ROHTANG TUNNEL PROJECT IN INDIA

Croatian experts on the top of the world: working experience on Himalayas

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Introduction

No road in the world is harmless. Ideal weather conditions, strict speed limits, and good visibility, can offer just a limited help to drivers. However, some of the roads around the world can certainly not be ranked among the brightest points of transport infrastructure. Moreover, some of them are known as the most dangerous roads in the world. The list is headed by Indian roads, especially those built in the Himalayas. To prevent accidents, Indian authorities have decided to build a tunnel through the Himalayas. The tunnel will be of much help to villages cut off from the rest of the world during wintertime, when most over-ground roads remain inoperable due to heavy snowfalls, landslides and strong winds.

Marko Mrazovac, the only Croat in the international team working on the project belonging to the category of extreme engineering, shared with us his experience of the life and work on the Himalayas. Why is the project classified as an extreme engineering endeavour? Simply because every project considered as physically unrealisable by normal standards is no less than extreme. However, the experts and engineers somehow find the way to turn this impossible task into reality. How else could we describe successful excavation of the Rohtang Tunnel through Himalayas, during which the workers were faced, in addition to other hardships, with the lack of oxygen in the air?

Road across the Rohtang Pass

Marko Mrazovac at the Rohtang Tunnel construction site

The international team is working on the project belonging to the category of extreme engineering - excavation of the Rohtang Tunnel through Himalayas, during which the workers were faced with the lack of oxygen in the air

Marko Mrazovac, MBA, is an economics expert with 12 years of domestic and international working experience in the operational and financial management relating to the construction sec-

tor. His professional career started in 2006 at the construction company *Viadukt d.d.,* based in Zagreb, Croatia. There he worked in the Finance Department, where he gained professional knowledge in the field of operational management, financial operations, cost control, logistics, procurement and strategic planning of construction projects. Young but highly ambitious, few years later Mrazovac was promoted as the person responsible for all apects of financial and commercial activities at the Viadukt branch office in Libya. From 2008 to 2011, he was working on a design/build project for the Libyan Transportation Department involving realisation of a 320km highway in West Libya with the budget of € 128 M. His international working experience included organization, supervision and development activities for his company in the field of finance, accounting, business analysis and planning, and negotiation with banks, suppliers, and foreign investors.

In the spring of 2016, Mrazovac made a new career step, moving to *Strabag AG*, a large construction concern based in Austria. Currently, he works on the Rohtang Tunnel project in Manali, India. Mrazovac is the Commercial Project Manager responsible for financial and commercial side of the project, involving finance activities, accounting, procurement, stores, and human resources. He is currently managing an international multidisciplinary team of 191 employees. Some of the challenges and risks faced by Mrazovac and the project team during implementation of this megaproject are presented in the paper.

Rohtang Tunnel on the map

Indian road to Roof of the World

The Himalayan road, approximately 475 km in length, is located at the northernmost end of the Indian subcontinent. It connects the cities of Manali and Leh in the centre of the Ladakh Province. The road crosses top five highest passes in the world, including Rohtang La at 3978 m, Lungalacha La at 5059 m, and Taglang La at 5328 m above sea level. The road is known to be a *highly perilous challenge* even to the best drivers.

Mountain peaks are usually under snow cover even in the middle of summer, and beautiful landscape transforms each journey into a fascinating adventure,

Himalayan landscape

which unfortunately sometimes leads to a tragic outcome. Translated into English, the name of this mountain pass ''Rohtang' means "pile of corpses", which vividly depicts extremely dangerous driving conditions on that road.

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The Rohtang Pass is located in Northeast India, at 4000 meters of altitude in the Himalayan mountains, connecting the Kullu Valley with the Lahaul and Spiti valleys. Every year, the Indian *Border Road Organization* uses GPS to locate the road after rockfalls and avalanches, so that it can subsequently dig it up and restore normal traffic. In the middle of the Rohtang Pass, sudden landslides and snowstorms are quite frequent and expected. However, although very dangerous and unpredictable, the Rohtang Pass attracts tourists eager to enjoy this beautiful and unforgettable mountain landscape.

Every year, from October to May, and sometimes until mid-June, the road is inoperable due to heavy snowfalls. The race to supply remote villages with food lasts from June to September when a continuous flow of trucks, buses, delivery vans, and passenger cars passes along that road. However, once the Rohtang tunnel is open to traffic, that route will be closed and the villages will finally be connected with other cities in India.

Supply of remote villages with food lasts from June to September

Strabag Afcons JV project team

The idea of building a tunnel underneath the Rohtang Pass dates back to 1983. However, the project was approved by the Indian Cabinet of Security in September 2009, and the contractor selection process was initiated. The tunnel construction contract was awarded to Strabag-Afcons, a joint venture between the India-based Afcons Infrastructure and Austria's Strabag.

Once the tunnel and the new road are complete, the travel time between Manali and Keylong will be reduced by five hours

The Client is the Ministry of Defence of India (i.e. its technical department *Border Roads Organization*), and the project is estimated at approximately € 235 million. The *Snowy Mountains Engineering Corporation - SMEC International* Pty. provided design for the project. The construction supervision was awarded to the consortium D2 Consult ICT JV in association with PEMS, which is formed of the Linz-based Austrian consulting company D2 and local Indian partners.

Rohtang tunnel construction

The tunnel provides ample room for two-way traffic, and is designed to cater to a maximum vehicular speed of 80 km/hr. It is built at the foot of the Rohtang Pass, 3060 m above sea level. It is 9 km long and 10 m wide, with the longitudinal slope of 0.5 %. The tunnel is one of key structures along the future Manali – Leh road section and will, once it is open to traffic, reduce the distance between Manali and Keylong by approximately 46 km, while the travel time on this section with be reduced by as much as five hours.

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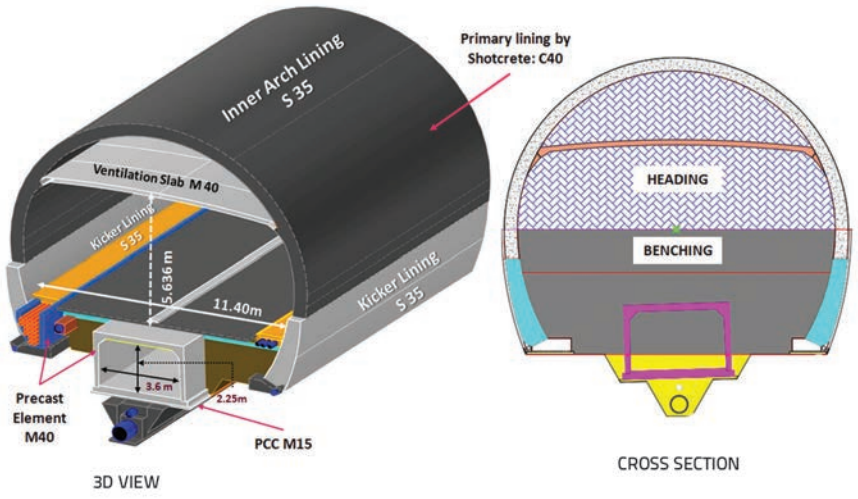

Tunnel cross-section

The construction site organization was not simple, and the engineers were not fully aware of what they could expect up in the mountains. The project team arrived from Europe to Delhi by airplane, and was to travel additional 600 km to the construction site in the middle of the Himalayas. At the first sight, it did not seem so far as a relatively functional motorway was used for the first 340 km. However, the real nightmare were the remaining 260 km with the continuous ascent along steep mountainous roads, locally no more than three to four m in width, full of mud and stone fragments. It took eight long hours to complete this seemingly short trip to their temporary home in the middle of the Himalayas.

View of construction site near south portal of the tunnel

As to the site preparation work, the electricity was provided from a nearby village, because this area in India is very well electrified, so that even some smaller villages in the Himalayas benefit from electricity. However, power cuts are frequent, and the construction site is therefore equipped with diesel generators that allow construction work even when electricity is not available. Some construction machines had to be transported to the site in parts, and assembled on the construction site by site crews.

To enable proper functioning of the construction site, appropriate site installations and plants were assembled immediately next to the north and south portals of the tunnel: concrete plant, storage shed for construction material and equipment, plant for the production of precast concrete elements, rock crushing and crushed material selection plant, and office premises. The construction site was officially opened on 28 June 2010, by symbolic cornerstone laying.

The tunnel, with a horseshoe shaped cross-section, has two portals (north and south). The cross-section is composed of three main parts: heading, benching, and invert. The south portal excavation started in August 2010, and the digging and blasting work for the north portal commenced in October 2010. In the light of geological and geotechnical on-site conditions, two excavation techniques were adopted: blasting and drilling. Construction of the 9

Formwork for concreting tunnel lining

km long Rohtang Tunnel is based on the NATM (New Austrian Tunnelling Method), which is a tunnel construction procedure founded on scientifically determined and practically confirmed ideas and principles, the objective being to achieve an optimum safety and economy by mobilising the surrounding rock mass capacities.

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The concept of this method relies on the fact that the surrounding rock mass of the tunnel is integrated into the overall support structure, and that the rock is activated via the load bearing ring around the tunnel. The rock drilling and transport of excavated material was followed by construction of primary support. The primary support varied according to the rock type encountered, and so the builders combined the technique of shotcreting (using concrete strengthened with steel fibres or ordinary concrete) with installation of reinforcement, trusses, bolts and ventilation pipes. An appropriate area of the construction site is reserved for stockpiling construction waste, which is then transported to a waste tip. 2.5 km of the tunnel were excavated by January 2012 and most of the works were being carried out in accordance with the time schedule. It should be noted that excavation of the south portal progressed a bit faster, as the north portal is situated under the Rothang Pass, which is inoperable in winter, and so the access to this part of the site is then impossible.

LSC-elements (Lining Stress Controllers) were installed in areas with high deformations caused by rock pressure so as to avoid uncontrollable cracking due to stress concentration in the corners where progressive failure is normally initiated (near openings, at sudden transitions, or in zones affected by concentrated force action). The construction of the final tunnel lining with unreinforced concrete started after completion of the primary tunnel lining. The use of reinforced concrete lining was anticipated only in tunnel zones with weak rock conditions, where the entire support was additionally strengthened. Ventilation duct slabs are installed section-wise using the cast-in-situ method. Below the road level there will be an emergency escape tunnel that is accessible every 500m from the main tunnel. Precast concrete elements are used for construction of this emergency escape tunnel.

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On-site precast-concrete plant

3,5 km of the future tunnel were excavated by June 2012 when the works were suddenly brought to a halt. In fact, builders were in for a big surprise in the middle of the tunnel, in the zone called Seri Nallah, where a ground water stream was encountered during rock drilling operations. That part of the mountain is characterized by extremely poor geological conditions and, considering that the river traversed the planned tunnel route, a good quality waterproofing system composed of geotextile and waterproofing membrane had to be installed. That is why the planned tunnel opening time was extended considerably, but this was an extraordinary situation that was successfully overcome with the support of the Client.

Construction site

Life and work above the clouds

Although building a tunnel at an altitude of 3000 m is a highly complex and dangerous enterprise, this challenge represented an even stronger motivation for the project team, whose members gave their best to reach the light at the end of the tunnel, and that day finally came in October 2017, when the tunnel excavation work was completed.

This project is a hazardous enterprise due to complex working conditions the workers had to cope with in this geographically hostile environment. Housing units were built in the immediate vicinity of the north and south portals to accommodate some of the workers, while the remaining employees were lodged in the

Construction site at north portal in winter (left) and summer (right)

nearby communities, from where they were transported to the site by buses. Up to one thousand workers were present at the construction site during some phases of the tunnel construction work. A relatively frequent health problem that affected many workers was high blood pressure caused by lack of oxygen at such high altitudes.

In October 2017 the tunnel excavation work was completed, up to one thousand workers were present at the construction site during some phases

That is why some workers were unable to take part in the work and had to leave the project. It is interesting to note that such health problems were not limited to workers that came to the site from Europe, but were also experienced by Indian workers that came to the construction site from low-lying areas of the country. Researchers from all over the world have struggled to explain this medical problem. Thus one can find in literature many testimonies of people who travelled to higher altitudes and experienced vertigo and sleeping disorders immediately upon arrival, while some even awoke in the middle of sleep with choking sensation. This condition has been named "periodical breathing" by medical community. Studies have shown that almost half of the people who find themselves at an altitude of more than 3000 m experience health problems due to lack of oxygen. The greater the altitude, the lower the atmospheric pressure. Thus the air contains about 20 percent less oxygen at an altitude of 2000 m, compared to the air at sea level. At an altitude of 4000 m the air contains even 40 percent less oxygen, which affects almost the entire organism: muscles are weaker, and the nervous system is less able to cope with stress.

Another problem of the Rohtang site is its location: because of high altitude, there is no hospital nearby. Fortunately, health care was organized as part of the project, and so medical services were available to all employees on the site 24 hours a day. Educational activities and safety controls were carried out throughout the project duration, which is why no severe injuries or other accidents were reported on the site. Despite cold mountain climate, it is unbelievable but true that many houses in nearby villages do not have any kind of insulation systems. Thus the water often freezes in pipes due to low temperatures and sometimes even the simple tasks, such as cooking or personal hygiene routines, may seem impossible.

A rather unpleasant situation occurred in the winter of 2014 when all telecommunication links with the rest of the world failed in the middle of a snowstorm. The situation remained unresolved for no less than fourteen days, and the workers could not do anything but wait for the specialists to restore the communication system. The problems were also experienced with the delivery of fuel to the site, and so the *Team Procurement Department* had to find solutions in a number of ways. Cold winters with heavy snow caused problems related to construction equipment and storage sheds. Sometimes a winter storm dumped up to two meters of snow in just a few hours. Therefore, in

Part of construction site in January 2018

View of north portal of the Rohtang Tunnel

winter months, construction aggregate had to be stored in sheds, and construction machinery was transported into excavated parts of the tunnel.

The Himalayas have been created (and are still growing) as a result of collision between the Indian and European tectonic plates. Since this area is seismically active, the earthquakes on the construction site are relatively common but, luckily, the magnitude is small, so they have not so far damaged the construction machinery or caused any other material damage. However, in winter months, seismic activity has been known to initiate avalanches. In order to increase consciousness about possible hazards and educate workers about the situation, an on-site expert team provides special education for employees focusing on the behaviour and protection rules to be observed in case of seismic action.

Current activities include realisation of concrete work and additional excavations, after which fire protection, ventilation, lighting systems and other equipment will be installed

The work on the tunnel is performed 24 hours a day and the working system has been adapted to such a rapid work schedule. Current activities include realisation of concrete work and additional excavations, after which fire protection, ventilation and lighting systems, and other equipment, will be installed. Due to specific on-site work conditions, the Indian military is careful in defining the project closing date. However, once it is open to traffic, the Rohtang Tunnel will probably be officially included in the Guinness World Records books as the longest tunnel in the world situated at an altitude of more than 3000 m above sea level.

Conclusion

What happens when you allow engineers to dream? Concepts of new world wonders may then see the light of day, and the Rohtang Tunnel will undoubtedly be one of such wonders. This highly complex construction project is now nearing completion, despite numerous obstacles the nature has placed in its pathway. An experienced international team of experts who anticipated some potentially dangerous scenarios, and prevented financial losses and site accidents, was the key factor for successful implementation of the Rohtang Tunnel project. In addition to the experience and good quality communications, managing cultural diversity of the multidisciplinary team was also very important. The *Strabag Afcons Joint Venture* has managed to reach its first common goal – tunnel excavation - and is now looking with optimism to the final completion of the tunnel and the works. Considering all perils – such as human health hazards - that have been successfully overcome by the workers on the Himalayas, it can finally be concluded that this project, a veritable endeavour that exceeds current limits of engineering, can simply be described with three words: *Impossible is nothing.*

Literature:

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Tunnel photo taken in January 2018