DEFORMATION CONTROL DURING ASSEMBLY AND BACKFILLING OF A CORRUGATED STEEL STRUCTURE, OSTRAVA, CZECH REPUBLIC

Adam CZEREPAK*, Jaromir ZOUHAR**
*) MSc. Eng., ViaCon Polska, Rydzyna, Poland
**) MSc. Eng., ViaCon CR, Olomunc, Czech Republic

Abstract

In 2009 in Ostrava, Czech Republic, a corrugated steel structure, pipe-arch profile, with span of 12.02m and rise of 9.89m was built. The structure has a corrugation profile of 200x55mm and steel thickness of 7.00mm. Above the structure a 6m-high cover was made. During backfilling the structure deformed above the expected value. It was necessary to remove a part of the backfilling material and backfill it again under deformation control. This paper will try to explain why this deformation occurred and will show the entire process of structure deformation, including stages of assembly, backfilling and operation, and under live load.

Key words: flexible soil-steel structure, backfilling, deformation.

1. INTRODUCTION

The authors present a corrugated steel structure with a corrugation profile of 200x55mm built in Ostrava in the Czech Republic in 2009. This structure was biult as a viaduct under a new road. Because of the necessary size of the clearance box a special custimozied profile had to be built, which was a bit larger than the standard that can be found in the technical documentation of European producers [1]. Vertical distance from the crown of the structure to the grade line level, the so-called cover depth, was 6m.

Pipe-arch profile was chosen (Figure 1 shows a cross section of this structure) with the following parameters:

- span 12.02m
- rise 9.89m
- bottom length 58.50m
- top length 48.00m.
- 7.00mm-thick plates
- 20 bolts/m. hot-dip galvanized bolts M20x50 and M20x45mm,

– plates galvanized acc. to EN ISO 1461:2009,
– steel S235JR.

Both sides of the structure were painted with epoxy painting 200 microns thickness coat acc. to EN ISO 12944. Plates were painted in factory, before assembly and bolts and nuts were painted after assembly on the site.

This structure was designed using Canadian Highway Bridge Design Code and Finite Element Method with the use of CandeCad software [2].

sand-gravel mix was planned to be used as a backfilling material, but waste rock from coal mines, which was hardly compactable, was used instead. During assembly and backfilling survey measurements were performed, starting from October 2009. It was continued after backfilling process and after installation of road layers and when the viaduct was opened for traffic. Measurements had been preformed until October 2011 to observe long-term deformation and settlement. This paper presents results of 2 years of observation and measurements.

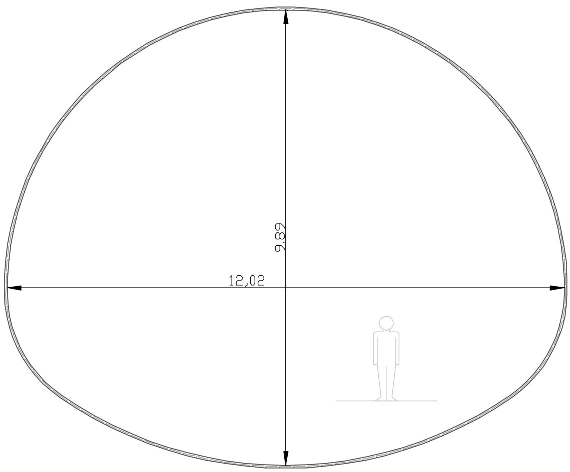

Fig. 1. Designed shape of MP200 profile used on viaduct in Ostrava

2. DEFORMATION DURING INSTALATION PROCESS

2.1. Assembly stage

Assembly took place during October and November 2009. Bedding under this structure was shaped to follow the shape of the bottom part of the steel profile (Figure 2). First measurement was done after assembly, registered as stage 0 (Figure 3). The shape of the structure after assembly was different than designed and deformation under dead load was observed. Deformation of the structure measured in the middle section is shown in Figure 4.

Fig. 2. Soil bedding preparation

Fig. 3. Structure after assembly, before backfilling

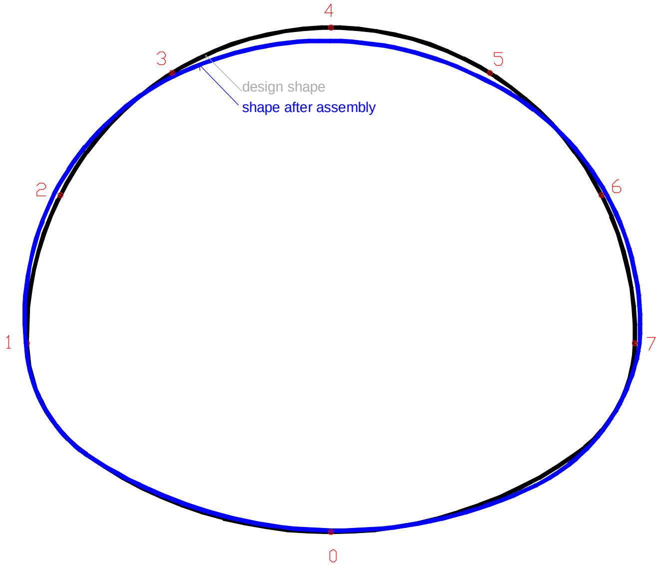

Fig. 4. Designed shape compared to the shape after assembly

Vertical displacement of measurement point no. 4 was 257mm.

2.2. Backfilling stage

Backfilling started in the middle of November. There were 23 stages of measurement starting form stage O just after assembly until stage 23 when embankment and road pavement were finished. The last few measurements were done when the structure and the road were ready and opened for traffic, to control deformation of the structure in the long run (table 1).

During backfilling a few problems occurred. When backfilling material reached 8,7m from the bottom excessively large and fast deformation of the structure was observed and the contractor stopped backfilling . Crown point picked up around 32cm which accounts for 3,3% of the structure's height. Commonly acceptable deformation is 2-3% of dimensions.

Excessive deformation occurred because the compaction equipment used by the contractor was too heavy and worked to close to the structure.

After analysis, a decision to remove 3m of backfilling was taken and the contractor started backfilling again from the level of 5,7m, using light-weight compaction equipment. Moreover, the contractor together with the designer decided to put ballast on the crown of the structure using concrete panels (Figure 5) [3].

Backfilling with light equipment and with ballast allowed to keep deformation and shape of structure under bigger control [3].

Fig. 5. Ballast with the use of concrete panels

The biggest deformation was observed when the backfilling level was 11m, 1.1m above the crown of the structure – stage 9. Measurement point no. 4 in the crown picked up 30cm compared to stage 0 and 38cm compared to the level of spring line. It was the biggest horizontal deformation in stage 9, measurements point 2 and 6 moved towards inside of structure by 20-22cm in relation to stage 0 and between stage 9 and 23 these points moved back towards the outside of the structure because of loads from cover and traffic. After stage 9 measurement point no. 4 in the crown descended 4cm compared to the spring line. Last three measurement stages, 21, 22 and 23 were done during the first year from the time when the road was opened for traffic. No deformation of the structure was observed, but in the measurement result we can see settlement of embankment together with the structure. During this year the shape of structure didn't change. In table 1 below we can observe rising of point no 4 for each stage. Crown rise was calculated as a change in the distance between the spring line (horizontal line between points 1 and 7 form figure 4). Figure 7 shows crown picking in relation to the spring line (values from table 1) and second line with crown picking with relation to stage 0 where results include settlement of embankment.

Horizontal displacement of spring line (points no. 1 and 7 in Figures 4 and 6) didn't change significantly (0-5cm towards the inside of structure) and in final stage 23 with relation to stage 0 ther was a 1-2cm difference only.

The final shape of the structure from stage 23, which was done in October 2011, is shown in Figure 6.

Table 1

date	stage	beckfilling level [m]	Crown peaking [mm]	comments
20-11-2009	stage 0	0,00	0,00	bottom of structure
23-11-2009	stage 1	4,50	62,00	
01-12-2009	stage 2	6,50	236,00	
08-12-2009	stage 3	8,20	317,00	
08-12-2009	-	8,70	no measuerment	removed backfill to the level of 5,7m
09-12-2009	stage 4	5,70	300,00	
10-12-2009	stage 5	5,70	268,00	after loading with concrete panels
12-12-2009	stage 6	7,40	256,00	
14-12-2009	stage 7	9,10	336,00	
15-12-2099	stage 8	9,90	364,00	crown level
17-12-2009	stage 9	11,00	379,00	
18-12-2009	stage 10	11,20	377,00	
22-12-2009	stage 11	11,20	371,00	
18-02-2010	stage 12	11,20	369,00	
08-03-2010	stage 13	13,40	364,00	
22-04-2010	stage 14	15,25	349,00	
13-05-2010	stage 15	15,40	348,00	
25-05-2010	stage 16	15,40	348,00	
14-06-2010	stage 17	15,40	346,00	bottom of road superlayers
26-07-2010	stage 18	15,90	339,00	
31-08-2010	stage 19	15,90	339,00	
23-10-2010	stage 20	16,00	339,00	construction finished
04-12-2010	traffic opening			
24-02-2011	stage 21	16,00	340,00	
12-05-2011	stage 22	16,00	340,00	
24-10-2011	stage 23	16,00	340,00	

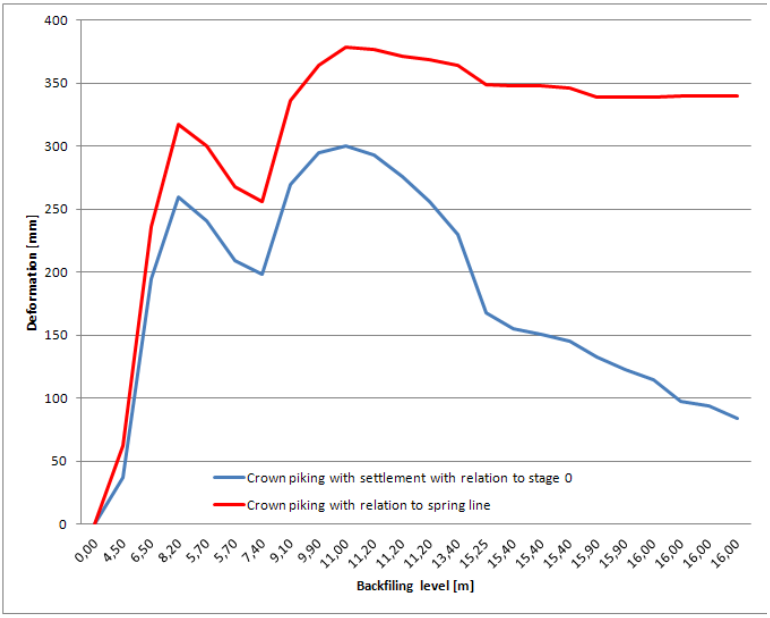

Fig. 6. Graph showing crown point picking during backfilling process and under live load

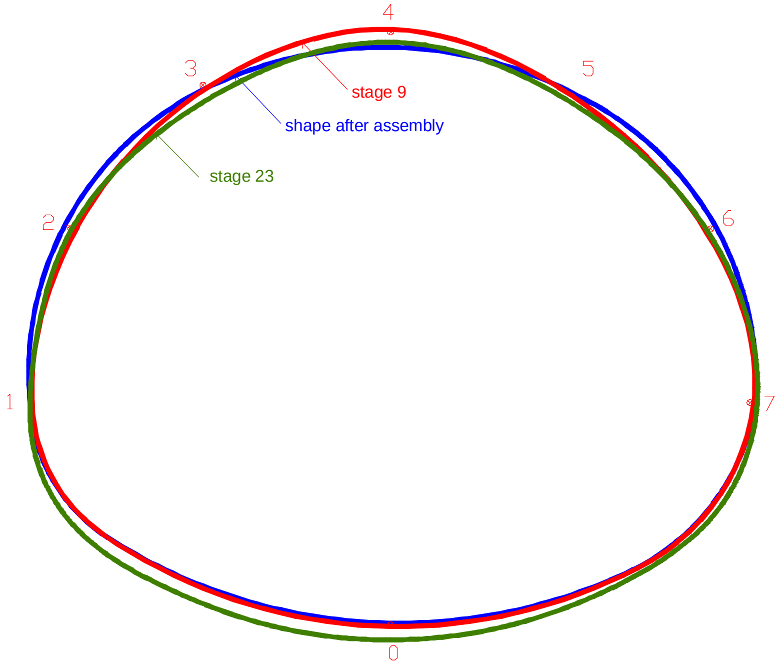

Fig. 7. Shapes comparison

3. CONCLUSIONS

Stresses analysis gave satisfactory results, proving that structure was designed properly. But deformation during installation was bigger than assumed in the design stage.

One of the reasons was the backfilling material used. It was completely different than the one which was included in static analysis. Second reason was the wrong method of backfilling in the beginning of the installation process done by contractor. Too heavy equipment was used too close to the structure. Another serious problem was the fact that the contractor did not give enough attention to deformation, although he received complete information from the designer supported by the manufacturer on how to control this deformation [4]. The contractor concentrated more on achieving required compaction than to control the shape of the structure. This example shows that shape and deformation control are of key importance in this type of structure. Required and acceptable deformation should be designed and presented before the installation stage and a contractor has to be obligated to fulfill this requirement.

It is clear that the backfilling process has significant influence on the shape of a structure and we are able to control this influence during backfilling.

The structure describedis one of the biggest flexible soil-steel structures installed with corrugation of 200x55mm in Europe.

Even though theoretical analysis shows stress levels below critical values, in the authors' opinion this size of a flexible soil-steel structure using corrugation profile of 200x55mm is close to the limit of safe installation.

Fig. 8. Photo of finished structure – view from north

Fig. 9. Photo of finished structure – view from south

REFERENCES

1. Leszek Janusz, Arkadiusz Madaj. *Engineered structures made of corrugated steel plate strustures. Design and construction*, WKŁ, Warsaw, Poland 2009.
2. Cande-Cad Pro SSIS Merketing International (Pty) Ltd. Copyright reserved 2002. Terms & Conditions. www.ssismint.com.
3. *Czesław Machelski*. Modeling of soil-steel flexible structures, Poland 2008.
4. *Jan Bernard Michalski*. Predicting of deformation in cross section of soil-steel flexible structure. "Obiekty Inżynierskie", Poland 2011.

Streszczenie

W 2009 r. w Ostrawie w Republice Czeskiej zbudowano konstrukcję ze stali falistej, o profilu rurowo-łukowym, o rozpiętości 12,02 m i wysokości 9,89 m. Konstrukcję cechuje profil fali 200x55mm i grubość blachy 7,00 mm. Wysokość naziomu konstrukcji wynosi 6 m. Podczas zasypywania odkształcenia konstrukcji przekroczyły oczekiwane wartości. Konieczne było usunięcie części zasypki i przeprowadzenie ponownego zasypywania z kontrolą odkształceń. W tej pracy podjęto próbę wyjaśnienia przyczyn odkształceń. Omówiono również cały proces odkształcania się konstrukcji na etapach montażu, zasypywania i eksploatacji, a także przy obciążeniu zmiennym.

Słowa kluczowe: podatna konstrukcja gruntowo-stalowa, zasypywanie, odkształcenia.