A R C H I W U M I N S T Y T U T U I N Ż Y N I E R I I L Ą D O W E J
Nr 12 ARCHIVES OF INSTITUTE OF CIVIL ENGINEERING 2012

THE (NONE)DEFORMATION OF THE BIGGEST MP200 ELLIPSE UNDER HIGH COVER

Tamás BELLA[*] ,Zoltán BRAUNMÜLLER[**]
[*]) MSc civil engineer, Magyar Aszfalt Kft., Győr, Hungary
[**]) MSc civil engineer, ViaCon Hungary Kft., Budapest, Hungary

Abstract

The biggest possible ordinary ellipse from the 200 x 55 mm corrugation with a span of 12,09 m was constructed in the South ofHungary in 2009. The corrugated steel structure was designed and built under the highway M60 with a cover of 4,59 m which is a very high cover related to the span. Longitudinal concrete ribs were used to increase the stiffness of the structure . The paper shows the steps of the structure's construction. Continuous measurement of the span and the displacements has been carried out, starting from the assembly phase, to the backfilling phase, but the monitoring was not finished with the handover of the highway. The structure is still being monitored today.. The paper presents the result of these measurements, vertical displacements of the big ellipse throughout 24 months and shows the importance of ensuring drainage of embankment.

Key words: ellipse, big span, high cover, vertical displacement, monitoring, drainage

1. INTRODUCTION

As Pécs became the cultural capital of Europe in 2010 the last part of the highway between the Hungarian capital Budapest and the city of Pécs had to be finished beginning of 2010. The general contractor of the whole project was a consortium of Colas Hungaria Zrt. and Magyar Aszfalt Kft. (the daughter company of Strabag AG). An underpass for dirt road and animal crossing had to be built as bridge No 271 on that M60 motorway section. The underpass is located in a deep valley, the motorway is placed on a 10-11 m high embankment over the structure. Soil conditions were not favorable under the structure, as there were thick cohesive clay and silt layers with poor water permeability.

2. DESIGN - CONSTRUCTION

2.1. Original design

A precast reinforced concrete portal was originally designed according to the tender documentation. According to geotechnical calculations the settlement was expected to be around 60-70 cm, but the bigger problem was to reach 90% of the consolidation which was planned for 10 years. That would have meant that huge (40-50 cm) unequal settlements are to be expected in pavement layers in the spring of 2010, but the concrete portal would behave as a rigid structure and these two reasons would have cause significant local damages in the wearing and binding course which, wpuld be unacceptable from the operator’s point of view. The conclusion of the contractor was that an intervention was necessary.

Figure 1. Original design scheme with precast reinforced concrete portal

2.2 New design

Magyar Aszfalt Kft., the contractor of that structure has convinced the Board of Roads to build a corrugated steel structure instead of the concrete bridge.

To speed up consolidation prefabricated vertical drains were used combined with pre-loading of embankment overfill and a 40 cm thick quarry-stone horizontal drainage blanket. These methods have helped to reach 90% of subsoil consolidation in 6 months. The use of a corrugated steel structure and the mentioned interventions regarding consolidation has brought an optimal result. There have been minimal deflections expected in the pavement layers and the construction period of the whole project has been shortened by 5-6 months.

Statical calculation was made according the Swedish Design Method [5]. The calculation has showed that with the use of longitudinal concrete stiffening beams the 12,09 m span ellipse with 7,0 mm thickness can take the live and dead loads from the 4,59 m cover. To ensure the stability of the end solutions - where the rings are not closed - concrete collars were designed and used.

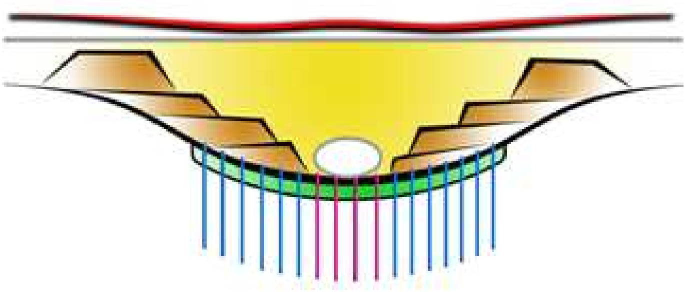

Figure 2. New design scheme with corrugated steel structure

2.3 Construction

The construction of the structure was made according to the above mentioned new design, it was started with the application of prefabricated vertical drains, and the 3 m overfill embankment and horizontal drainage blanket. After the biggest part of the consolidation was completed (ca. 25-30 cm – in practice only the half of the theoretically calculated consolidation was taking place) the overfill embankment was removed and a stage work area was established.

The assembly of the biggest possible MP200 structure with 12,09 m span was started in the summer of 2009. The assembly and the backfilling procedures had to be carried out very carefully, as the cover was 4,59 m thick – which was close to the limit at this corrugation and span. The steel structure has a skew angle of ca. 68 degrees to the road axis.

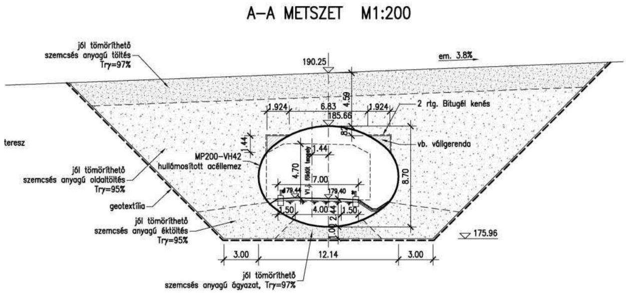

Figure 3. Cross section

The bottom (5 pcs), the side (3 pcs) and the top (5 pcs) plates were preassembled and lifted onto their final place by a crane. After the assembly of the bottom plates, the side plates on both sides were assembled – which, as we have realized after finishing the assembly, was not the best idea. The small problem was, that the side plates of the ellipse couldn't take their own weight and were deformed a bit to the outside – as there were no rings closed yet. After some first rings were closed the shape of the structure was forming back close to the designed span. Belts were used to reach the exact span, which has kept the designed shape of the structure until the backfilling has taken over that role.

Longitudinal reinforced concrete ribs were used to increase the stiffness of the structure.

When the level of the backfilling has reached the biggest span, the belts were not in use anymore, as the 97% Standard Proctor compacted backfilling has pushed the structure itself and its span started to decrease and the rise started to increase. According to the calculation, ca. 12 cm rise of the top axis of the structure was to be expected – in practice it was 15 cm. After the whole 4,59 m cover was laid over the bridge the top axis sank back exactly to its original level (-15 cm).

4. DEFORMATION

6 months after the assembly of the structure and 3 months after the pavement layers had been built cracks were noticed on the asphalt pavement along the axis of the road. The measurements have shown that the displacement of the crown (top axis) was 3 cm in the middle of the structure and 8 and 11 cm on both ends.

The problem causing the deformation was the yet not effective drainage of the rain /snow water coming from the pavement to the slope and the backfill, the undersized drainage ditches and the low roadside which could not drain rainwater coming from the 450 m long 2,5 + 3,5 lane highway section with an inclination of 4%. Test cores were drilled on 2x5 point to investigate the water content in the cover and the backfill. These test have shown that the cover and the backfill material at the middle of the structure are relatively dry compared to drill results close to the end of the structure. The cover and the backfill material were already saturated with water close to the slopes of the road embankment. This saturation has caused loosening of the compacted material which could move to the side at the ends of the structure much easier as there was no pressure from the other side. This is why we have had bigger displacements at the ends than in the middle of the structure where the material could not be moved so easy.

The tests have shown that there were no problems with the structure and the backfill , and only the road embankment (covering material) had to be dried and repaired. The covering soil was stabilized with jet-grouting walls on both ends of the embankment which was able to prevent more water coming into the road embankment. The jet-grouting wall, the dehydratation of the covering and surrounding soil and the finishing of the road drainage system have ensured that there was no more significant movement of the corrugated steel structure.

5. MONITORING

After the above mentioned reparation works a monitoring plan was made for continuously measuring the behavior and movements of the corrugated steel culvert for 24 months. The monitoring plan was made by the main contractor (Magyar Aszfalt Kft.) and was approved by all the parties included in the project (Consultant, Investor, and Customer).

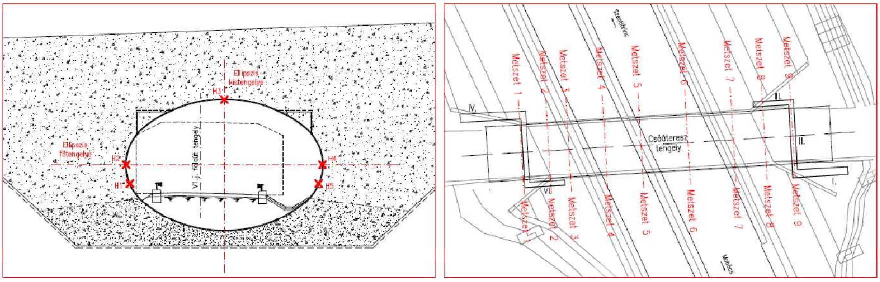

Figure 4. Measurement points (H1-H5) and cross sections (1-14)

After 18 months of monitoring (20 measurements) we can say that the corrugated steel structure is behaving according to our expectations. These expectations were based i.a. on investigations of large span corrugated steel structures in Canada [3] and Norway [4]. It is moving a little bit, but maximum displacements are much smaller than what the structure could stand without any intervention (2% of the span, which is ca. 250 mm).

The maximum horizontal displacement of the span (distance between point H2 and H4) was 22 mm in the last 18 months.

The maximum vertical displacement of the crown (point H3) was 33 mm. The result of all 20 measurements can be seen in Figure 6.

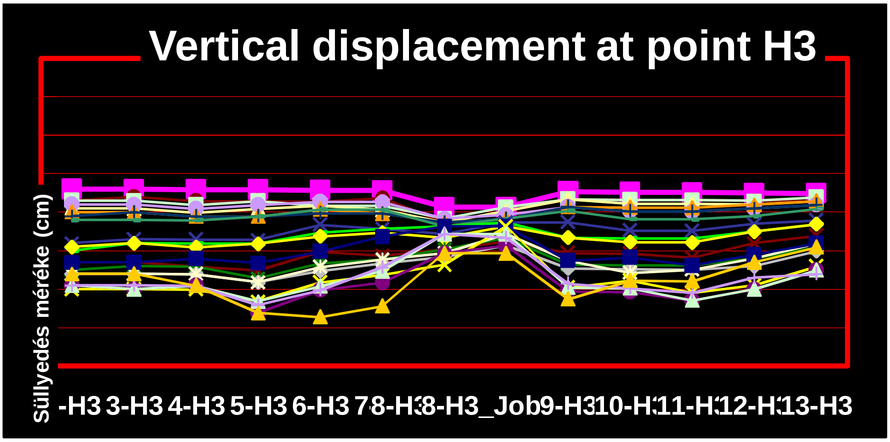

Figure 5. Vertical displacements in point H3 over the last 18 months

5. BENEFITS

These benefits could help the constructor convince the Board of Roads to go for the corrugated steel solution. The benefits of the corrugated steel structure over the originally designed precast reinforced concrete portal for the operator and the customer are:

- Draws the embankment environment into the load-bearing role, the structure moves together with the embankment (not an immovable rigid point, as the portal),
- Unnecessary warranty costs will not rise,
- The construction of the culvert structure could be completed in 2 months instead of 8 months, so the full completion time could be reduced to 6 months,
- The underpass could be handed over earlier to enable an earlier start of main road construction works,
- Easier to keep the tight deadline,
- The construction works are independent from weather conditions,
- Experience with maintenance is very positive: the steel structure is much less sensitive to failure, than reinforced concrete structures,
- Especially minor repairs and maintenance tasks caused by unequal settlement could be fixed without disturbing the traffic on the main carriage way,
- Significant deformation of the main carriage way is avoidable,
- Short term (concession maintenance period) and long term (designed life-expectancy) maintenance and operational costs are low,
- Sucha technical solution will not be completed, which accepts the risk of possible later deformation (failure) of the main carriage way,
- Minor repairs, operational tasks could be realised without disturbing the traffic of the main carriage way,
- The Benefit for the State = The Benefit for the Citizens, which means the benefit for the drivers and passengers travelling on the motorway. These benefits have to be considered not only after the 30 years of maintenance cycle, but within this period,
- If we are able to eliminate the settlements detailed in this presentation with the proposed technical solution, we can avoid the need of road closings and traffic redirections for binding course repairs caused by unequal settlements. A continuously operating makes citizens satisfied, with a benefit to the state,
- In case the above-mentioned road closings were necessary (within or beyond the 30 years maintenance period), such traffic redirections mean a potential safety risk for travelling citizens, who might be in danger unwillingly. Thanks to the use of a corrugated steel structure, these safety risks could be reduced.

Figure 6. The VH42 structure under highway M60

6. CONSLUSIONS

There are many lessons we can learn from this project:

- First of all: use deep corrugation (381x140 mm) instead of MP200 (200x55 mm) profiles, as those have nine times higher stiffness and are safer for structure with a span exceeding 10 m.
- Degree of compaction of the backfill material and the drainage have a significant impact on the stability of the structure. These should be designed and carried out very carefully.
- It is favorable to use 90 degree crossings, if that is not possible use non-90 degree end cut solutions to avoid the formation of a triangle at the junction of the culvert and the road embankment, where the water can heavily infiltrate into the backfill and can reduce the compaction level.
- The first full ring should be closed as soon as possible to be able to keep the designed shape at the assembly.
- The corrugated steel structure has proven that it can stick to limited displacements without any statical problem.
- A corrugated steel underpass with a span in exces of 12 m is working very well under the 4,59 m cover.

REFERENCES

1. Dr. Németh, Gy., Dr. Szepesházi, R. (2009): *Technical expertise about the application of the SuperCor structures at road construction projects*, Széchenyi István University, Győr.
2. Bella, T. (2008): *Proposed variation for bridge No 271. – construction of corrugated steel culvert crossing instead of precast reinforced concrete portal*, Presentation for the Hungarian Board of Roads, Győr.
3. Byrne, P. M., Srithar, T. and C. B. Kern. (1993): *Field Measurements and Analysis of Large - Diameter Flexible Culvert.* Canadian Geotechnical Journal, Vol. 30.
4. Vaslestad, J. (1990): *Soil Structures Interaction of Buried Culverts*. Department of Civil Engineering, the Norwegian Institute of Technology, Trondheim.
5. Pettersson L., Sundquist H., (2000), *Design of soil steel pipe bridges*, Technical report 58, Dept of bridge and structural engineering, KTH Stockholm.

Streszczenie

Największa dopuszczalna konstrukcja o kształcie elipsy z blachy o fali 200 x 55 mm i rozpiętości 12,09 m została zbudowana na południu Węgier w 2009 r. Konstrukcja z blachy falistej została wykonana pod autostradą M60 z naziomem wynoszącym 4,59 m, co stanowi bardzo dużą wartość naziomu w stosunku do rozpiętości. Do zwiększenia sztywności konstrukcji użyto wzdłużnych żeber betonowych. Praca przedstawia etapy budowy tej konstrukcji. Prowadzono ciągłe pomiary rozpiętości oraz przemieszczeń, rozpoczynając od fazy montażu, aż po fazę zasypywania, ale monitoring nie został zakończony w momencie oddania autostrady do użytku i trwa nadal. Praca przedstawia rezultaty tych pomiarów i pionowe przemieszczenia elipsy w okresie 24 miesięcy oraz omawia znaczenie zapewnienia odpowiedniego drenażu nasypu.

Słowa kluczowe: elipsa, duża rozpiętość, wysoki naziom, przemieszczenie pionowe, monitoring, drenaż