future.

LOCAL CAPABILITIES

Through the five local institutions, namely the Himal Hydro and General Construction Company, Nepal Electricity Authority, Khumbu Construction Company, Nepal Metal Company, and Udaipur Cement Industries, have tunnelling experiences, the Himal Hydro and General Construction Company is the leading company for the tunnel works in Nepal (WECS 1998). This institution has built up significant strength in terms of human resources development and availability of equipment. As observed in the under-construction tunnels, the Nepalese manpower has the capacity of undertaking all activities involved in tunnelling through rock. They include drilling, mucking, ventilation, shotcreting, and earth moving including supervision works that are essential between the face preparation for excavation and tunnel lining for support. The Chilime Hydroelectric Project is an illustration where the Nepalese capability in tunnelling is well demonstrated by undertaking all the activities commencing from tunnel design through excavation and supervision to the completion of the project.

Currently, three local agencies constitute the combined equipment facilities capable of carrying out tunnelling

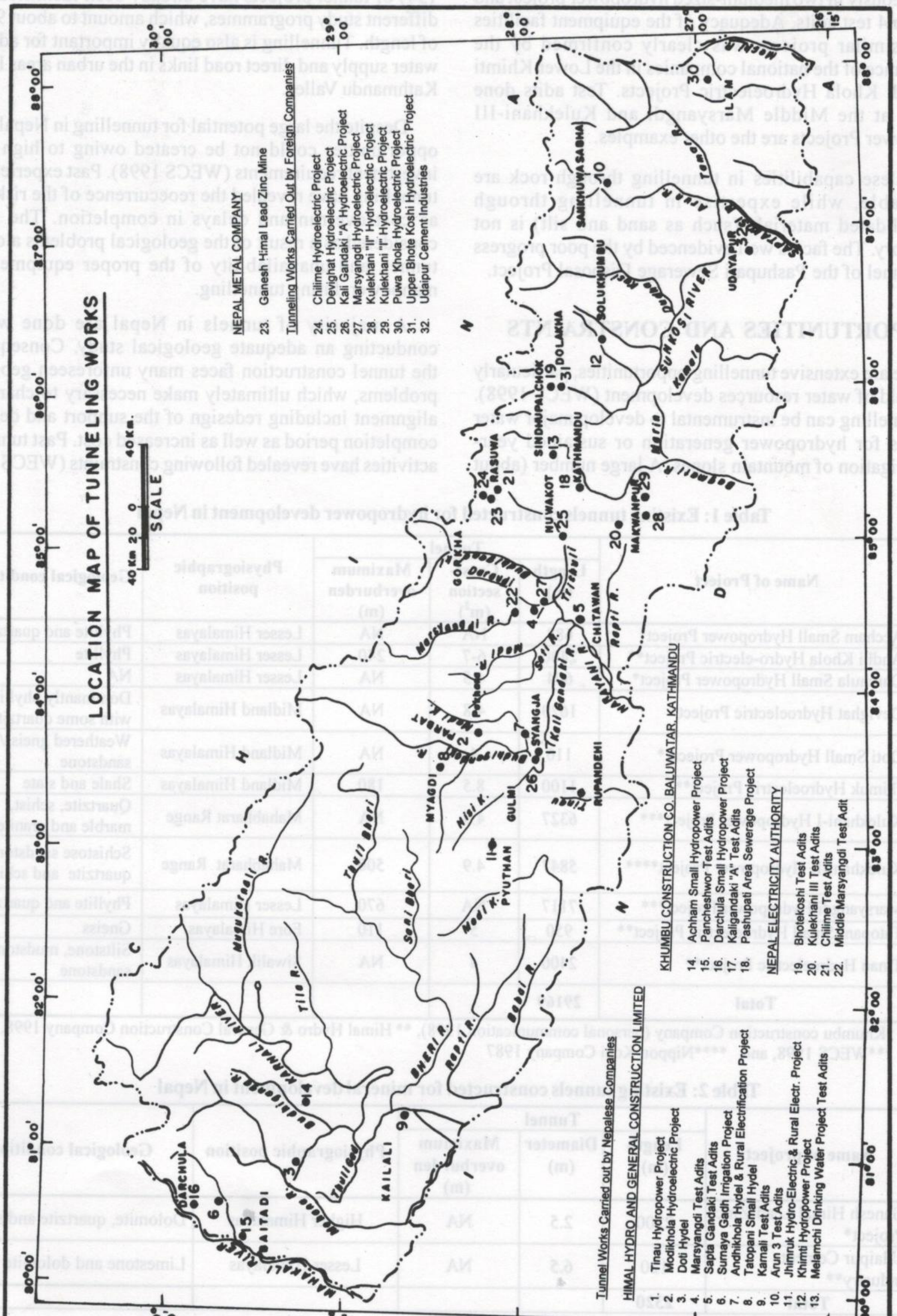

Fig. 1: Location map of tunnelling works

simultaneously in two medium-sized hydropower project and from 3 to 4 test adits. Adequacy of the equipment facilities for the similar projects was clearly confirmed by the performance of the national companies in the Lower Khimti and Modi Khola Hydroelectric Projects. Test adits done recently at the Middle Marsyangdi and Kulekhani-III Hydropower Projects are the other examples.

Nepalese capabilities in tunnelling through rock are appreciable, while expertise in tunnelling through unconsolidated materials (such as sand and silt) is not satisfactory. The fact is well evidenced by the poor progress at the tunnel of the Pashupati Sewerage Disposal Project.

OPPORTUNITIES AND CONSTRAINTS

There are extensive tunnelling opportunities, particularly in the field of water resources development (WECS 1998). Only tunnelling can be instrumental to develop major water resources for hydropower generation or sustained year-round irrigation of mountain slopes. A large number (about 134) of tunnel projects have already been identified under different study programmes, which amount to about 915 km of length. Tunnelling is also equally important for adequate water supply and direct road links in the urban areas like the Kathmandu Valley.

Despite the large potential for tunnelling in Nepal, many opportunities could not be created owing to high initial investment requirements (WECS 1998). Past experiences in tunnelling have revealed the reoccurrence of the risks such as cost overrun and delays in completion. The risk is considered as a result of the geological problems along the tunnel, and unavailability of the proper equipment and manpower during tunnelling.

A majority of tunnels in Nepal are done without conducting an adequate geological study. Consequently, the tunnel construction faces many unforeseen geological problems, which ultimately make necessary to change the alignment including redesign of the support and delays in completion period as well as increased cost. Past tunnelling activities have revealed following constraints (WECS 1998).

Table 1: Existing tunnels constructed for hydropower development in Nepal

S. No.	Name of Project	Tunnel			Physiographic position	Geological condition
		Length (m)	Cross-section (m^2)	Maximum overburden (m)		
1.	Accham Small Hydropower Project*	688	NA	NA	Lesser Himalayas	Phyllite and quartzite
2.	Andhi Khola Hydro-electric Project**	2400	6-7	240	Lesser Himalayas	Phyllite
3.	Darchula Small Hydropower Project*	604	4.5	NA	Lesser Himalayas	NA
4.	Devighat Hydroelectric Project	1620	4.8	NA	Midland Himalayas	Dominantly phyllite with some quartzite
5.	Doti Small Hydropower Project**	116	4	NA	Midland Himalayas	Weathered gneiss/ sandstone
6.	Jhimuk Hydroelectric Project**	1100	8.5	180	Midland Himalayas	Shale and slate
7.	Kulekhani-I Hydropower Project***	6327	4.9	NA	Mahabharat Range	Quartzite, schist, marble and granite
8.	Kulekhani-II Hydropower Project****	5847	4.9	500	Mahabharat Range	Schistose sandstone , quartzite and schist
9.	Marsyangdi Hydropower Project***	7117	NA	670	Lesser Himalayas	Phyllite and quartzite
10.	Tatopani Small Hydroelectric Project**	950	5	110	Fore Himalayas	Gneiss
11.	Tinau Hydroelectric Project**	2400	4	NA	Siwalik Himalayas	Siltstone, mudstone and sandstone
	Total	**29169**				

Source: *Khumbu construction Company (personal communication 1998), ** Himal Hydro & General Construction Company 1998, ***WECS 1998, and ****Nippon Koei Company 1987

Table 2: Existing tunnels constructed for mineral development in Nepal

S. No	Name of project	Tunnel			Physiographic position	Geological condition
		Length (m)	Diameter (m)	Maximum overburden (m)		
1.	Ganesh Himal Lead-Zinc Project*	2200	2.5	NA	Higher Himalayas	Dolomite, quartzite and schist
2.	Udaipur Cement Industry**	120	6.5	NA	Lesser Himalayas	Limestone and dolomite
	Total	**2320**				

Source: *C. K. Chakrovorti (personal communication 1999), and **Udaipur Cement Industries Limited (personal communication 1994)

Table 3: Existing tunnels constructed for irrigation purpose in Nepal

S.N.	Name of project	Tunnel Length (m)	Tunnel Cross-section (m^2)	Tunnel Maximum overburden (m)	Physiographic position	Geological condition
1.	Surnayagad Irrigation Project*	800	4	NA	Higher Himalayas	Quartzite
	Total	800				

Source: *Himal Hydro & General Construction Company 1998

Table 4: Other existing test adit/ underground works driven in Nepal

S. N.	Name of Project	Tunnel Length (m)	Tunnel Cross-section (m^2)	Physiographic position	Geological condition
1.	Arun-3 Test Adit *	1400	4	Lesser Himalayas	Gneiss and mica schist
2.	Bhote Koshi Test Adit**	87	9	Lesser Himalayas	Quartzite and phyllite
3.	Chilime Test Adit **	98	4	Lesser Himalayas	Phyllite, schist and quartzite
4.	Kali-Gandaki "A" Test Adit***	585	NA	Lesser Himalayas	Phyllite, shale, dolomite and quartzite
5.	Karnali Chisapani multipurpose project Test Adit*	550	4	Siwalik Hills	Sandstone, siltstone and mudstone
6.	Kulekhani-III Test Adit**	NA	NA	Mahabharat Range	Quartzite and schist
7.	Marsyangdi Test Adit*	36	4	Lesser Himalayas	Quartzite and phyllite
8.	Melamchi Drinking Water Project*	585	7.5	Lesser Himalayas	Schist and quartzite
9.	Middle Marsyangdi Test Adit**	100	NA	Lesser Himalayas	Quartzite and phyllite
10.	Pansheswor Test Adit***	300	4	Lesser Himalayas	Chloritic mica schist, gneiss and granite
11.	Sapta Gandaki Test Adit*	100	4	Siwalik Hills	Sandstone, mudstone and siltstone
	Total	3841			

Source: *Himal Hydro General & Construction Company 1998, **WECS 1998, and ***Khumbu Construction Company (personal communication 1998)

Table 5: Hydropower tunnel projects under construction in Nepal

S. N.	Name of project	Tunnel Length (m)	Tunnel Cross-section (m^2)	Tunnel Maximum overburden (m)	Physiographic position	Geological condition
1.	Chilime Hydroelectric Project*	3400	5.3	550	Lesser Himalaya	Schist, quartzite, and phyllite
2.	Kali Gandaki "A" Hydroelectric Project**	5925	43.00	650	Lesser Himalaya	Phyllite, dolomite, and quartzite
3.	Lower Khimti Hydroelectric Project***	10,000	11.5	230	Lesser Himalaya	Weathered gneiss and schist
4.	Modi Khola Hydroelectric Project***	2000	15.5	225	Lesser Himalaya	Quartzite
5.	Pashupati Sewerage Disposal Project****	520	4	25	Intramontane basin in the Midlands	Sand and silt
6.	Puwa Khola Hydroelectric Project******	3290	5.30	165	Lesser Himalaya	Schist and gneiss
7.	Upper Bhote Koshi Hydroelectric Project******	3301	16.00	460	Lesser Himalaya	Quartzite, phyllite, and dolomite
	Total	28,436				

Source: *Chilime Hydro-electric Project 1996, **Morrison Kundson 1994, ***Himal Hydro & General Construction Company 1998, ****Khumbu Construction Company (personal communication 1998), *****Puwa Khola Hydroelectric Project 1997, and ******WECS 1998

Table 6: Various projects with tunnel component

S. No	Name of the project	Total number of tunnels	Proposed tunnel length (km)	Purpose
1.	Master Plan Study for Koshi Basin Water Resources Development*	45	336.6	Hydropower
2.	Gandaki Basin Power Study	11	75.81	Hydropower
3.	Karnali Basin Studies	24	138.1	Hydropower
4.	Medium Hydropower Study Project	43	248.92	Hydropower
5.	Master Plan Study for Koshi Water Resources Development*	2	24.00	Irrigation and hydropower
6.	Gandaki Basin Power Study	1	25.20	Irrigation and hydropower
7.	Karnali Basin Studies	1	9.00	Irrigation and hydropower
8.	Medium Hydropower Study Project	5	10.68	Irrigation and hydropower
9.	Water Supply for Kathmandu – Lalitpur from outside the Kathmandu valley	3	38.9	Drinking water supply
10.	Direct Link Between Hetaunda and Kathmandu	3 1	7.5 3.8	Road
	Total	**134**	**915**	

Source: *WECS 1998

- Projection of geological characteristics from the surface studies for the tunnel level is generally inaccurate. It is particularly true where the depth of overburden is considerable;
- Development of skilled human resources is declining owing to the failure to get a new tunnelling project immediately after the completion of the project in-hand;
- Limited tunnelling opportunity is available to retain the skilled human resources continuously; and
- There are not many competitive contractors.

CONCLUSIONS

Through large opportunities for tunnelling works exist in Nepal in the hydropower generation, irrigation, drinking water supplies, and road network improvement, there is no adequate commitment to promote tunnel projects in different political and bureaucratic levels. As a result, there remain some uncertainties in creation and availability of tunnel works. Similarly, tunnel projects involve considerably higher costs in Nepal than in other countries owing to fragile geological conditions. Therefore, such projects require not only a high initial investment but also considerable time in financial arrangements. Consequently, tunnelling works could not be easily created as needed, and it ultimately hindered the involvement of local construction contractors.

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