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

LONG TERM OBSERVATIONS OF A 3-SPAN HIGHWAY CORRUGATED STEEL BOX BRIDGE ON GNIEZNO BYPASS

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Abstract

The paper describes 5 years of behavior of a corrugated steel box 3 span bridge with a 14.1m span. The bridge is located on Gniezno by-pass in Poland. After few months of operation road surface over the bridge showed signs of ruts. An expertise was performed to evaluate causes of rut formation and provide suggestions for repair of the bridge. Deformations of road surface, structure and foundations wer measured.

Key words: corrugated steel box, measurements, deformations, long term, repair

1. INTRODUCTION

The first triple deep corrugated corrugated steel box bridge in Europe located on the bypass of Gniezno in Poland was built in 2004/2005. The aim of it was to cross the land with high thickness of organic soil and peat. There is also a local road and drainage ditch under the viaduct. These types of structures have been used in Europe since 2000 (Madaj et Janusz 2008).

The structure was designed to carry a class A live load acc. to PN–85/S–10030.

Each of the three boxes have following parameters:

- rise – 3.7 m,
- span – 14.075 m,
- bottom length – 23.56 m,
- skew angle – 90°,
- corrugation – 380 × 140 mm,
- plate thickness/rib thickness – 7.00 mm,
- bevels – 1:1.5,
- minimum cover : 1.0 m.

The corrosion protection was the 85 μm of zinc coating and additionally the inside of the structure was painted with 200 μm of epoxy. The structure was reinforced by means of additional ribs situated on the whole perimeter in the distance of 1143 mm.

Steel structures were designed to be backfilled with the use of 0-32 mm sand–gravel mix compacted to Standard Proctor density of minimum 97%.

As a preventive measure gainst rain water a layer of 1,5 mm HDPE geomembrane and 500g/m^2 non-woven has been placed over the structures.

Figure 1 Deep corrugated steel box grade separation under construction

Figure 2 Ready bridge directly after completion

The by-pass is a busy road carrying heavy trucks that are allowed on national roads in Poland. The bridge was built on very poor, soft, compressive soil (i.e. peats, silts, gyttja) reaching down to 10,4 m. The reinforced concrete foundations were placed on steel piles driven into the subsoil.

2. PERFORMANCE OF THE BRIDGE IN SERVICE

One year after the construction the road administration noticed signs of deflection of road surface located over the spans of the bridge. Moreover, settlement of soil at boths ends of the bridge abutment as well as underneath pile cappings were recorded. In order to limit further settlement of embakment near bridge abutments, concrete restraining beams placed on Larsensteel piles were built in 2006 (Figure 4 a). It turned out, settlement persisted despite this installation. Figure 4b shows space under capping of the piles after 6 years of performance

Figure 4 a) View of concrete beams placed on Larsen steel pilles (walls) at the bottom of the embakmant; b) view of space under pile capping

The deformations of the surface were reflected in the deformations of the steel bridge parapets which were installed alongside both ends of the bridge (Figure 5).

Figure 5 View of deformed parapets

Fig. 6 Outlet of drain with fine particles that are washed - out from the backfill

Fig. 7. Visible settlement of paved bevel end of the bridge

Further investigation of bridge performance show that deflections of road surface started also in front od and behind the ends of the bridge (not only above the spans). Visible settlement of paved bevel ends of the bridge were reported (Figure 7). Inspection of performance of drains that were placed over two middle supports showed that with water their were transporting also fine particles of soil (Figure 6). Further analysis showed that grain size as below the pore size of the openings in the geotextiles wrapped around the drains.

Backfill soils tests performed in 2005 showed that compaction of the backfill was sufficient (from 0.97 to 1.01 SP), however, the uniformity index U= 3.5 , was below recommended U=5. Moreover, the soil contained a lot of silty fraction, in the range from 1% to even 6% (grain size from 0.002 to 0.05 mm). This kind of soil is classified as susceptible to frost. All above mentioned defects contributed to a discomfort of passengers traveling, who felt as if spans were swiginging.

3. MEASUREMENTS

Since observations ofperformance brought some concern the wwner of the bridge, Polish Road Directorate ordered measurements of the bridge in selected points in order lear about measured deflections and the possible cause of the problem. The measurments started in September 2005 and continued until June 2010.

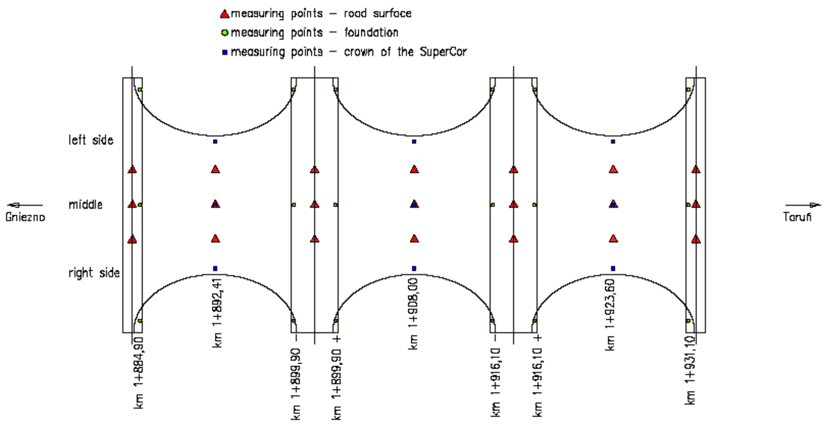

Fig. 8 Location of the masuring points

The measurements were performed in three elements of the bridge:
1. corrugated steel structure (crown)
2. concrete foundations (at the top of them)
3. road surface above the bridge

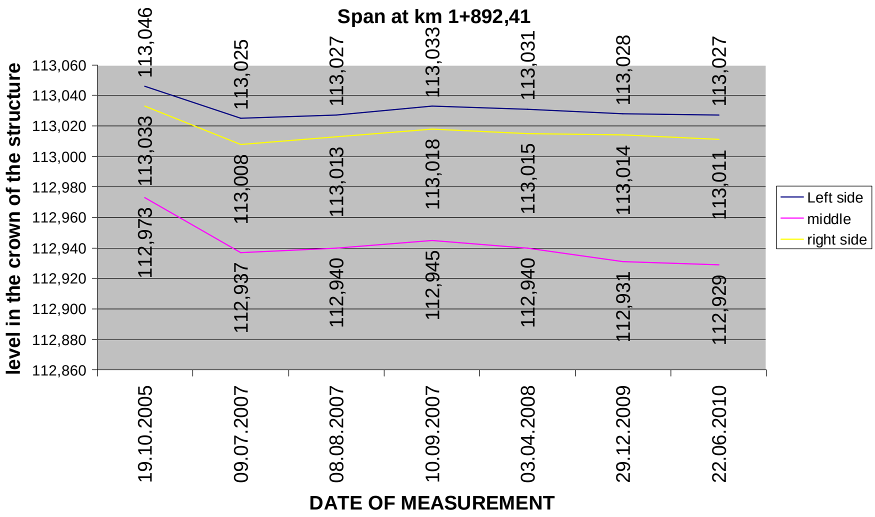

Fig. 9 Deflection measured in the crown of the corrugated steel structure in km 1+892,41

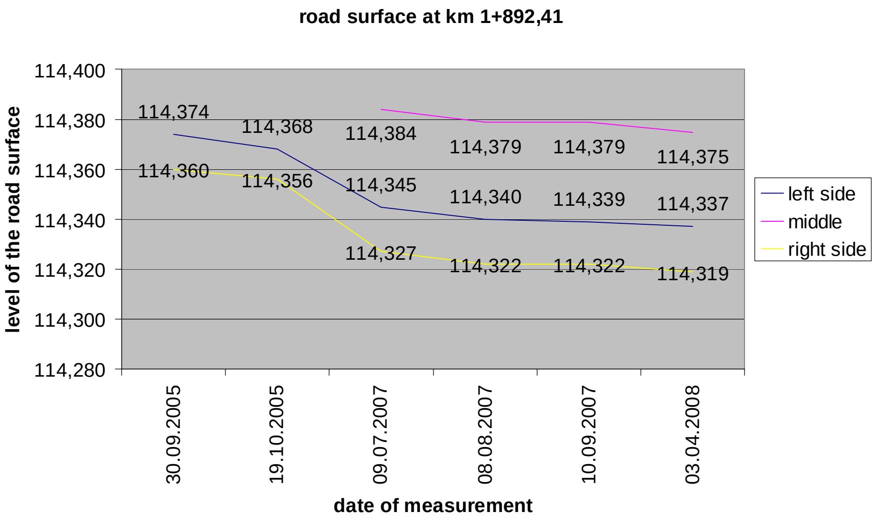

Fig. 10. Deflection of road surface measured in km 1+892,41

Changes between initial measurement and final measurement for asphalt road surface and crown of the span in left side (L), middle (S) and right side (P) locations were recorded. The below table shows maximum differences at km 1+892,41 (Table 1)

Table 1. Maximum changes of levels (deflections) of road surface and steel structure during measurement period

km	[m]	[m]	[m]
1+892,41	**L**	**S**	**P**
road	-0,052	-0,024	-0,064
structure	-0,034	-0,059	-0,037

3. DISCUSSION OF RESULTS AND CONCLUSIONS

From the results obtained from measurements one can observe that there has been some deflection of corrugated structures in the crown. Maximum level measured over 5 years was 59 mm, which is 42% of the allowed deflection (140 mm) (CHBDC). Deflection has basically stabilized from 2007 to 2010. Deflections of the road surface were mostly progressing from 2005 to 2007 and since then the incremental change was minor, finally reaching the maximum level of 49 mm in 2008. There was no direct correlation between deflection of the road surface and deflection of the crown of the structures e.g. in km 1+892,41 in location (S) the final change in road surface was -0,024 m and the crown deflected -0,059 m. Opposite observations relate to other measurement points. Basically, foundations have been very stable. This conclusion was presented also in an expertise by (Madaj, 2008). Other independent expertise by (Gryczmański et al., 2008) concludes that the main result of the road surface deflection is settlement of the of road embankment at the abutments of the bridge. The difference between deflection of road surface in measurements points was caused by behavior of asphalt under live load (point S is located at road centerline which is affected less by the wheels of moving vehicles). In 2008 the top layer of road surface over the bridge has been replaced as the first repair measure. Observations of the bridge behavior from that moment on don't show alarming results. The bridge performs well. Authors are convinced that one of the reasons is that the consolidation of the soil has occurred and no major settlements of the embakment has occured recently. Generally it is of importance when building such types of bridges to be especially careful with backfill and other surrounding soil that would contribute to soil-structure interaction in order to avoid problems during service.

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Streszczenie

Praca opisuje 5-letnie zachowanie trójprzęsłowego mostu skrzynkowego o rozpiętości 14,1 m. Most znajduje się na obwodnicy Gniezna w Polsce. Po kilku miesiącach użytkowania na powierzchni drogi nad mostem pojawiły się koleiny. Przeprowadzono badanie w celu oceny przyczyn powstawania kolein i przygotowania propozycji naprawy mostu. Dokonano pomiarów odkształceń powierzchni drogi, konstrukcji mostu oraz fundamentów.

Słowa kluczowe: skrzynki z blachy falistej, pomiary, odkształcenia, długi okres, naprawy