High Speed Solution

By Claire Smith

Polish State Railways is undertaking a major network upgrade to create a high speed rail system that is capable of using modern Pendolino trains with a top speed of 200km/h. The initiative is highly political with Poland's prime minister and minister of infrastructure pushing for the work to be completed and has received mass coverage in mainstream media.

While the scale of the project may have been a national challenge, the issues on one rail embankment in northern Poland presented a much bigger problem – an embankment failure occurred just as upgrade work was about to start.

Work was already planned to strengthen the embankment at Jurkowice on the E65 line for the high speed upgrade but heavy rain before the work started caused the embankment to fail. Rather than upgrading the route for high-speed trains, work was needed to restore the embankment for all rail services.

Polish State Railways challenged main contractor Trakcja and geotechnical contractor Keller Polska to stabilise the embankment in Jurkowice in just 30 days in order to reopen the rail line and clear the way for high speed services. The solution called for Keller to deploy a number of ground engineering techniques in order to achieve the stabilisation work in the tight timescale.

Weak Ground

“The E65 railway line runs from Gdynia on the coast near Gdansk to Warsaw,” says Keller Polska senior designer Oskar Mitrosz. “The rail line through Jurkowice was originally built as a single track in the mid-19th century and was converted to a double track with embankment widening in 1967.”

Ground investigations at the site ahead of the planned work revealed weak bearing capacity soils to 10m depth on the left side and up to 17m under the right side of the embankment. Undrained shear strengths ranged from 10 to 35kPa but locally the strength was as low as 5kPa.

“The thickness of the organic soils – especially muds – suggests that the embankment was built in a river valley or an old river bed,” says Mitrosz. “Beneath the layer of organic soils occurs a 5m thick layer of soft and firm clays. These layers are located under the embankment in a 10° dip from the left to the right, which

In Summary

Polish State Railways is undertaking a major network upgrade to create a high speed rail system that is capable of using modern Pendolino trains with a top speed of 200km/h. At Jurkowice an embankment due for upgrade to increase the line speed failed as work was about to start on site.

Where

In Figures

11,252m
Linear length of controlled stiffness columns installed

160m
Length of embankment that was repaired

Who?
The client for the project was Polish State Railways. Consultancy work was undertaken by Egis Poland and Halcrow with work on site delivered by main contractor Trakcja and geotechnical contractor Keller Polska.

Challenges

Polish State Railways challenged Trakcja and Keller Polska to stabilise the embankment in Jurkowice in just 30 days in order to reopen the rail line and clear the way for high speed services. The design had to be revised five times as ground movement was still occurring as design started.

More Information

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corresponds with the direction of movement of the landslide.

“Several decades of loading from the existing 10m high embankment had resulted in creation of a natural basin from anthropogenic soils and a partial displacement of the organic soils below. The thickness of organic layers underlying the embankment, determined in field tests, reached up to 4m.”

According to Mitrosz, the process of consolidation had a profound effect on the soil strength parameters of material located under the embankment. “The strength was increased in comparison to the characteristics of layers situated remote from the embankment,” he explains.

**FAILURE MECHANISM**

Mitrosz believes that the embankment had undergone settlement over a prolonged period before it failed completely. “Before the landslide, we found that there was 2m to 3m of rubble pressed into the embankment which suggests this was used to underpin the track as settlement progressed,” he says.

The stability issue was noticed on site following a period of heavy rain when part of the top of the embankment subsided, uncovering a 50mm crack.

“The observable crack took the shape of a 130m long curve with settlements of up to 300mm,” says Mitrosz. “The geometry and character of the loosened slope showed that the embankment was failing and had been set in motion as a result of an earlier formed deep shear path.”

Initially only the rail line on the side of the settlement was closed and the other rail line remained open to passenger services with a speed limit of 10km/h imposed, but the line was later closed as displacement on the landslide increased to 1.5m. Closure was also necessary to allow remediation to be undertaken.

Analysis of the failure led Keller to propose that stabilisation was extended over a 150m section of the embankment but there was some debate about the approach to stabilising the slope.

“In the process of designing the repair of the embankment two variants were taken into account – a stiff engineered solution or a susceptible [flexible] approach that could cope with some further settlement,” says Mitrosz.

“The first solution would have caused big stiffness differences between the reinforced and unreinforced part of the embankment. Transitional zones, which would have been required for the stiff solution, increased the scale and cost of the repair work.”

“On the basis of static analysis and experience gained from other investigations, a susceptible reinforcement solution was designed. Finite element modelling using Plaxis 2D and GGU-Stability based on the Bishop Method showed that the stabilised embankment would behave similarly to the neighbouring un-remediated sections of embankment founded directly on the natural ground.

“The analysis showed that there would be no differential settlement.”

Designs for the stabilisation work had to be revised five times due to the dynamic conditions of working with an active landslide.

The final solution involved installation of over 5,000m of 800mm diameter continuous flight auger piles, almost 11,000m of 400mm diameter screw displacement columns, more than 11,000m of 400mm controlled stiffness columns and over 5,400m of compaction grouting, along with 2,200m of load transfer platforms, 2,500m of post-tensioned strands and 453m of concrete capping beams.

“We had to combine a number of different techniques to deliver the work in the timescale,” says Mitrosz.

“We also used a number of innovative ideas for the work including the advanced use of inclined compaction grouting which was undertaken with a modified Raupen TR 54 rig to drill to depths of up to 24m and boreholes that were inclined at 45°.

Also the load transfer platforms were reinforced using prefabricated steel rolls to save time and use of alternative directional drilling techniques – that are more commonly used for sewage systems –
for the installation of 90mm diameter HDPE pipes and post-tensioned steel strands.”

Delivering such a wide number of techniques in a short space of time was not the only challenge; space on site was also limited too. According to Mitrosz, movement of equipment and staff had to be carefully planned.

**DESIGN SOLUTION**

“In order maintain slope stability during the main repair works and to ensure the safety of the workers during the construction, 2m high, 1m wide soil buttresses were formed on either side of the embankment at the start,” says Mitrosz.

“The buttresses also provided working platforms for the specialist construction machinery used on site.

“However, due to very low soil strength parameters at the bottom of the embankment it was decided to strengthen the buttresses below the area where pile driving would be undertaken for the concrete columns.

“The CFA pile wall was then formed with an axial spacing of 1m between the piles. The toe position of the piles was carefully designed so that the wall was embedded in the bearing layer but did not restrict flow of groundwater at depth in order to prevent issues with the piles forming dams.”

With the piled wall completed, capping beams were installed and the walls on either side of the embankment were tied together using post-tensioned strands installed in HDPE pipes that were placed using horizontal drilling through the embankment’s foundation. The post-tensioned strands consisted of three or four steel strands to ensure a double anticorrosive protection.

“In the last stage of the repair works, the compaction grouting was undertaken below the embankment and to strengthen the low strength soils below the embankment,” says Mitrosz. “The longitudinal spacing of the injection points was 2m but was adjusted to take into account the position of the installed strands.

“The compaction grouting points were designed to be executed from the embankment crown with injections formed alternately on either side of the embankment. The injections provided deep compaction of the soil that had been loosened during the landslide.”

Work to stabilise and reconstruct the embankment was delivered on time and, according to Mitrosz, monitoring of the vertical and horizontal deformations following the work, and once the rail line was reopened, proved that the solution was successful. Following completion of the stabilisation, the high speed Pendolino trains are now operating on the line.