# Design and monitoring of EPS embankment on D1 near Ivanovice in the Czech Republic

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**Abstract**

*The D1 motorway east of Brno in South Moravia crosses near Ivanovice a small valley with the Runza stream. The area is marshy with organic and muddy deposits reaching more than 8 m deep. Vertical alignment of the road was 16 m above the valley bottom and required a high fill at both sides of the bridge. As the improvement of subsoil by vertical drains or gravel piers would not eliminate very high settlement of the embankment of natural soil, the lightweight fill with EPS blocks was proposed as a viable alternative. As this type of construction had never been used before on highways in the country a detailed monitoring of the construction was realised both during and after the EPS fill construction. The building took place in 2003 to 2005.*

## SUBSOIL CONDITIONS AND DESIGN CONSIDERATIONS

The central part of the valley is filled with fluvial deposits represented by soft silty clay soil of 4 to 6 m thickness. Stiff highly plastic neogene clay is beneath the fluvial deposit. The valley sides are covered by loess soil reaching 8 m thickness overlying soft to stiff colluvial-fluvial silty clay soil. Underground water table corresponds with free water level in the stream, i.e. approx. 1 m below ground level, however at the upper rim of the valley it is 8 m deep.

Originally proposed three span bridge supported by bored large diameter piles was later changed to one span 15 m wide filled spandrel bridge (partially soil covered deck bridge) with spread footings placed within the embankment. The max. fill height was 14 m. Stability analysis has proven critical shear zones at the toe of the fill particularly the sides oriented towards the centre of the valley. Without additional measures the originally proposed fill did not meet the required stability level. Also the settlement calculation which considered natural soil fill had shown results between 0.6 and 0.8 m. The contact pressure of the spread footings of the filled spandrel bridge was too high (reaching 600 kPa) which caused stability problems at the embankment side slope even if a gravel layer was placed under the footings.

All these analysis have led the designer to consider an alternative solution based on lightweight fill. After studying various arrangements the final solution of the embankment in the approach zones to the bridge was based on 8 m natural soil fill and 6 m EPS fill, total height of the embankment was 14 m. Between the bridge slab and the pavement construction there was 2.75 m of the EPS blocks. The lower part of the embankment of the natural soil oriented towards the valley centre was reinforced with polyester geotextiles 400/50 kN/m in 0.5 m vertical spacing and reaching 10 m in horizontal distance (see longitudinal cross section in Figure. 1). The reinforced block made of sandy gravel served as the foundation for spread footing of the deck bridge. In addition to the above described measures the soft subsoil under the reinforced embankment was improved by the system of gravel piers 0.8 m in diameter, 6.5 m deep in 2 x 2 m span. The remaining subsoil below the embankment in the approach zone to the bridge was improved by 0.4 m diameter gravel piers 10 m deep in 3.4 m span. Newly calculated settlement with the EPS fill should not exceed 0.4 m.

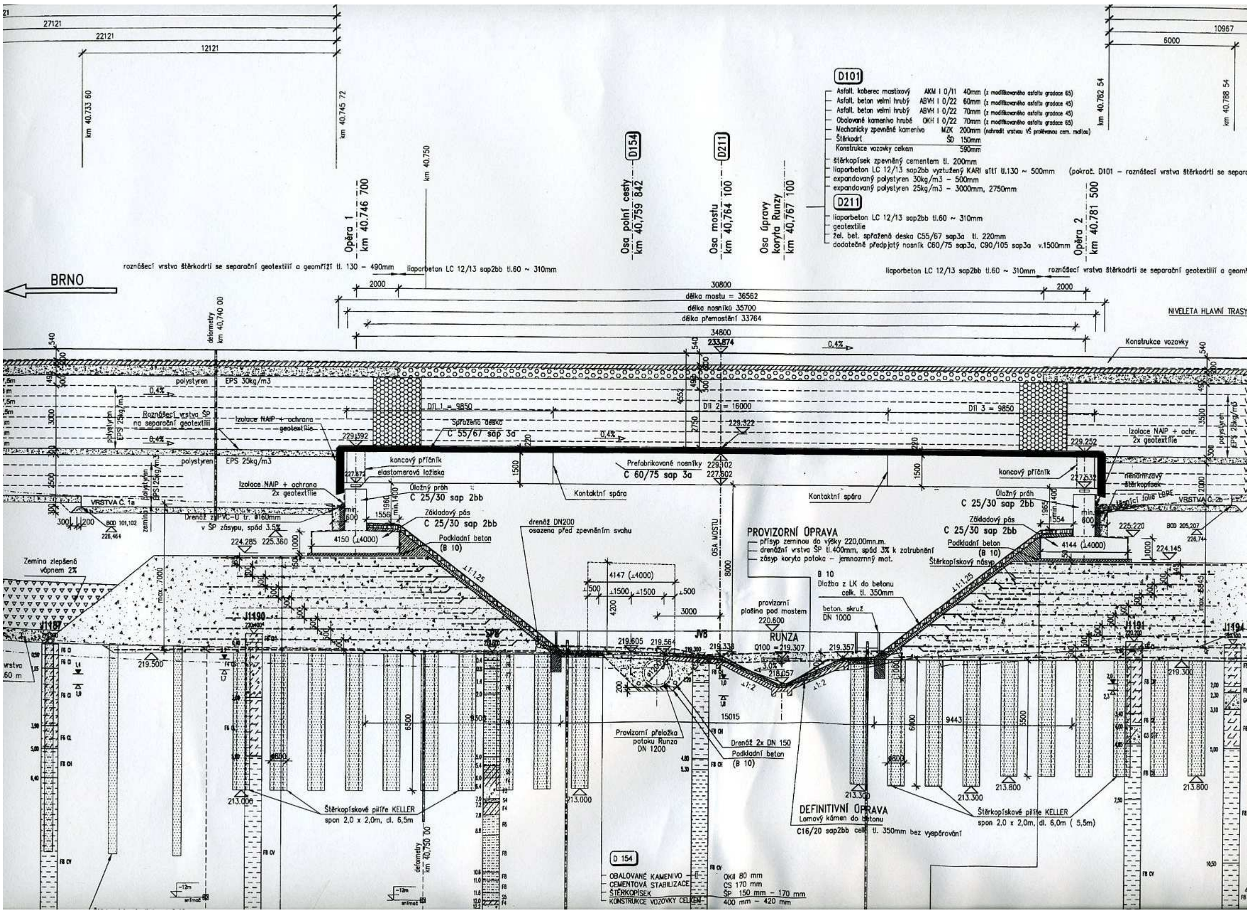


Figure 1 Runza filled spandrel bridge. Longitudinal cross section.

## EPS FILL DESIGN

At the time of the design there was no specification or standard for EPS fill. The design was prepared based on the Swedish specification [1], [2] and consultations with foreign experts. Later the Czech technical specification TP 198 was prepared [3] as well as the proposal of the European standard prEN 14933 [4].
The following EPS blocks were considered in the design (Table 1).

Table 1

| Min. volume weight (kg/m$^3$) | Min. stress at $\varepsilon$ = 10 % strain (kPa) | Remarks |
|---|---|---|
| 20 | 100 | Less stressed parts of the embankment |
| 25 | 150 | Common embankment |
| 30 | 200 | Layers under the pavement |

The blocks of 2 x 4 x 0.5 m were laid in a brickwork pattern with overlapping joints by 0.5 m in the next layer. The EPS blocks were fixed in every horizontal layer by the steel saw toothed pegs (Bulldog 104 mm diameter). The cross section of the arrangement of the EPS blocks in the embankment is on the Figure 2. Cover of the EPS fill side slopes was realised with loess soil mixed with 2 % of hot lime.

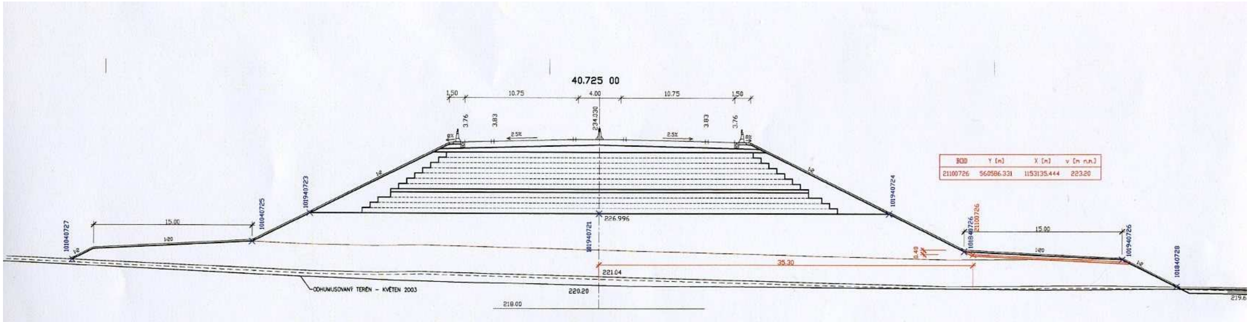



Figure 2 Cross section of the EPS embankment

**GEOTECHNICAL MONITORING**

The geotechnical monitoring system included:

- measurement of settlement of the subsoil by hydrostatic methods in two cross sections under the embankment (one profile at each abutment)
- measurement of pore pressures under the central part of the embankment at 3 depth levels (3m, 12 m and 20 m), 6 cells in total
- inclinometric measurement in 4 boreholes near the toe of the fill
- compression of the EPS layers by deformetric cells

The settlement was measured in regular intervals as the construction proceeded. Maximum settlement registered after the completion of the embankment was 420 mm and was a little bit over predicted 400 mm. Pore pressures generated during the construction has never exceeded values more than 30 kPa over the basic level, which corresponded to average level of the underground water table.

Much more concern was on the stability of the side slopes oriented towards the Runza stream. All inclinometric boreholes indicated mobilisation of shear at 2 m depth (see figure 3), in one borehole even at 7 m depth.

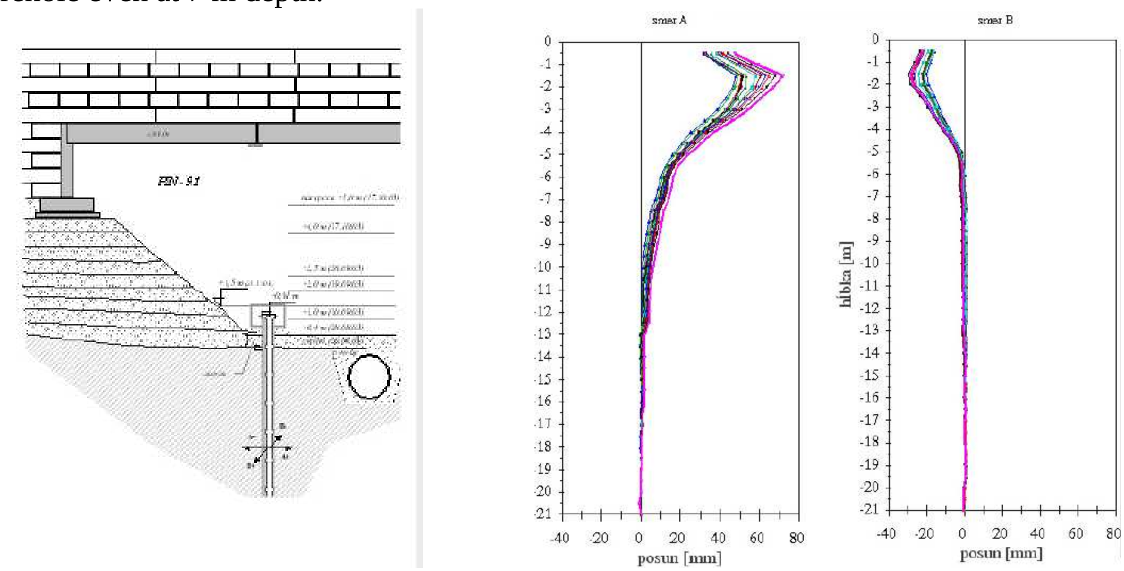



Figure 3 Shear movements at 2 m depth below the toe of the embankment

The spreading of the shear zone was controlled with backfill at the toe of the embankment. One of the key tasks was the determination of the compression of EPS blocks in the embankment.

Measurement cells were installed in 4 profiles at different depth levels between the EPS blocks. Scheme is in the figure 4.

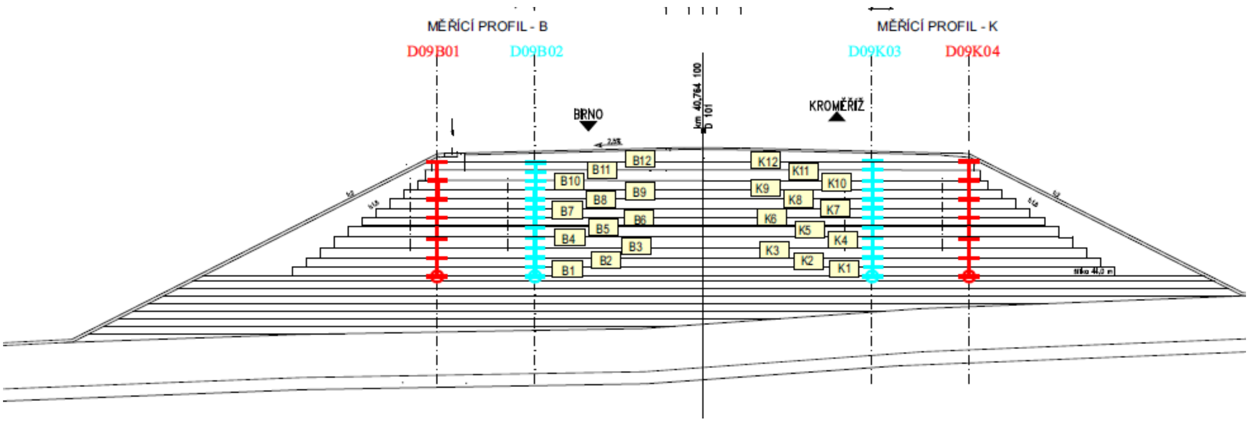
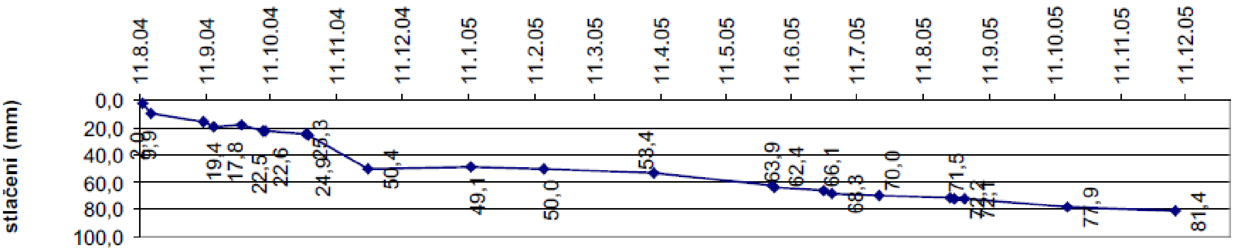



Figure 4 Location of cells for measurement of compression of EPS fill

Compression of EPS blocks followed immediately with the embankment construction. Evaluating the data from all cells we have found out that the compression of EPS blocks varied between 4 and 12 mm, i.e. 0.8 to 2.4 % of the thickness of the block. Total compression of 6 m high EPS fill with the concrete slab on the top of the EPS fill and pavement in place reached 81.4 mm in the left (B) side of the fill and 83.6 mm in the right (K) side. Summary time – compression curve of the B profile is in the figure 5. Average compression of the EPS fill was 1.4 % of the total 6 m height. This was far below the required max. 2 % value of compression. Compression of 2 % was recommended as the upper limit for EPS blocks as higher values may lead to breaking of EPS pearls in the compressed blocks.




| | 11.8.04 | 12.8.04 | 16.8.04 | 9.9.04 | 14.9.04 | 27.9.04 | 7.10.04 | 8.10.04 | 27.10.04 | 28.10.04 | 25.11.04 | 12.1.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Celkové stlačení (mm) | | 2,0 | 9,9 | 15,6 | 19,4 | 17,8 | 22,6 | 22,5 | 24,9 | 25,3 | 50,4 | 49,1 |

| | 15.2.05 | 7.4.05 | 1.6.05 | 2.6.05 | 25.6.05 | 29.6.05 | 21.7.05 | 23.8.05 | 25.8.05 | 30.8.05 | 17.10.05 | 6.12.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Celkové stlačení (mm) | 50,0 | 53,4 | 62,4 | 63,9 | 66,1 | 68,3 | 70,0 | 71,5 | 72,2 | 72,1 | 77,9 | 81,4 |

Figure 5 Summary time – compression curve of EPS blocks in the B profile of the embankment

## CONCLUSION

First EPS embankment in the highway construction was realised on D1 motorway in the SE Czech Republic in 2005. EPS solution was evaluated as the most economic way of crossing highly compressible fluvial deposits in the Runza valley by a 14 m high fill. French and Swedish experiences with these constructions were used as the base for design of the EPS embankment. Detailed geotechnical monitoring of subsoil settlement, shear movements inside the subsoil as well as pore pressures and compression of EPS blocks helped to understand the mechanism of this special fill. Comparison of predicted behaviour by both analytical and numerical models with the measured values has confirmed that correct models were used in the design. The motorway was opened to traffic 4 years ago and no defect on the EPS embankment has been observed.

## REFERENCES


1. Cellplast som lättfyllning i vägbankar. Vägverket, 1990 (in Swedish)
2. Lättfyllning i järnvagsbankar, Banverket, 2000 (in Swedish)
3. Technical Specification TP 198 Vylehčené násypy pozemních komunikací (Lightweight fills in road constructions), Ministry of transport Czech Republic, 2008 (in Czech)
4. prEN 14933 Thermal insulation and light weight fill products for civil engineering applications – factory made products of expanded polystyrene (EPS) – Specification