Lorraine Fourie
012 343 1434
lfourie99@telkomsa.net

Dr Alexander Tarasov
Technological University of Belgorod, Russia
alexandrstarasov@gmail.com

Dr Maxim Kovtun
Technological University of Belgorod, Russia
maksimkovtun@yandex.ru

A railway line 70 years in the making

A journey by rail through a vast and desolate landscape sounded like an interesting read to armchair traveller Lorraine Fourie. Dervla Murphy's book *Through Siberia by accident*[1] not only proved a splendid second-hand travel experience, it also highlighted the existence of a railway line described by the author as "an awesome witness to Russian engineering ingenuity". Post-doctoral fellows Alexander Tarasov and Maxim Kovtun from the Technological University of Belgorod in Russia, who were doing practical research within the Department of Civil Engineering at the University of Pretoria, delved into a few Russian websites and provided more recent information on the project

THE BAIKAL-AMUR MAINLINE (BAM) branches off from the more well-known Trans-Siberian railway at Taishet in Eastern Siberia, 4 520 km east of Moscow. It then runs north of Lake Baikal, the world's deepest lake, and after winding its way through several mountain ranges it descends to the Pacific harbour of Sovetskaya-Gavan, 900 km north of Vladivostok.

The BAM was developed as an infrastructural support element for the sparsely populated and economically poorly developed area of some 1,5 million km² stretching from Ust'-Kut (56°50' N, 105°42' E) in Eastern Siberia to the Pacific Ocean.

In winter, the climatic conditions in the region are little short of arctic, with temperatures dropping to -58°C. For more than half the year, the average day-time temperature is below zero; the summers are short, wet and hot, reaching 40°C. The geology of the region is extremely complex with crystalline rocks varying in age and composition overlain by a mantle of quaternary rock, ranging in thickness from a few to hundreds of metres. The area, especially north of Lake Baikal, has a high level of seismic activity and experiences on average about 400 tremors a year.

The non-Russian's interest in BAM may not so much be aroused by the mechanics or economics of the line – it carries much less traffic than the Trans-Siberian and, in truth, has not yet proved itself a profitable undertaking – but one has to be intrigued by the saga of its existence.

EARLY HISTORY OF BAM

Ms Murphy's work divulged the following details about BAM's fluctuating fortunes:

"When the Trans-Siberian railway was planned in the 1880s two routes were considered, north and south of Lake Baikal, but at the time geologists and engineers pronounced the northern route's terrain too daunting.

"By 1924 a long-term USSR development plan included a map showing the northern BAM line as an acknowledged fact. From a military viewpoint BAM seemed essential as, with stretches of the Trans-Siberian line – built between 1891 and 1916 – running close to the Chinese and Mongolian borders, the Russian Far East

was vulnerable to foreign interference. When Japan occupied Manchuria in 1933 and then extended its influence into Outer Mongolia, the case for a northern railway line was strengthened. An updated development plan of the same year stated that the BAM would bring to life an enormous new territory with its riches of amber, gold and coal, as well as open it up to agriculture."

According to the *BAM Guide*[2], "it was the largest civil engineering project ever undertaken by the Soviet Union, devouring the same gigantic amount of resources as were used to conquer space in the 1950s and 1960s."

Building on the BAM started in 1933, with the first tracks laid from Oldoi on the Trans-Siberian line to Tynda (then an isolated village called Tyndinsky), a distance of some 180 km. Four years on, under Stalin's regime, flaws were found in earlier surveys and a purge followed, during which engineers, geologists, scientists and administrators were executed on his orders. Others were condemned to the railway workers' *gulag* camps, known as BAMLags, as cheap labour for taiga (conifer and birch woods) clearing and track-laying. When the state archives were opened after *glasnost* in 1992, they showed that of Stalin's approximately five million victims some 400 000 were BAM builders.

From its inception BAM provoked dissension. Throughout the 1930s, an anti-BAM lobby rallied forces against the project and their clamours seemed justified when the most immediate military threat was countered in 1939 by Mongolia's defeat of Japan. However, work had already begun on the Taishet – Bratsk – Ust'-Kut section of the line, designated a state priority project because of a new hydroelectric scheme built at Bratsk. At the time 26 aircraft, 28 motor boats, 28 tractors, 133 vehicles, 1 500 horses and countless reindeer sledges were harnessed for the project.

When Hitler attacked the Soviet Union in 1941 railway construction stopped, except in the Russian Far East, and soon those tracks laid at such a high cost in human suffering were torn up for use as part of a relief line to besieged Stalingrad. Only the stretch from Komsomol'sk-na-Amure to Sovetskaya-Gavan on the Pacific coast was left intact.

Soon the BAMLags were filled with German and Japanese PoWs. Only 10% of the 100 000 Germans who worked on BAM's western end survived to be repatriated, and most of the 46 082 Japanese prisoners who died in the Soviet Union were BAM builders.

Post-war, Stalin specified 1955 as the railway's completion date and in 1950 the Taishet – Ust'-Kut section (692 km) was opened. But closure of the gulags after Stalin's death in 1953 caused BAM building again to be suspended. Also, European Russia's (west of the Ural Mountains) post-war reconstruction needs meant that mineral- and timber-rich Siberia was being disregarded. However, when huge copper reserves were discovered at Udokan, halfway between Severobaikalsk and Tynda, it proved positive for BAM. In 1960 the decision was taken to develop this deposit – which could not be done without the railway – but Russian bureaucracy befuddled progress.

Meanwhile, rising tension between the Soviet-Union and China that erupted in fighting on the frontier in 1969 within a rifle shot of the Trans-Siberian line fuelled the military lobby to again insist that BAM had become vital to national security. Ironically, the counter-argument was as strong: with modern advanced weaponry, the BAM route would be no less vulnerable than the Trans-Siberian line. The pro-BAMs finally won and in 1972 the relaying of the track to Tynda began.

In 1974, Soviet leader Brezhnev stipulated BAM's completion date as 1982, a deadline that once again proved over-optimistic. Only ten years later, on 27 October 1984, the first part – the section from Ust'-Kut to Komsomol'sk-na-Amure – came into operation. This is seen as the official launching date of the main BAM.

In reality only a third of the track was fully operational, and the trickiest tasks still lay ahead. These included the construction of complex railway infrastructure and tunnelling for which the available workers were unskilled. Their retraining delayed progress for another two years and by 1986 Gorbachev had come on the scene. Declaring himself to be anti-BAM, he described the project as "the greatest monument to the period of stagnation" and "an example of Brezhnev's personal economic adventurism".

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1 At Taishet the Baikal-Amur Mainline (BAM) heads northeast into the mountains (black line on map), while the Trans-Siberian runs across flat land to the southeast

In 1988 the authority in charge of BAM was disbanded, a signal decoupling the line from any new plans for Siberia's future. This was disheartening for the regional administrators and workers who were still slogging away on a dwindling budget – some of whom, by that date, were second-generation BAM workers.

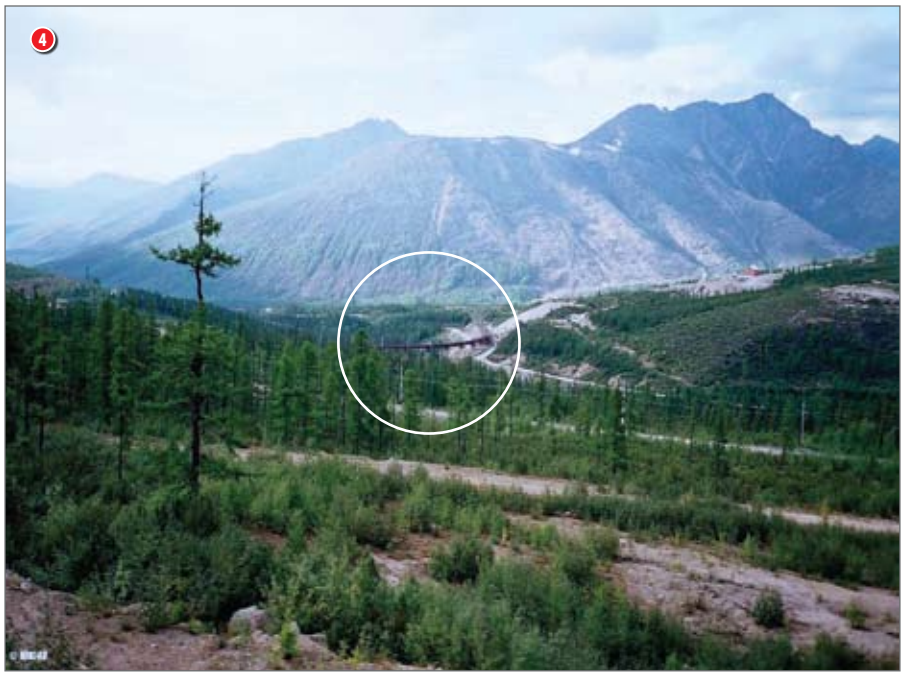
SEVEROMUISK BYPASS AND TUNNEL

Finally, in March 1990, the line became fully operational – 57 years after the first tracks were laid – that is, except for the Severomuisk tunnel.

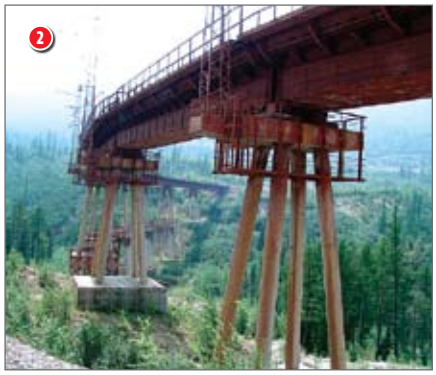
Between Lake Baikal and Tynda, the formidable Severomuisk mountain range rises to heights of 2 286 m. Construction on a tunnel through the mountain barrier started in 1977 and was scheduled for completion by 1984.

Needless to say, the completion date wasn't met. A bypass, an engineering feat in itself, was completed in 1987, but was not designed to last beyond 1992, the tunnel's new 'target date'. At the time, *Sotsialisticheskaya Industriya* reported that the grades were so steep that, when trains were heading downhill, the drivers rode on the locomotives' running boards (up to three electric units were used) so they would be able to jump off in time should an accident occur. Soon the 1992 target was abandoned and the building of a second bypass began. The maximum grade of the new bypass was 1,8% compared to 4,0% on the old line – a height difference of 4 m for every 100 m of track.

When Ms Murphy travelled the route in 2001, the *BAM Guide* assured travellers that it was safe for lightweight



2 and 3 and 4 and 5 The *Chjortov most* (devil's bridge) viaduct, where train drivers allegedly crossed themselves before entering the bridge, is situated at a steep gradient turn



passenger trains, though there were regular derailments of heavily laden goods trains. She reported on their two-hour crawl over the mountains: "Looking up... one can see four levels of track. I begin to wonder about my fellow passengers' silence; perhaps they are contemplating the chance that even a lightweight passenger train might fall over the edge... which is a mere yard from the train's wheels."

Located on this trajectory is a high viaduct called *Chjortov most* (the devil's bridge), where it is said the drivers crossed themselves before entering the bridge, which have double-deck supports and is situated at a steep gradient turn.

When construction started on the Severomuisk tunnel, the tunnelling team faced some daunting challenges. A geologist to whom Ms Murphy spoke considered the decision to build the tunnel as fundamentally wrong: "Back when the route was being surveyed, we warned the designers about the highly complex conditions in the Buryatiya sector.... We felt it would be better to bypass it from the south with minimal excavation work. However, the shortest path was chosen ...."

The *BAM Guide* states that, apart from the high level of seismic activity, the granite mountain range contains four major fault lines which offer a conduit for numerous underground lakes and rivers. At pressures of up to 35 atmospheres it meant that the subterranean water was always leaking through the tunnel walls. On one occasion, when a drilling team hit an unexpected fault line containing a 140 m deep underground lake, 12 000 m^3 of water, sand and rocks surged into the gallery, drowning several miners.

The main tunnel had a cross-sectional area of 67 m^2. In order to provide advance warning of adverse geological conditions, a pilot tunnel with a cross-sectional area of 18 m^2 was driven between 200 m – 300 m in advance of the main tunnel. This tunnel ran parallel to and 15 m away from the main tunnel.

The construction methods and design solutions commonly used in the Soviet Union and around the world in the 1980s couldn't satisfactorily be applied in these complex hydro-geological conditions. Apart from supplying excavation equipment, none of the engineering companies approached outside of the Soviet Union were interested in participating in the construction effort.

A technology subsequently applied by the BAM builders was the injection of liquid nitrogen into the granite to freeze the water and temporarily stop seepage, allowing time to line the tunnel with concrete as a permanent seal. This was combined with the use of specially designed grout consisting of cement, alkali silicate and chemical additives together with the drilling of vertical and horizontal dewatering wells up to 500 m in length to drain water from the rock. The tunnel lining was applied in two layers and was designed to withstand the thermal and seismic conditions.

In Russia, the Severomuisk tunnel was considered a unique civil engineering construction. The tunnel excavation yielded almost 3 million m^3 of spoil, while more than 1 million m^3 of concrete, 55 345 m of cast-iron tubing and 70 000 tons of rolled steel sections were used during operations. The maximum depth of the tunnel – at the highest point of the mountain range – is 1 000 m.

When the western and eastern headings met in 2001, the discrepancy in the opposite facing axes was a mere 13 mm compared to a permissible tolerance of 317 mm. At 15 343 m the longest tunnel in Russia, it eventually became operational on 21 December 2003, cutting the train journey through the Severomuisk mountains to 15 minutes.

The Severomuisk tunnel was only one of the projects along the 3 200 km long BAM railroad that was carried out under a multitude of unfavourable physical conditions. It should be kept in mind that practically the whole of BAM lies in a permafrost zone. The permanently frozen subsoil may be hundreds of metres thick, and is not (as Ms Murphy affirms) a consequence of Siberia's low winter temperatures, but is a leftover of the last Ice Age which hasn't thawed – a scenario that may be changing rapidly due to global warming.

The *BAM Guide* reports that track often had to be relaid after the ground beneath it had subsided. An increase of seasonal thawing depth resulted in adverse phenomena during construction works – such as differential settlement of the formation, frost boils and ice mounds, heaving of piles, and so forth. It seems that however much consideration is given to protecting and sustaining the environment, heavy construction is bound to disturb the permafrost.

FUTURE OF BAM

Without the infrastructural development of the whole BAM zone, the line does not have a viable future.

At the beginning of 2008, 113 billion RUR (roughly R33 billion at the time) were earmarked for the development of the rail infrastructure of the Russian Far East, with 63 billion RUR (roughly R18,4 billion) allocated to BAM. BAM then comprised 3 200 km of railroad, 10 000 km of motorway, 2 230 bridges and several tunnels.

6 A section of the Severomuisk bypass

If a shortage of funds does not again lead to the freezing of development programmes, a railroad connecting Yakutsk with BAM will be constructed by 2010. According to the President of the Yakutiya Republic, the 800 km railway will enable the rich mineral resources of the Yakutiya region to be accessible to the Russian economy. It will also allow year-round transport of goods to the Far North.

The BAM is seen as somewhat of an endearing white elephant in *Through Siberia by accident*. The present-day viewpoint is that the line does have a future, but that times past have deprived it of its true potential. Despite this, it remains a tribute to the sacrifices made and the determined efforts by those who constructed this impressive project.

ACKNOWLEDGEMENTS

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NOTES

All sources are fully acknowledged. The Editorial Panel of Civil Engineering does not accept responsibility for the accuracy of facts. Readers' comments will be welcomed.

Photo captions were supplied by Alexander Tarasov (alexandrstarasov@gmail.com) and Maxim Kovtun (maksimkovtun@yandex.ru). □

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