HERRENKNECHT Project Report

October 15, 2010

WORLD RECORD. MAIN BREAKTHROUGH ON THE EPOCH-MAKING GOTTHARD PROJECT.

The breakthrough at the Gotthard Base Tunnel on October 15, 2010 in the Eastern tunnel marks the most significant milestone on the way to completing the longest railway tunnel in the world. With the 2 times 57 kilometer long epoch-making project, Switzerland is connecting northern and southern Europe by rail through the Alps. After completion of the project, Herrenknecht Gripper tunnel boring machines have excavated and secured more than 85km of the main tubes.

Sedrun, Switzerland / Schwanau, Germany, October 15, 2010.

Giants in hard rock.
In 2017, the first high-speed trains will travel along, or rather through, the New Alpine Transversal (NEAT) at speeds of 200 to 250 kilometers per hour. This will cut the journey time from Zurich to Milan by one hour to 2 hours and 40 minutes. Swiss Railways are expecting, in particular, to cut freight transport times – yet another important improvement in traffic logistics between Germany and Italy. A new era in trans-Alpine rail travel is dawning. Setting off from Bahnhofstrasse in Zurich for a morning's leisurely shopping in the stylish Galleria Vittorio Emanuele II in Milan and returning the same afternoon with your shopping bags full of the best Italian designer wear. Only a dream? In 2017, this vision could be reality.

This quick jaunt between the two commercial centers will be made possible by a unique, epoch-making project – the construction of the new Gotthard Base Tunnel along with the Ceneri and Zimmerberg Base Tunnels. With a length of 57 kilometers and a maximum altitude of 550 meters above sea level, i.e. truly at the foot of the St. Gotthard mountain, two single-lane tunnel tubes will cross the Alpine range from valley floor to valley floor, as it were, on an almost level course. This will put an end to travel that was so slow, passengers could almost pick the flowers along the line, and the need for double locomotives to drive freight trains up steep gradients will be a thing of the past.

"This will be a high-speed rail corridor for Europe straight through the Alps, to transport goods in an environmentally friendly way from Rotterdam to Genoa," says Moritz Leuenberger, Swiss Federal Councillor, in describing the 'longest wonder of the world'. "We are working together with our partners on developing Europe's infrastructure, even though we are not members of the EU," he continues. This truly great feat is part of Switzerland's plan to transfer as much freight transport from road to rail as possible, as a way of protecting the environment.

The Alpine country is nearing this goal in leaps and bounds. The 'shell' of the world's longest railway tunnel is almost complete – the final and crucial breakthrough at the halfway point, the border between the Faido and Sedrun construction lots, took place on October 15, 2010. This will mark the completion of one of the most important stages in this spectacular undertaking, which has seen such impressive feats throughout its history. It is the result of almost half a century of intensive planning and has evolved continuously along with technology and geological science. It has also required courageous and farsighted political decisions to be made. The idea of a Gotthard Base Tunnel was first voiced in 1947 – but construction work on the tunnel did not begin until 2001.

FOUR TIMES THE VOLUME OF THE GREAT PYRAMID OF GIZA.
More than 85km of the main tubes have been excavated and secured with Herrenknecht tunnel boring machines. These high-tech steel giants from Schwanau, with a length of more than 400 meters and cutterheads measuring 9.5 meters, tunnelled their way through the tremendously hard rock, while the crowds of skiers enjoying the snow some 2,000 meters above in the Lukmanier Pass remain oblivious to the ear-splitting noise and the machine's brute force. Since beginning their mountain-munching journey in 2003, the cutting wheels of the four Herrenknecht machines have 'swallowed' around 10.5 million cubic meters of rock. This is about four times the volume of the Pyramid of Cheops in Giza. Around 75 % of the tunnel's main route have been or are being excavated by these 'mega-moles', as the tunnel boring machines (TBMs) are sometimes known. However, with the sum total of 114 kilometers of parallel tunnels, the project is far from being complete.

A TOTAL OF 152KM OF TUNNELS, SHAFTS AND GALLERIES
A total of 152 kilometers of tunnels and shafts need to be created for the Gotthard Base Tunnel project. The planners have divided the two main tunnels and the almost 180 cross passages into five construction phases. The overall construction time could be considerably reduced, because work on the five sections could be carried out simultaneously. However, extensive logistics provisions were also necessary. Access and supply tunnels had to be built, and enormous underground caverns had to be excavated to serve as bases for the tunnelling activities or drill & blast operations.

There are three such access tunnel and supply caverns at the Gotthard giga site – at Amsteg in the north, at the Sedrun intermediate heading in the middle and at Faido in the south (see illustration). Access to the tunnel is relatively easy from the mountain pass roads at the tunnel mouths near Bodio and Erstfeld in the north, while at Amsteg it is approached via a short tunnel of 'only' two kilometers' length. The access tunnel in Faido is 2.7 kilometers long with a gradient of almost 13 percent. Work on the Sedrun intermediate heading was far more complex, as it involved first excavating a horizontal access tunnel with a length of around one thousand meters far above the tunnel level, and then sinking two vertical shafts from its end to a depth of around 800 meters down to the tunnel. A 450-meter-long ventilation shaft completes this spectacular construction.

BETWEEN HIGH-PRECISION PLANNING AND GEOLOGICAL IMPONDERABLES
Surprises can always occur when boring tunnels the size of the Gotthard project. It is not for nothing that tunnel constructors have great respect for their task. Their work is a tightrope walk between the highly planned and the unforeseeable. In spite of the many preparatory investigations, unexpected difficulties can always occur. For example, at the very beginning of tunnelling from the southern side of the Gotthard in February 2003 – after only 200 meters – work was interrupted by unconsolidated rock. The two TBMs that set off from Bodio – affectionately known to the tunnelling teams as 'Sissi' (S-210) in the eastern tube and 'Heidi' (S-211) in the western tube – encountered geological disturbance zones known as kakirite zones. Such geological conditions are too soft for Gripper TBMs, which are designed for very hard rock, and make rapid tunnelling progress almost impossible. Every meter of excavated tunnel must be secured in a complex process. The machines could not leave these disturbance zones behind them until August 2003, after around 400 meters of tunnelling.

But a construction log can also include unexpected positive reports. For example, there was good news from the northern side in spring 2004. In the construction plan the geologists had predicted a tunnelling interruption of up to four months to deal with the Intschi zone. Luckily, however, this zone was around 50 % shorter than expected, and the teams operating the machines with the innocent-sounding names 'Gabi 1' and 'Gabi 2' were able to pass through the zone, albeit with reduced tunnelling speed. That said, however, the ups and downs in the mountain seemed endless. Good monthly tunnelling performances of 560 m and penetration rates of up to 12 mm per revolution were followed by difficult stretches, some with a penetration rate of only 3 mm per revolution and an advance of only 140 m per month.

There was bad news for the engineers and clients in June 2005. Suddenly and without warning, loosened rock mixed with mountain water infiltrated Gabi 2's cutterhead in the western tube. At first, the tunnellers tried to clear the cutterhead of the fine material by hand and back up the TBM a few centimeters. Without success. Eventually, the unconsolidated area ahead of the machine's cutterhead was solidified by injecting it with a mixture of cement and bentonite. At the same time, the tunnel builders excavated a 50-meter-long tunnel from the east tube to the west tube to free the TBM's cutterhead from the front. Regular tunnelling was not resumed until November 2005 after a standstill of five months.

The machines also had to deal with changeable geological conditions in the south on the stretch from Bodio to Faido, which impaired tunnelling performances. Noticeable improvements were attained by adapting the two TBMs to the unforeseen circumstances. In December 2005, 'Sissi' achieved the best daily performance in the Gotthard Tunnel so far, with 38 meters in the east tube.

2006: THE YEAR OF THE FIRST BREAKTHROUGHS

In June and October 2006 the construction teams in the north celebrated the end of tunnelling in the Amsteg – Sedrun section with a spectacular performance. The machines sped towards the end of the construction lot six and nine months ahead of schedule, respectively. But it all ended with an anticlimax. Just before the end of the lot they met with a geological obstacle – kakirite. This is why the TBMs were dismantled in advance in the solid rock zone. The workers then transported the machine components out of the tunnel with the tunnel train.

In fall 2006, breakthrough was finally made in the south, too, with the required precision at the Faido multifunctional station. The TBMs with diameters of more than eight meters reached their targets after 13.5 and 14 km respectively, with vertical and horizontal deviations of only a few centimeters. This degree of accuracy is comparable to a marksman hitting a 1 euro coin at a distance of two kilometers. After a total overhaul and a refit with new, larger cutterheads with diameters in excess of nine meters, Sissi and Heidi set off again in July and October 2007, tunnelling northwards from Faido towards Sedrun.

TUNNELLING SAFELY THROUGH THE "ORDEAL" OF THE PIORA BASIN

A further difficult zone awaited the tunnel builders on this stretch – the Piora Basin – a funnel-shaped formation filled with sugargrained dolomite and water, which reaches deep into the rock of the mountain range. Its existence was long known, and hardly any other part of the Gotthard had been investigated as intensely prior to the construction work. Since no one knew how far into the mountain the funnel reached, a decision was taken to make exploratory drills. A horizontal tunnel with a length of around 5.5 kilometers was driven from the cantonal road to the disturbance zone. In 1996, this zone was penetrated. The loose grains of rock turned out to be exposed to the enormous pressure of around 150 bar. A thick jet of water mixed with dolomite shot out of the mountain and flooded the road. The media called it 'D-Day at Piora Beach'.

19 inclined drills were made from the exploratory tunnel to the vicinity of the future base tunnel, finally giving the engineers the all clear. They hit on hard rock with no water pressure. Examining drill cores, temperatures and seismic results brought the geologists to the conclusion that the bottom of the Piora Basin was sealed with gypsiferous cap-rock. And so, on October 12, 2008, Sissi reported: 'Piora Basin successfully crossed', and its sister machine soon followed suit.

Tunnelling using conventional drill & blast methods between the Faido and Sedrun intermediate headings was also an extreme technical challenge. Here, the tunnellers blasted huge underground stations out of the rock. They will serve as special stopping bays for trains in emergencies. The branching tunnel will also allow trains to change from one tube to another during operation. A sophisticated system of transverse and connecting tunnels guarantees that smoke can escape and fresh air can enter the tunnel. The two 'multifunctional stations' are huge construction sites in themselves. Here, the rock presented tunnellers with a particular drill & blast challenge.

The mountain pressure in some sections was so high that the usual method of increasing the target dimensions of the excavating cross section was of no use. Normally, this gives the mountain the opportunity to 'let off steam' – the more it deforms, the more mountain pressure is released. But in the critical zones of the Gotthard Base Tunnel, stability could not be achieved by just permitting deformation. A counterforce was needed against the mountain to stop the cavity from reclosing completely. The solution was to use telescopically slidable rings. In this method, two telescopically slidable steel half-rings are connected to form full rings inside the tunnel cross section, excavated with an overcut of about 70 centimeters. The ring segments slide slowly together under the mountain pressure until their ends meet and they stabilize each other.

56 METERS IN JUST 24 HOURS

After a major overhaul, the two Herrenknecht Gripper TBMs, Gabi 1 and 2, completed the northern Erstfeld-Amsteg section with a length of just over 7 kilometers in 2009. The geological conditions there were almost ideal. This meant a Gotthard tunnelling record could be set in late summer 2009. In the space of only 24 hours, Gabi 2 chomped its way through no less than 56 meters of mountain – a world record for a tunnel boring machine of such dimensions. On June 16 and September 16, 2009, the construction site teams in the north reached their destinations in Amsteg after only 18 months, that is, six months ahead of schedule. This breakthrough was a prime example of the tunnel builders' and the machines' precision. Both TBMs had deviated from the ideal line, horizontally by 4 millimeters and vertically by 8 millimeters – millimeter precision in the truest sense.

At this time, Sissi and Heidi were still working in the mountain in the south. Although Heidi had some problems with a rock collapse in the western tube between Faido and Sedrun in March 2010, the subsequent stabilization measures only interrupted tunnelling until July 2010. Luckily enough, this event had almost no impact whatsoever on the project schedule. Work continues, including that of the two (vault) lining units supplied by the Herrenknecht branch company Maschinen- und Stahlbau Dresden, which follow the two tunnelling 'ladies' at a respectful distance. These 600-meter-long 'worms' lay drainage pipes, install sealing systems and concrete the vaults in twelve-meter stages. In a nutshell, they prepare the tunnel tubes, with top monthly performances of 600 meters, for the installation of the railway technology.

At Herrenknecht headquarters in Schwanau and at the company's Swiss branch we are proud to have supplied the essential technology for the excavation of the Gotthard Base Tunnel, in the form of four TBMs.

OCTOBER 15, 2010: MAIN BREAKTHROUGH AT THE GOTTHARD BASE TUNNEL

On Friday, October 15, 2010, breakthrough was achieved in the eastern tube and an "unhindered view of the Mediterranean" has become a reality. Breakthrough in the western tube is expected to take place in spring 2011. A few years of finishing work will then follow, to turn the tunnel into a functioning high-speed rail route with massive security precautions, for example the two emergency stations where trains can stop in case of danger. Here, passengers will be able to move quickly from one tunnel to the other – each of the two tubes serves as an escape route for its twin. This is a clever solution, which came after lengthy consideration of all the alternatives by all those involved in Switzerland. The work of the tunnel builders and the machines is now approaching its end. And the results are very satisfying. All risks were dealt with, all setbacks were overcome, all emotional rollercoaster rides were survived. And schedules were adhered to, despite the almost unimaginable complexity of the project. Time lost in one place was made up for elsewhere. On the occasion of the last stage goal, the Erstfeld – Amsteg breakthrough – Moritz Leuenberger, Member of the Swiss Federal Council, spoke of a "triumphant victory over the doubters and moaners". His motto was "no matter how high the mountain and no matter how hard the rock, where there's a will there's a way. We can do it, because we want it."

Martin Herrenknecht, Chairman of the Board of Management of Herrenknecht AG, also summed it up in his own words: “Anyone who masters such a huge project is at the pinnacle of infrastructure development. Europe will take off its hat to Switzerland as soon as the first trains start speeding through the new Gotthard Base Tunnel. The trust the Swiss have placed in Herrenknecht technology is the greatest complement we could ever receive as a company.”

Herrenknecht hard rock Gripper TBMs “Sissi” and “Heidi” in the south:

TBM diameter Bodio-Faido: 8.83m
TBM diameter Faido-Sedrun: 9.43m

Construction Consortium in the south:
TAT Consortium (Tunnel AlpTransit – Ticino): Implenia Industrial Construction, Alpine Bau GmbH, CSC Impresa Costruzioni SA, Hochtief AG, Impregilo SpA

Herrenknecht hard rock Gripper TBMs “Gabi I” and “Gabi II” in the north:

TBM diameter Amsteg-Sedrun: 9.58m
TBM diameter Erstfeld-Amsteg: 9.58m

Construction Consortium in the north:
AGN Consortium, Gotthard Base Tunnel North Consortium: STRABAG AG Tunnelbau Schweiz (CH) / STRABAG AG (A)

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