APPLICATION OF GPR DURING INVESTIGATION CONCERNING CAUSES OF FAILURE OF RAILWAY STATION PLATFORM IN JILEŠOVICE

VYUŽITÍ GPR PŘI ZJIŠŤOVÁNÍ PŘÍČIN PORUŠENÍ NÁSTUPIŠTĚ NÁDRAŽÍ V JILEŠOVICÍCH

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Abstract

Civil engineering works carried out as the renovation of existing buildings can be difficult to predict in terms of their behaviour over time. The heterogeneity of materials of a natural and anthropogenic origin can subsequently lead to either deformations, or breach threatening the existence of building structure in terms of statics. The platform of the station in Jilešovice underwent structural modifications within the reconstruction of the railway track from Ostrava to Opava. The largest building intervention was the reconstruction of an old bridge and adjacent embankment bodies now in addition secured due to stability by gabion baskets instead of the original natural grading. After a short time of its use, significant deformations appeared on the renovated object, whose causes and further evolution over time was not known. Within the design of investigation techniques, allowing uncovering the causes of violation quickly and efficiently, the survey with a georadar -GPR (Ground Penetrating Radar) was included, which as an indirect, non-destructive method of survey very quickly helped to clarify the causes of violations of the building structures.

Abstrakt

Inženýrské stavby realizované jako rekonstrukce stávajících stavebních objektů mohou být z hlediska jejich chování v čase obtížně predikovatelné. Heterogenita materiálů přirozeného i antropogenního původu může vést následně buď k deformacím, nebo až k porušení staticky ohrožujícímu existenci stavební konstrukce. Nástupiště nádraží v Jilešovicích prošlo stavebními úpravami v rámci rekonstrukce trati ČD z Ostravy do Opavy. Největším stavebním zásahem byla rekonstrukce starého mostu a přilehlých násypových těles navíc v současnosti zajištěných stabilitně gabionovými koši místo původního přirozeného svahování. Na rekonstruovaném objektu se po krátkém čase jeho užívání projevily závažné deformace, o kterých nebylo známo, co je způsobilo a jaký bude jejich vývoj v čase. V rámci návrhu průzkumných technik, schopných rychle a efektivně odhalit příčiny porušení byl zařazen průzkum georadarem-GPR (Ground penetrating radar), který jako nepřímá, nedestruktivní metoda průzkumu velmi rychle přispěl k objasnění příčin porušování stavebních konstrukcí.

Key words: GPR, engineering-geological investigation, failure, building structure, anthropogenic material.

1 INTRODUCTION

The site is located in the Czech Republic, Moravia-Silesia Region, former district of Opava, in the cadastral territory of Jilešovice. The studied area is first viewed on the base of a well-arranged geological map of the Czech Republic (Fig. 1), further then a 1:50 000 geological map with marked locations of archival boreholes (Fig. 2) is used to approach the complexity of the geological environment and its geological evolution. The close proximity of the area of interest is then shown in Fig. 3 and Fig. 4 (a map and aerial photo). The train station is located in the northern part of the village of Jilešovice.

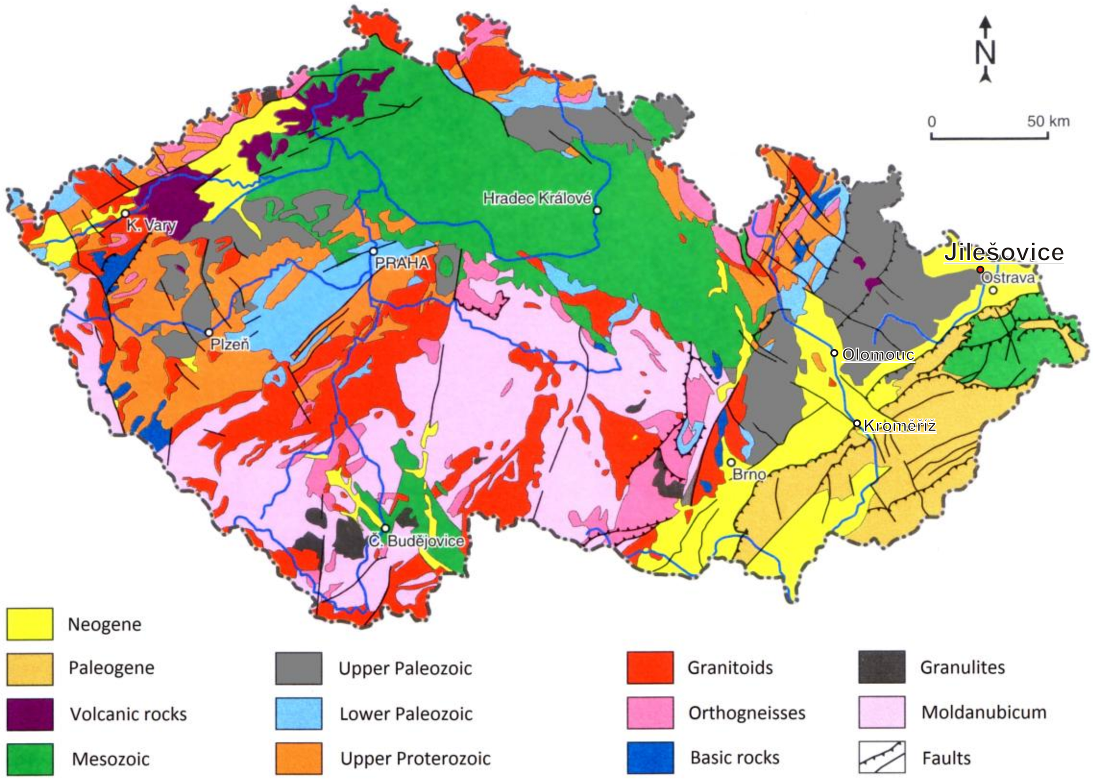

Fig. 1 Location of the area of interest on the base of a well-arranged geological map compiled by CGS**.**

According to the database of the CGS-Geofond, the survey with an archival number in Geofond P0102567 [Klimša at al. 2002] was carried out in the vicinity of the area in question in the past.

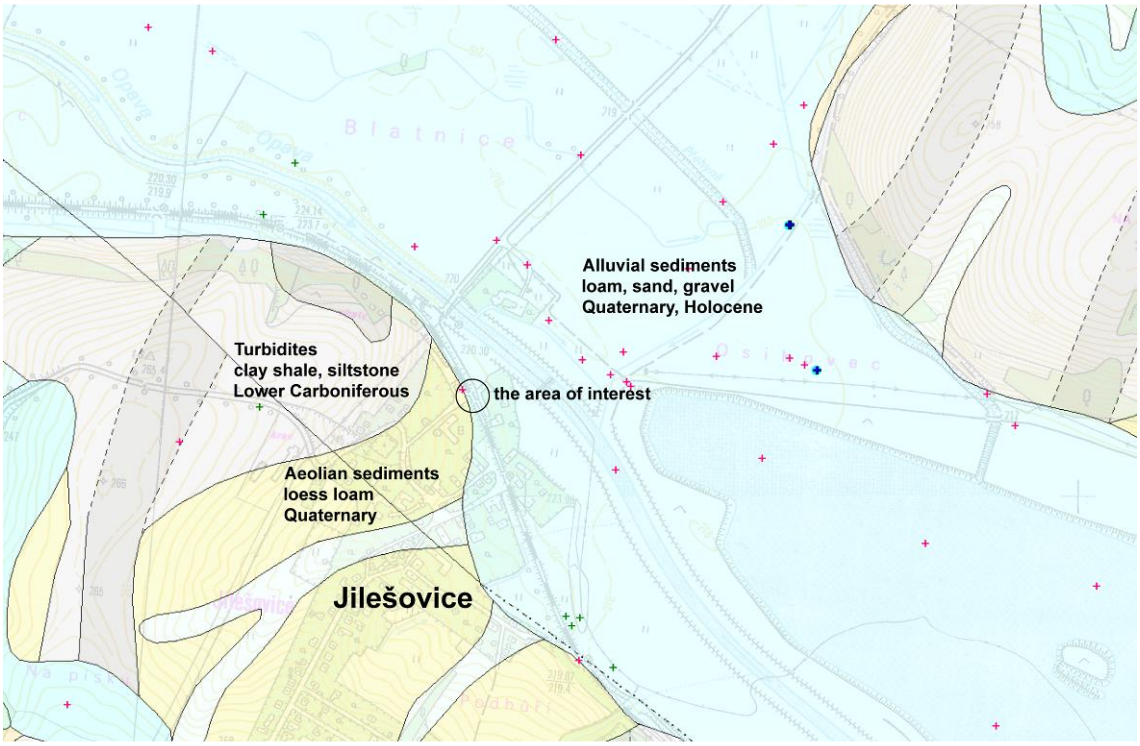

Fig. 2 Cut of the geological map 1:50000 published in an electronic form by the Czech Geological Survey with described basic rock complexes and locations of archival boreholes.

Fig. 3 Cut of the map with the survey location in the village of Jilešovice (source www.mapy.cz).

Fig. 4 Cut of the surveyed locality on an aerial image (source www.mapy.cz).

1.1 Geomorphological and geological conditions

According to the geomorphologic structure in the CR [Demek 1987], the area of operations belongs to the province of Central European Lowland, system of Central Poland Lowland, subsystem of Silesian Lowland, unit of Opavian Upland, sub-unit Poopavská Lowland, district of Opava-Moravice flood plain. It is an elongated plane on Pleistocene and Holocene sediments, which is formed by a flood plain with peculiar free meanders of the Opava River.

The altitude of the location is about 220 to 230 m a.s.l.

The area of operations is situated on the transition from a flood-plain terrace of the Opava River to a gentle slope with exposure to the east. According to the geological map of Quaternary surface deposits 1: 25 000, sheet M-34-73-Ad Hlučín, the Quaternary sediments are built by secondary loess the thickness of which is up to 2 m. Upwards the slope, the secondary loess usually loses its thickness and is represented by slope loams - by deluvia and deluvio-fluvial washes (Fig. 2).

In the area of the station, anthropogenic deposits are significantly applied - the body of the railway embankment.

The Pre-Quaternary bedrock in the area of operations is built by Paleozoic sedimentary rocks (Lower Carboniferous) rated among the so-called Kyjovice Member (Viseán stratigraphic level) [Mísař 1983]. From a lithological point of view, these are mainly pelitic sediments (shale), here and there with fine-grained psammitic greywacke layers. In the near-surface parts there are intensely weathered to decomposed rocks passing into sandy-loamy eluvia.

1.2 Stability conditions and undermining

In the area of operations, no active or potentially dangerous slope deformations are registered according to the Czech Geological Survey - Geofond CR Landslide Database.

The area is not affected by mining activities. According to CGS-Geofond, the location is not in an undermined area and there are no registered old mine workings (www.geofond.cz).

1.3 Hydrological and hydrogeological conditions

The area of operations is drained by the Opava River. The territory thus falls within the main stream basin of the Odra River (first-order basin). In terms of a detailed breakdown, the area in question is part of the sub-basin of IV order with the number of hydrological order 2-02-03-019 (www.heis.vuv.cz).

In terms of hydrogeological zoning, the area falls within the broader surroundings of the area of interest into the zone 6611 - Kulm, Nízký Jeseník in the Oder River basin.

Natural underground water of the area is bound to a water-bearing fissure system of Lower Carboniferous shale and greywacke.

With regard to the thickness and granulometry of anthropogenic deposits, the migration and infiltration of rain waters in these materials (intrinsic permeability) as well as the emergence of local, discontinuous, sporadic shallow sub-surface aquifers occur.

1.4 Building structure of the Jilešovice station

The railway track Ostrava-Svinov - Opava construction started on 20 August 1853. The route consisted in total of 15 archs and 16 straight lines, and its total length was 28,118 km. The total length involved 24.8 km of embankments and 2.84 km of cuts. There were 65 bridges and gates on the route; the structures of bridges were mostly of stone, rarely iron. The largest bridge was built across the Moravice River and consisted of 3 fields per 6 fathoms (11.37 metres).

On 27 October 1855, the first steam locomotive Neptun arrived to Opava on still not fully completed track and a loading test of the bridge across the Moravice River was performed. Officially, the track was opened on 17 December 1855, when at about half past four in the afternoon a festive train came to Opava from Vienna.

Since the beginning of operation, there have been just a single intermediate station in Háj and stops in Dvořisko-Štítina and Komárov on the track. At that time, the only railway siding was on the track that led from the station Háj to the local sugar mill built in 1855. In 1857, a stop Děhylov-Hlučín was added (since the 90s of the last century a loading point as well), the stop Dvořisko-Štítina was extended to a stop and a loading point as of 15 October 1893, and in the period before the creation of Czechoslovakia also the Jilešovice stop was established in 1913 [Štefek].

The composition of material of the historical embankment of the railway track in Jilešovice is not known. The embankment was naturally sloped. Within the reconstruction a bridge was newly built over a local road and the embankment was secured by supporting walls (Figs. 5 and 8). After the reconstruction was completed a deformation of the platform surface occurred (Figs. 6 and 7).

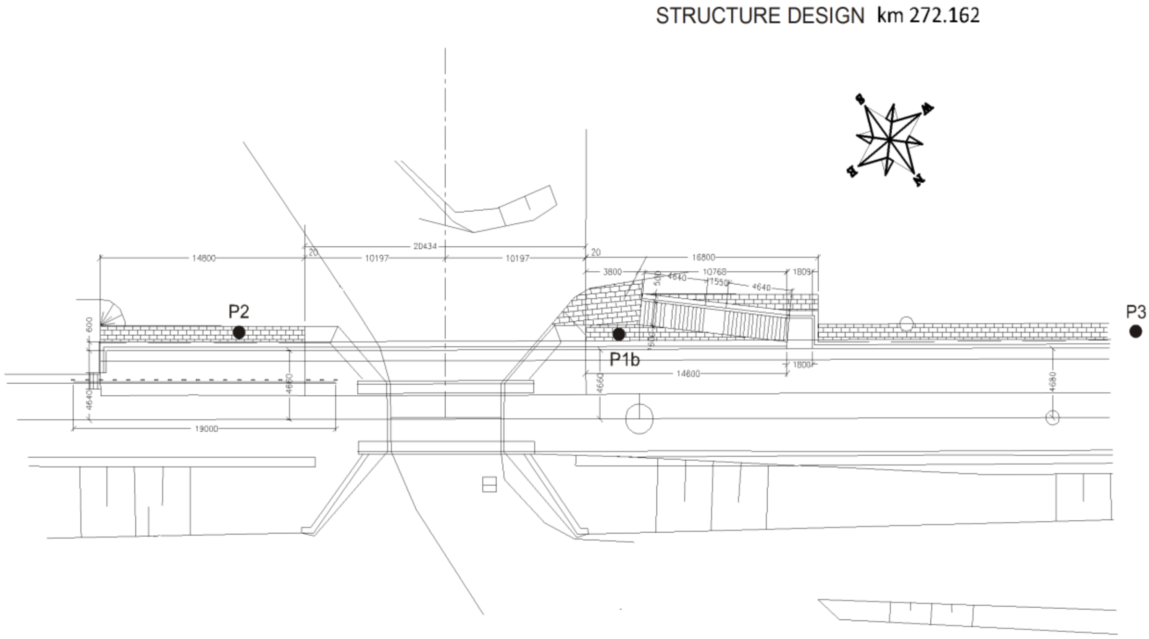

Fig.5 Ground plan of the embankment, bridge and the platform at the station of Jilešovice with the indication of positions of performed penetration probes P1b, P2 and P3 according to the documentation of Minova Bohemia s.r.o.

Fig. 6 View in the longitudinal axis of the platform with visible deformations. Photo A. Poláček.

Fig. 7 Detail of the platform surface deformation at the interface between interlocking pavers and concrete panels. Photo A. Poláček.

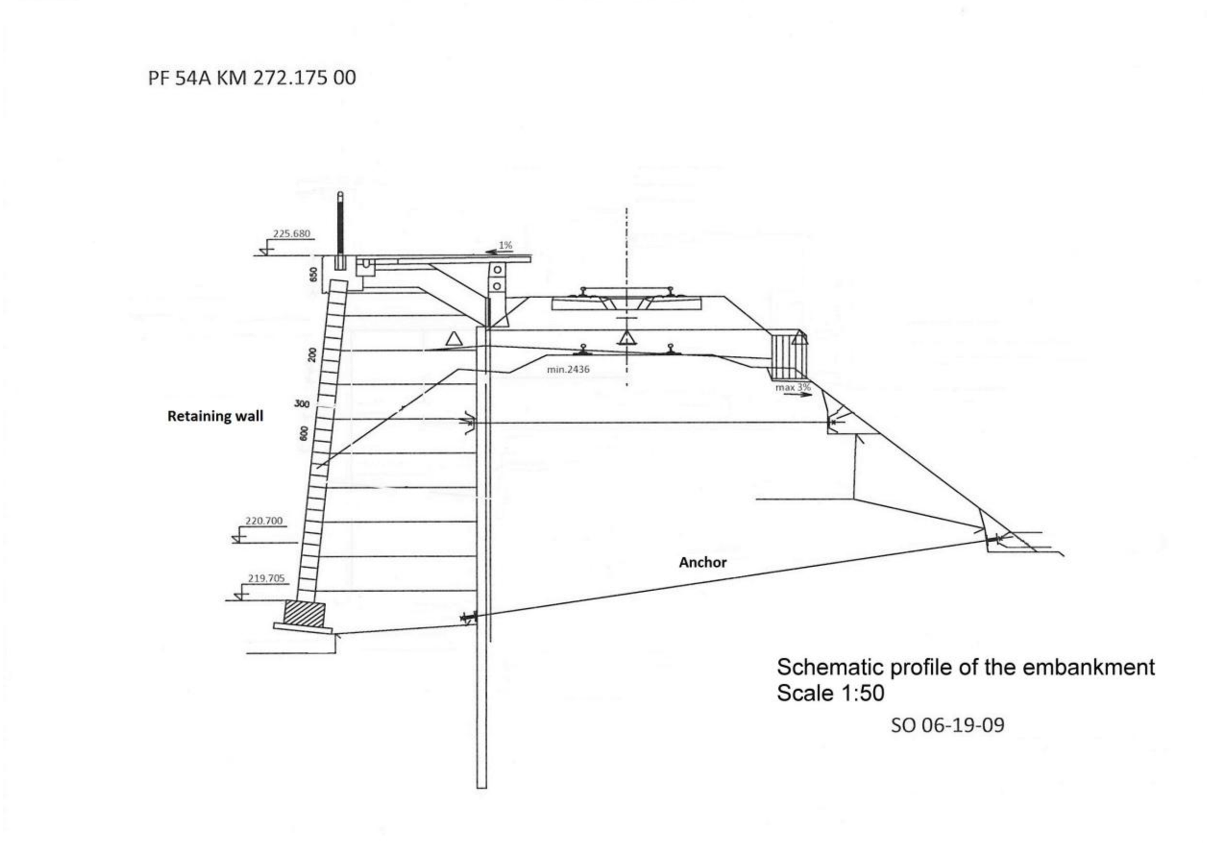

Fig. 8 Cross section of the embankment body after the reconstruction according to the documentation of Minova Bohemia s.r.o.

2 METHODOLOGY OF STUDY

Within the survey, the measurement was conducted in relation to the P1b, P2, and P3 penetration probes, by the technique of dynamic penetration using an georadar (GPR - Ground Penetrating Radar), aiming at verifying the quality of the platform ground at the station of Jilešovice continuously in the longitudinal profile.

The application of GPR as a survey method must always be properly considered with regard to the nature of environment in which the measurements should be performed. For example, [Lucius et al. 2007] dealt with the description of restrictions or limits in GPR applications, clearly demonstrating that GPR measurements are locally specific. Electrical conductivity of bedrock is the main limiting factor of the depth range of the GPR survey method. The depth of survey can be extremely limited (often for less than 1m), if the bedrock conductivity is high (more than 30 to 40 mS/m). This may occur for example in some clayey soils. In case of the presence of conductive layers or lenses within the measured bedrock, the electromagnetic waves will be attenuated and the GPR measurement will not be able to "see" behind them. Another limiting factor of the measurement is the scattering of radar waves on large objects such as boulders. This effect can be minimized using low-frequency antennas. Finally, a constraint can be a little contrast in permittivity or conductivity between the potentially surveyed subject and the material in its vicinity. For the proper orientation of radar waves transmitted into the ground, the antenna must remain in close contact with the ground surface. Therefore, the terrain surface must be even without obstacles such as tree trunks, boulders, etc.

The application of GPR in surveying the embankment and bedrock material of railway tracks is discussed in professional works such as [Hugenschmidt 2000] and [Loizos et al. 2007], where not only the benefit of this indirect technology is analyzed, but also the problems associated with measurements especially in the area of railway stations. The GPR method based on transmitting and receiving electromagnetic waves is very sensitive to interferences of the environment created by electromagnetic fields induced by electric wires under high voltage or metal wires in general, affecting the propagation of electromagnetic waves from the transmitting antenna to the receiver. This can be eliminated by the choice of proper antennas for measurements. In environments with anticipated signal interference, shielded antennas should be used. On railway tracks, with regard to the need to show the environment indirectly to a depth in the order of metres, high-frequency antennas with frequencies in hundreds of MHz and a short wavelength of propagated electromagnetic waves should be used.

During the survey at the Ješovice station the GPR set by the Swedish producer Mala was used. The set contained antenna systems of 500 MHz and 250 MHz. Both antenna systems are designed to be shielded against electromagnetic interference from outside influences. As a control unit the RAMAC Pro EX was used, then the display unit View XV11. For the measurements the set with the shielded 500 MHz antenna was first used, then the control measurements were performed using the shielded 250 MHz antenna.

The measurements were performed in three mutually parallel profiles, spaced 80 cm. After the initial assessment of measured data one of the profiles measured by the set with the shielded 250 MHz antenna marked as PRad1, in Fig. 9 first left, was then selected for further interpretation.

During the measurements, the most important was to see to eliminate interference caused by electromagnetic fields from surroundings, for example - not to measure during the passage of an electric train through the station or to track the distance of the antenna system from electrical conductors in the vicinity.

To evaluate the data in the form of radargrams, the RadExplorer 1.41 software was used.

Fig. 9 Schematic representation of the directions of 3 parallel radar profiles, spaced 80 cm (used antennas with a frequency of 250 MHz and 500 MHz). Photo A. Poláček.

3 DISCUSSIONS OF MEASUREMENT RESULTS

The measured data displayed in the form of radargrams was not of the same quality. When measured by the 500 MHz antenna system, the vertical profile was surveyed into a depth of 6m with a higher resolution of detail, but with a larger wave scattering on the embankment layers. When using the 250 MHz antenna system, the depth of the signal range was 12 m, and the basic structures, or the interface between the original embankment and the new material used to repair the embankment after the construction of the new bridge over an local road (interface marked by a purple colour in Fig 10) were more distinct. When evaluating the GPR measurements and the dynamic penetration measurements made by the firm UNIGEO, a.s., an agreement occurred in the interpretation in the vicinity of the right abutment (see Fig. 10), where a sharp drop in resistance on the tip at a depth of 5.5 m to 6 m was verified by penetration, as well as the GPR measurement recorded a change in environmental quality. This can be explained by saturation of porous embankment material system by water, which also causes a change in mechanical properties of this material. Based on the survey, the embankment material may be divided into two completely different material layers. The top layer is significantly more coarse-grained. Sudden changes in the interface between the two layers of the embankment (in Fig. 10 marked in yellow), in the right of the image, are not caused by the different quality of the material in the embankment, but by the interference of surroundings during the measurements (proximity of steel columns of electric traction lines). The interference was manifested more markedly in measurements by the 250 MHz antenna system than when using the 500 MHz antenna system.

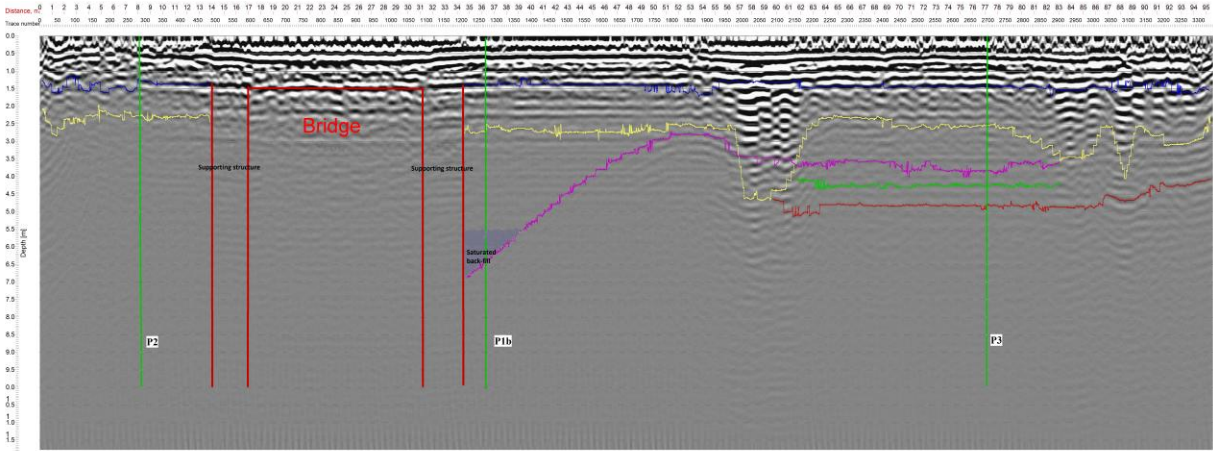

Fig. 10 Longitudinal section through the embankment (95 m) to a depth of 12 m interpreted in the radargram including the positions of penetration probes P1b, P2, P3.

4 CONCLUSIONS

The civil engineering works carried out as the reconstruction of existing building objects can be difficult to predict in terms of their behaviour over time. The basis of this behaviour of building structures is an increase in heterogeneity of materials by using new embankment materials in anthropogenic layers or a change in the method of ensuring the embankment stability. This can result in deformations of the embankment or related structures. The platform of the station in Jilešovice underwent structural modifications within the reconstruction of the railway track from Ostrava to Opava. The largest building intervention was the reconstruction of an old bridge and adjacent embankment bodies now in addition secured due to stability by gabion baskets instead of the original natural grading. The GPR measurements in conjunction with other survey techniques contributed to find the causes of the platform deformation. The place of increased saturation by water of the pore system of the embankment material and thus related changes in mechanical properties of the material tested by the dynamic penetration were clearly demonstrated. The heterogeneity of the embankment material was proven as well. By the GPR measurements in contrary to the point survey techniques the material beds can be verified in selected continuous profiles, led through the examined object or geological environment.

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RESUMÉ

Inženýrské stavby realizované jako rekonstrukce stávajících stavebních objektů mohou být z hlediska jejich chování v čase obtížně predikovatelné. Heterogenita materiálů přirozeného i antropogenního původu může vést následně buď k deformacím, nebo až k porušení staticky ohrožujícímu existenci stavební konstrukce. Nástupiště nádraží v Jilešovicích prošlo stavebními úpravami v rámci rekonstrukce trati ČD z Ostravy do Opavy. Největším stavebním zásahem byla rekonstrukce starého mostu a přilehlých násypových těles navíc v současnosti zajištěných stabilitně gabionovými koši místo původního přirozeného svahování. Na rekonstruovaném objektu se po krátkém čase jeho užívání projevily závažné deformace, o kterých nebylo známo, co je způsobilo a jaký bude jejich vývoj v čase. V rámci návrhu průzkumných technik, schopných rychle a efektivně odhalit příčiny porušení byl zařazen průzkum georadarem-GPR (Ground penetrating radar), který jako nepřímá, nedestruktivní metoda průzkumu velmi rychle přispěl k objasnění příčin porušování stavebních konstrukcí.

Využití geofyzikálních, nepřímých průzkumných metod je zejména u liniových inženýrských staveb velkou výhodou, neboť mohou poskytnout spojitý obraz o zkoumaném prostředí. V poslední době je zejména měření pomocí GPR často aplikováno, ale je nutno si uvědomovat i jeho omezení vyplývající z fyzikální podstaty tohoto měření a potenciálních rušivých vlivů okolí.

Měření GPR v součinnosti s ostatními průzkumnými technikami přispělo k nalezení příčin deformací nástupiště. Jasně bylo prokázáno místo zvýšené saturace pórového systému násypového materiálu vodou a s tím související změny mechanických vlastností materiálu ověřené dynamickou penetrací. Dále byla prokázána heterogenita násypového materiálu. Měřením GPR na rozdíl od bodových průzkumných metod je možno tyto materiálové vrstvy ověřit ve zvolených kontinuálních profilech, vedených přes zkoumaný objekt či horninové prostředí.