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PRELIMINARY ENGINEERING GEOLOGICAL STUDY FOR THE RAILWAY LINE DESIGN BETWEEN HUNGARY AND SLOVENIA

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Abstract

Due to the development of economic contacts between Hungary and Slovenia the establishment of a railway line connecting Zalalövő and Ormož has recently become an urgent issue. In this respect the Hungarian part set up the design of the 20 km long new railway line. MÁVTI Co. Ltd. has been contracted as general designer. The projected railway line passes through Zala-river valley – Balla hill – Kerka river-valley. This hilly region receives the most precipitation in the country ($>$ 800 mm/year). The two river valleys are wide, flat, humid areas intersected by a number of tributary streams and ditches. Since traversing Balla hill requires raising the railway line from 210, or 225 m to 260 m, the pull has to master a slope of 12%■.

In the valleys a geo-textile 0.5 – 1.0 m foundation of stone spreading and a drain ditch have to be constructed. Additionally, at Nagyrékás, in the region of Balla hill a 1400 m long viaduct with 15 – 18 m deep pile foundation, a 40 m span bridge over a river, a 300 m long tunnel in gravel and clay, along with 9 – 11 m deep cuttings supported by gabionwall in three sections will be completed. More than 50 engineering structures should altogether be established along the whole railway line.

Keywords: engineering geology.

1. Introduction

The economic relationship established between Slovenia and Hungary following the disintegration of Yugoslavia is important for both countries. The design of the railway line between Zalalövő – state boundary/Ormož led by MÁVTI Co. Ltd. and ensuring the establishment of railway connection started in this framework. The reunited railway line facilitates the improvement of the underdeveloped region and the establishment of the link to the transcontinental European axis.

2. General Features of the Region

A substantial part of the 20 km long Hungarian section of the new railway line passes in the *Őrség Nature Conservation Area* (*Fig. 1*). This aspect determines fundamentally the conditions of feasibility.

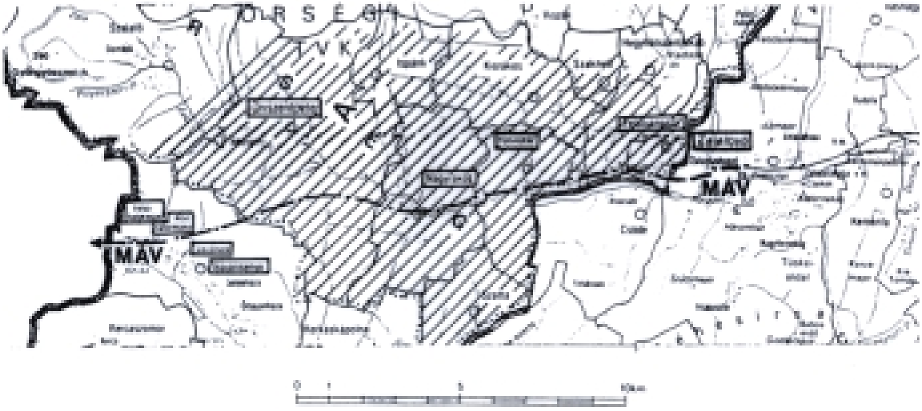

Fig. 1. The designed railway line with the Őrség Nature Conservation Area

The assessed area required for expropriation by railway line construction can be subdivided as follows:

– settlement	11 hectares
– agricultural land	35 hectares
– forest	21 hectares
– altogether:	67 hectares

2.1. Relief Characteristics

The design area is part of *Zala hills.* Its main section passes in the flat valley of Zala river. The valley is surrounded by 15 – 30° steep slopes broken up by side-valleys and slides. The landscape divided by erosion ditches attains its highest elevation on Balla hill (265 m) at the boundary of the villages Nagyrákos and Őriszentpéter. Afterwards, the railway line follows a gentle slope to Kerka valley representing the state boundary.

2.2. Overview of Geological and Tectonic Conditions

A several hundred m thick *Upper Pannonian* sequence is the prevailing geological formation in the hilly land. Its upper, 100 – 200 m thick part is made up of alternating sand, sandy clay and clay layers. It can be observed only in small patches on the surface. It is overlain by several m thick Lower Pleistocene fluvial gravel making up the alluvial fan of the ancient Rába river. The hills and slopes are covered by up to 10 m thick clay blanket. Zala and Kerka rivers did not form their erosion valley before *Late Pleistocene,* the valley floor is covered by their 2 – 7 m thick flood deposits.

Considering the structural regime of the area it can be regarded as calm. Though even Pleistocene sedimentation was affected by some faults, but instead of vertical dislocations they were manifested only by gentle tilts of some degrees.

Seismically, the area is safe, some 3 – 5° quakes on the MSK-64 scale occurred in its wider surroundings.

2.3. Hydrological Conditions

The investigated area features a dense drainage network. The designed railway line passes almost entirely in the valleys of *Zala* and *Kerka rivers.* Both of them are characterised by irregular regime. The substantial part of Zala valley is flood-plain, a humid, marshy area with a number of tributary streams and water courses.

This area receives the most precipitation in the country, the yearly average exceeds 800 mm. Summer precipitation is intense, the impermeable clay cover results thus in high specific drainage, intense erosion activity and frequent mass movements.

3. Engineering Geological Specification of the Designed Railway Line

Within the framework of the project a single track line has to be constructed designed with a configuration allowing to achieve the speed of 160 km/h. Due to the high number of level crossings it will be eventually realised for the maximum speed of 120 km/h. The engineering geological study was completed upon three railway line designs of MÁVTI Co. Ltd. According to relief characteristics requiring different tracing and execution the designed railway line can be subdivided in 3 typical sections as follows:

– 1st section: Zala valley
– 2nd section: Vicinity of Balla hill
– 3rd section: Kerka valley

3.1. Zala-valley Section

The main section of the designed railway line passes along the left side of the river. Four settlements can be found there. Consequently, their service must be given major consideration as well as reducing the noise and other pressures to minimum.

Considering *relief characteristics,* it is a flat, 200 – 450 m wide river valley with humid, swampy regions and some water streams (*Fig. 2*). The valley floor rises from Zalalövő to Nagyrákos from 182 m to 215 m, respectively.

Fig. 2. The humid part of the of Zala-river valley

Apart from the unfavourable hydrological features, the nearby settlements play a major role in defining the railway line, the new waterworks of Zalalövő has to be resettled.

The valley is rich in *surface waters.* The designed railway line follows the meandering incised bed of Zala at a distance between 20 – 400 m. The line crosses five streams and several ditches requiring the construction of a great number of engineering structures. It crosses Zala river at Nagyrákos through a bridge of 40 m span. The level of the railway line has to be raised at this point by 15 m. Constructing a railway embankment 60 m wide at its bottom would fundamentally change the landscape of this particular valley section, as well as the drainage pattern. It is the reason why we suggest a viaduct-related construction method instead.

The results of a drilling campaign with a density corresponding to the regulation of the Hungarian standard (MSZ 4488-76) showed a uniform *geological makeup.* The fluvial deposits of Zala river are underlain by grey Pannonian clay of high plasticity.

The Pleistocene–Holocene sedimentary series of the river starts with a 0.5 – 2 m thick silty sandy gravel deposit covered by 2 – 6 m thick clay, silty clay and silt.

Groundwater is present all over the area characterised by abundant precipitation and dense drainage network. Recordings in March–April showed groundwater entry and hydrostatic levels at 1 – 2 and 1 m, respectively.

Engineering geological investigations brought the following remarkable results:

- neither peat nor organic clay has been recovered in any of the 35 drillings
- despite frequent water cover and high groundwater level the state of the formations is generally appropriate ($I_c = 0.8 - 1.2$), showing some unfavourable values only locally along tributary streams ($I_c = 0.5 - 0.7$).

In order to ensure the stability of the railway embankment against water abundance we propose the following measures for its foundation along the whole railway line:

– removal of the loosened soil cover penetrated by the root network;
– installation of geo-textile as a filtering tissue under the embankment;
– apply a 25 – 30 cm thick rubble spreading and cover it by 50 – 60 cm thick rock debris. The embankment foundation should be thus invariably situated above the ground surface;
– establish a drain ditch at the foot of the embankment on its river side;
– establish a drain ditch and a belt ditch in the sections where the railway line passes in cutting or slope side.

3.2. Section in the Vicinity of Balla Hill (312+00 – 395+00 Section Part)

The most sophisticated part of the designed railway line passes along the boundary of the central village of the Nature Conservation Area – Őriszentpéter. Consequently, its proper adjustment into the landscape is of crucial significance.

Considering *relief characteristics* it is a variable hilly terrain between Zala and Kerka valleys rising to an altitude of 265 m asl. The landscape is broken up by deep erosion ditches, gullies and gravel pits (*Fig. 3*).

Fig. 3. A slope in the side of Balla hill disrupted by gravel mining

With regard to altitude tracing the area is unfavourable. Starting from 210 and 225 m asl. in Zala and Kerka valleys, respectively, the railway line must rise to

260 m at Őriszentpéter. Consequently, in the section parts 316+45 – 341+20 and 367+80 – 384+50 the pull has to master a slope of 12%■.

Due to its elevated position this section is considerably poorer in *surface water.* At the same time, several seasonal water courses can be observed with open water surfaces after snow melting. An important task is the prevention of backward erosion there.

Owing to the high number of drilling *the geological conditions* are well known down to several thousand metres. Middle Miocene formations positioned between 2800 – 3100 m below the surface have also an impact on tracing due to the presence of the *mining claim of the Hungarian Oil and Gas Co.* in the Bajánsenye region. According to the decree 6/1982 (V.2.) Ip.M. public railway has to pass outside a 50 m safety zone of CH wells which required the modification of the trace.

Pannonian deposits are affected in the design area solely by the pile foundation of the viaduct to be constructed in the Nagyrákos segment of Zala valley. Lower Pleistocene terrace gravel of the ancient Rába river (Ős-Rába) provides the geological framework for other sections. It crops out in the side of Balla hill (*Fig. 3*). It was recovered in bore holes down to 14.5 m without hitting its bottom. Gravel is made up of 10 – 50 mm grains of quartz and quartzite. It is compact, occasionally silty and clayey.

Terrace gravel can be traced further westward in bore holes towards Bajánsenye–Dávidháza at an altitude between 225 – 235 m.

In hillsides and slopes gravel is covered by 4 – 12 m thick terrestrial brown clay. It is essentially dry, with favourable consistence ($I_c = 1 - 1.3$), occasionally friable, but it is frequently characterised by intercalations of high plasticity ($I_p >$ 40%).

In the section of Zala valley near Nagyrákos where the designed railway line crosses the river, the Pannonian basement is covered by 3 – 7 m thick silty gravel and loose silt with organic matter deposited by the river.

Groundwater is present in the Nagyrákos section of Zala valley. Its level varies between 0 – 3 m. Recordings between 5 – 6 and 1.5 – 7.2 m in some bore holes at Balla hill and westwards near the village Baksaszer, respectively, show the absence of continuous groundwater table, there is only some local filtration instead.

Considering engineering geological features it has to be stressed that the horizontal tracing of the railway line in the strongly broken-up terrain requires significant earthwork. Apart from economic considerations adjustment in the landscape must also be given major attention.

That is the reason why we prefer a viaduct solution to a 12 – 15 m high railway embankment 60 m wide at its bottom in the elevated railway line section starting in front of the 40 m span bridge crossing Zala river (*Fig. 4*). Due to the high pressure of the viaduct, 20 – 40 m deep bore holes and dynamic soundings were completed for pile foundation. The results showed that superficial sediments are humid and deeper sequences are also made up of variable, loose formations.

The first pressure resistant layer occurred at 15 – 18 m depth capable of supporting Frank-type or large-diameter piling.

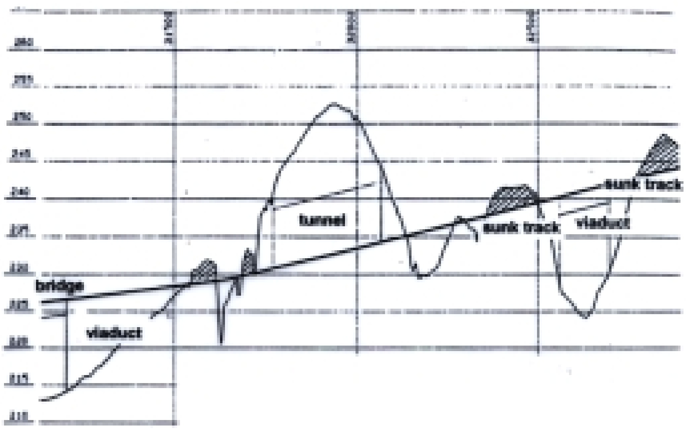

Fig. 4. Proposed solution for railway line construction in the area of Balla hill

In the section between 326+30 – 329+20 km at Balla hill emerging between erosion ditches the open cutting for horizontal tracing would require a 22 m deep excavation of 120 m wide crown width (*Fig. 5*). This section would thus need approximately 1500 m^3/running-metre earthwork, whereas the prevailing thick clay component of the excavated material cannot be used for embankment construction. Therefore several hundreds of m^3 of overburden should be disposed of. Protection of the large cutting surface against erosion and sliding, as well as the drainage of surface and percolating waters would also generate special problems and high additional costs.

On the basis of the above arguments and considering environmental protection, construction of a *tunnel* would be an appropriate solution.

The related study included the penetration of 5, 20 – 30 m deep drilling. The results showed that nearly 300 m long tunnel would be driven mainly in gravel and sandy gravel suitable for utilisation, only the roof of the section penetrates in thick clay (*Fig. 6*). The clay features essentially favourable characteristics, it is tough, hard ($I_c = 1 - 1.3$), pre-loaded. During longer contact with water it is susceptible to swelling. Some informative basic parameters: $\rho = 2$ t/m^3; $\varphi = 0 - 5°$ $c = 50 - 100$ kPa; $E = 10$ MPa. The reported values refer to a continuous, intact layer, excavation can result in slides and detachments.

The gravel is dry, massive with favourable load-bearing capacity. It is frequently compacted by clay or it is slightly cemented. Some informative basic parameters: $\rho = 1.8$ t/m^3; $\varphi = 30°$; $c = 0$; $E = 50$ MPa; $k = 10^{-4} - 10^{-6}$ m/s.

According to bore hole data some percolation can occur in the area of the designed railway line between 15 – 18 m depth.

This solution would require only 60 – 70 m^3/running-metre earthwork, gravel

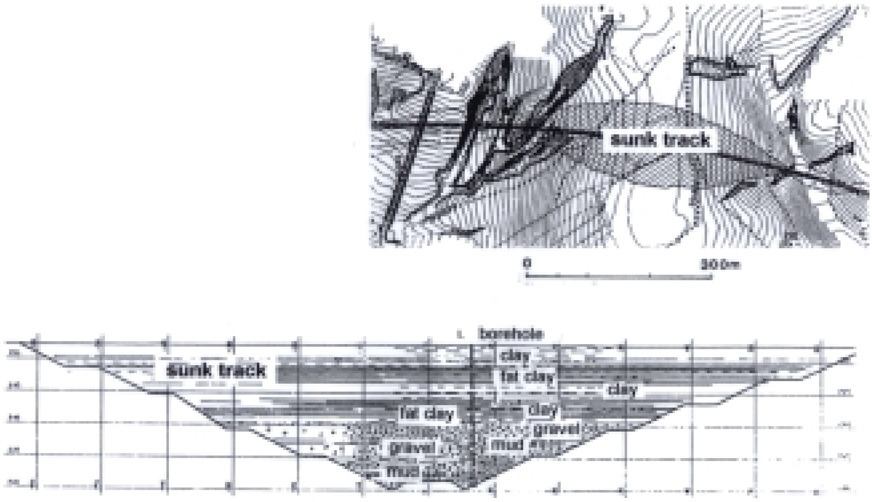

Fig. 5. Environmental impact of the section at Balla hill choosing the cutting solution

and sandy gravel could be reused, clay should only be disposed of.

Along the further part of the railway line 333+90 – 335+90 km construction of another, 200 m long viaduct seems reasonable. Subsoil is made up of more than 10 m thick clay there, but prevention of mass movements would require pile foundation again.

Passing towards Dávidháza, altitude tracing in three section parts: 336+70 – 337+30; 338+00 – 341+30; 368+00 – 377+00 km in Pleistocene terrestrial clay sequence demands the excavation of up to 9 – 11 m deep cuttings.

The study of several solutions showed *the gabionwall scheme* as the most favourable considering economic, technical, as well as environmental aspects. It demands less earthwork, results in less overburden to be disposed of, it has a supporting effect and filtration capacity, it is flexible to some smaller movements, does not require special foundation, it has a friendly effect on the environment and it is aesthetic while covered with vegetation.

3.3. Kerka-valley Section (395+00 – 407+10 Section Part)

It is the shortest, 1.2 km section of the designed railway line.

It features uniform *relief characteristics*, the 700 – 800 m wide, flat valley floor of the river developed at 222 – 225 m asl. The designed railway line, as well as two villages are situated on the left side of the river.

Surface water characteristics are similar to Zala valley. Kerka is running 0.5 km from the railway line, the trace is crossed by its several tributaries. Along their course, at the foot of the one-time embankment important surface water levels

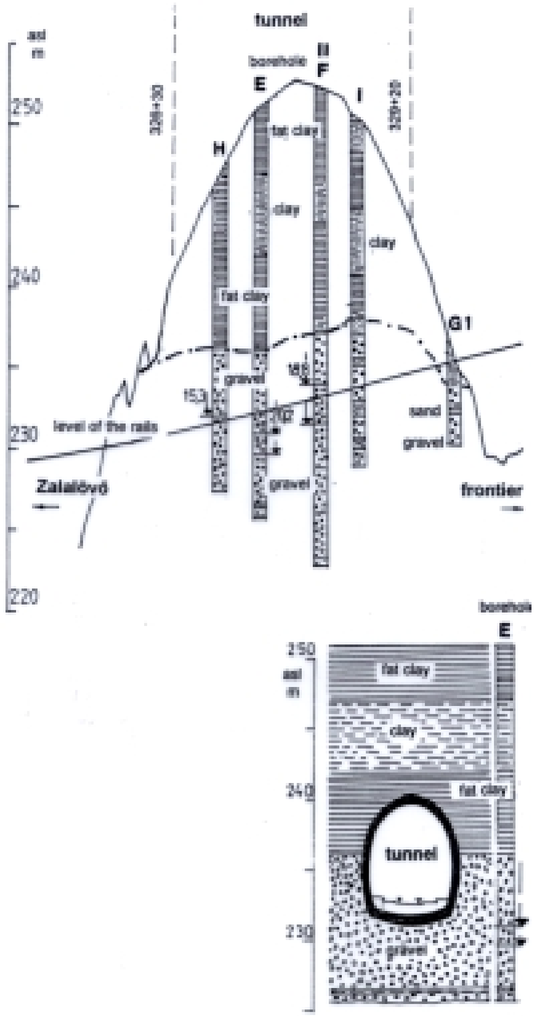

Fig. 6. Geological environment of the tunnel at Balla hill

have been observed. Several engineering structures have to be constructed thus in this section as well.

Considering *geological features*, the basement is constituted also by Upper Pannonian clay and sand. Investigating bore holes recovered the Pleistocene–Holocene fluvial sequence. It is finer and more heterogeneous than in Zala valley, represented by silty gravel, gravel-bearing silt, silt and clay. The whole series is softer, looser, though it features essentially appropriate consistence. Nevertheless, 0.2 and 0.4 I_c values occur occasionally in silty layers.

Groundwater is present all over the area, its hydrostatic level varies between 0.5 – 1 m.

From the point of view of *engineering geology* the features described at Zala valley apply. There are no major earthworks foreseen in the area except for the construction of a maximum 3 – 4 m railway embankment.

4. Summary

Construction of the merely 20 km long section is crucial essentially for goods traffic – it ensures renewed contact between Hungary and Slovenia through Őrség. MÁVTI Co. Ltd. worked out a number of slightly variable alternatives for railway line definition. Detailed in-situ investigation and 80 exploration drillings in the humid valley and broken-up hilly sections and regular consultations resulted in the adoption of the most favourable trace and execution method and technology. The execution plan just under preparation with additional bore holes and pressure tests can still bring some small modifications.

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