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 1 ARCHIVES OF INSTITUTE OF CIVIL ENGINEERING 2007

ELEMENTS OF THE DESIGN PROCESS OF THE FLEXIBLE STEEL ARCH OVER DOUBLE TRACK ELECTRIFIED RAILWAY

Piotr TOMALA*, Krzysztof MARKOWICZ**, Bogdan BRESCH***
*) MSc CEng, ViaCon Polska Sp. z o.o., 64-130 Rydzyna ul. Przemysłowa 6
**) MSc CEng., Mosty Katowice Sp. z o.o., 40-555 Katowice ul. Rolna 12
***)Ms CEng JacobsGibb (Polska) Sp. z o. o., 60-701 Poznań ul. Zachodnia 15

Abstract

This paper shows the elements of the design process of the flexible structure: deep corrugated steel arch over electrified railway line with a purpose of animal crossing. Procedures starting from the functional application program where all general conditions were showed through calculations to final design are described.

Keywords: Corrugated steel arch, design, animal crossing, electrified railway line, deep corrugation

1. INTRODUCTION

Due to increase of environmental awareness building of new animal crossings become more popular in engineering projects [1,2]. This challenge is referring also to railway lines which often collide with migratuion routes. Due to that Polish Railway Authority has commissioned a "design and build" project of two animal crossings located over double track electrified railway line E20 (Berlin-Poznan) to allow the migration of animals on the territory divided by this line.

General contractor had to ensure the complex design and build two animal overpasses over this line. Construction of crossing had to be executed without stopping a traffic on the line. The minimum width of the animal overpass (between antidazzling barier) was set to be 40 *m*. The design requirement was 100 years life time what had to be documented.

The construction sequence was a challenge due to restrictions related to traffic and safety. Both animal crossings are placed over the same railway line with a distance of 3,424 *km.* The requirement for construction called for parallel assembly of both structures at the same time. Another challenge was a very short construction time – approx. 21 days of assembly for both structures. The most difficult part of the construction is a railway traffic which would basically proceed during construction of the crossings.

In order to meet all above mentioned requirements deep corrugated long span structures have been used. The best shape that fited into adjoining terrain was low profile arch with span of 20 *m* placed on concrete footings.

The project is now at the execution stage and design documents have been approved for construction.

2. DESCRIPTION OF SOLUTION

The existing place has no restrictions except for trees around as shown in Figure 1. Both locations are surrounded by forest. The access roads have approx. 5 *km*.

Fig. 1. Location of one of the annimal crossing

The 20 *m* span arch structures placed on concrete footings were designed. The dimensions of railway clearance box cause that the SuperCor SCA-35 was used. Moreover, architectural form of single low profile arch excellent harmonizes with adjoining terrain. The maximum inclination of the terrain over the structures doesn't exceed 10%.

The basic dimensions of arch structure are:

- Span B=20,00 *m*
- Rise H=7,424 *m*
- Top radius is 13,93 *m*, side radius 4,43 *m*
- Height of cover h_c=1,4 *m*
- Skew 90º
- Plate thickness for barrel 7,0 *mm*
- Plate thickness for ribs 5,5 *mm*
- Live load "E" class[1]

Cross section of animal overpass is shown in Figure 2, longitudinal section is shown in Figure 3.

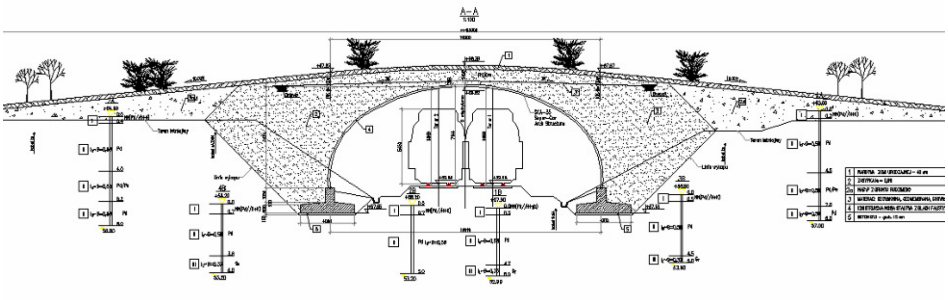

Fig. 2. Cross section

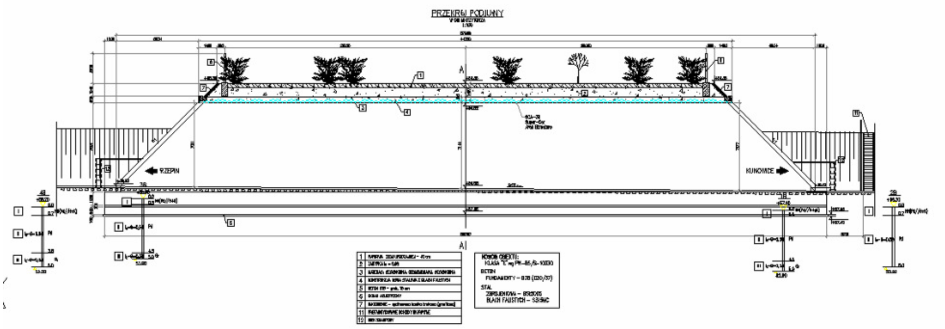

Fig. 3. Longitudinal section

Designed structures have a corrugation profile of 381x140 *mm*. They are reinforced with 5,5 *mm* plates ribs at 1524 *mm* c/c. Structures are protected by hot-dip galvanization with the minimum thickness of zinc layer of 85 *µm* acc. to EN ISO 1461:2000 what (together with 1 mm corrosion reserve) ensures required 100 years durability. It was documented by appropriate calculations.

[1] acc.to PN-85/S-100300 Obiekty mostowe. Obciążenia (4x60 *kN*)

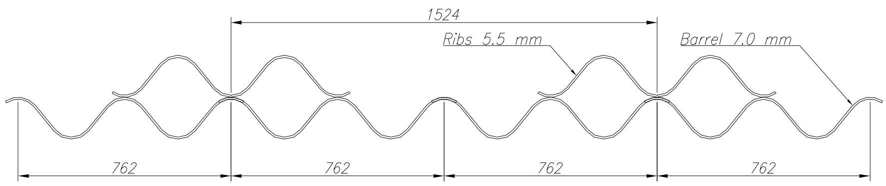

Fig. 4. Longitudinal section

One of these two structures has spread foundation, the second one, owning to poor soil conditions, on micro piles.

Minimum width of each overpass is 40 *m* in the middle section and it is increasing up to 100 *m* in the base (Figure 5). Inlet and outlet slopes are beveled 1:1 and steel collars are designed to reinforce inlet and outlet ends of the structures.

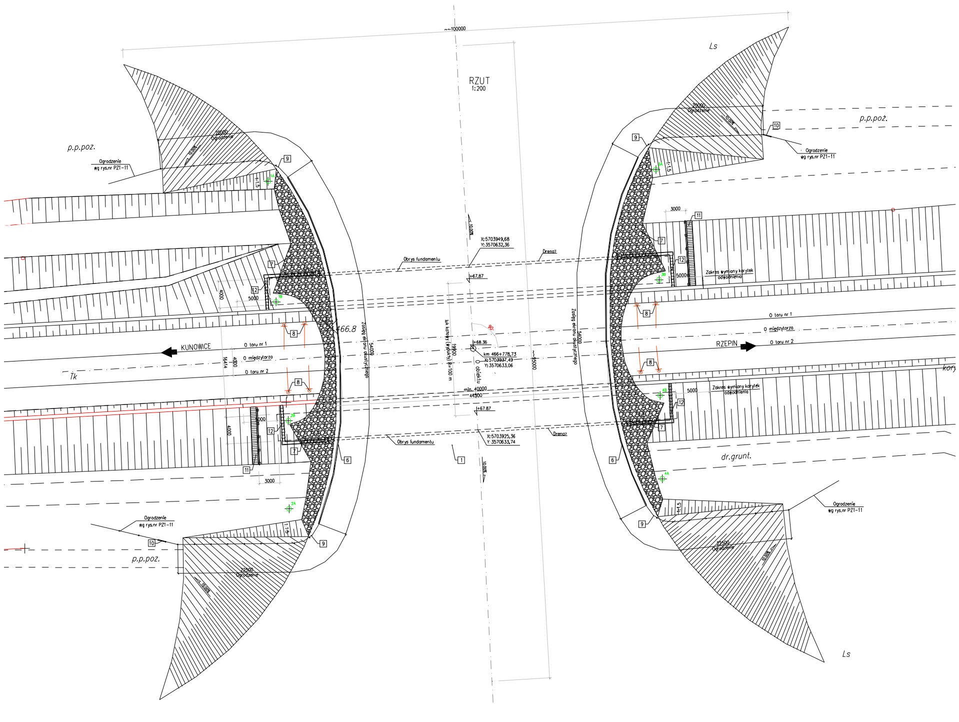

Fig. 5. Plan view

Structures will be backfiled using sand-gravel mix compacted to 98% Standard Proctor Density. Soil will be placed in 30 *cm* horizontal layers, taking into account symmetrical backfilling process. Difference of one layer only is acceptable. The top 40 *cm* of soil will be fertile soil to allow for existing of plants.

Accoustic screens, which are also antidazzling barier, are designed over the structure. Figure 3 and 4 show computer visualization of the overpasses.

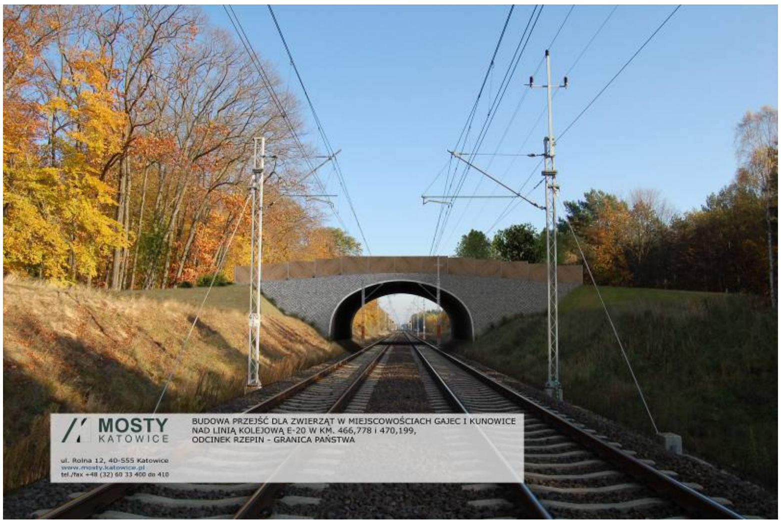

Fig. 6. Computer visualization

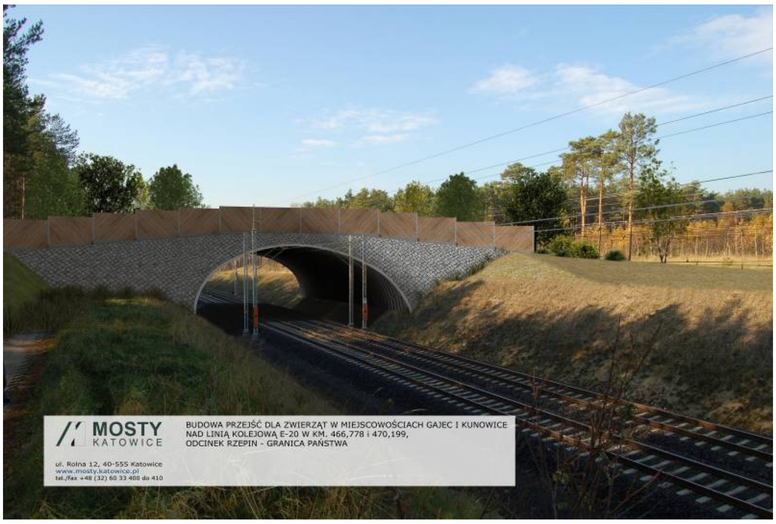

Fig. 7. Computer visualization

3. ASSUMPTIONS FOR CALCULATION

Structure was designed to hold:

- Weight of the structure itself
- Weight of soil
- Live load

Static analysis was run acc. to polish standards and regulations.
The basic material parameters are as follows:

- Steel for SuperCor Arch structure S315MC
  E_a=210 *GPa*
  R_a=315 *MPa*
- Concrete B35 (C30/70)
  E_b=34,6 *GPa*
  R_{b1}=20,2 *MPa* R_{b2}=22,4 *MPa* $R_{btk0,05}$=1,90 *MPa*
- Steel for reinforcing bars BSt500S
  E_a=210 *GPa*
  R_a=375 *MPa*

Where:

E_a – Young modulus of steel,
R_a – tensile strength of steel,
E_a – Young modulus of concrete,
R_b – ultimate compressive strength of concrete.

Calculation was made using Swedish Design Method [3].

This method is used for flexible corrugated steel plate structures for all types of corrugation and shapes. It is standards independent and gives possibility to design structures under different type of loads (railway and road live loads) in any configurations.

Basic calculation model was made to analyze the whole profile of the structure. Top part of structure where the influence of live load is the greatest is analyzed. The model can be used for analyze of other parts of the structure as well.

It is assumed that the structure has a uniform section over a long length in the pipe's longitudinal direction. The calculation model assumes that it is possible to consider a strip of 1,0 *m* length and that it is loaded with forces acting perpendicularly to the axis of structure.

The maximum stress in the wall of structure is calculated with the aid of Navier`s equation.

$$\sigma = \frac{N_{d,s}}{A_{s1}} + \frac{M_{d,s}}{W_1} < f_{yd}$$ where:

$N_{d,s}$- axial force in the wall of structure
A_{s1} – cross section area of top part of the structure
$M_{d,s}$- bending moment in the wall of structure
W_1 – section modulus

The method gives a possibility to check he stresses in the area which is the most subjected for corrosion i.e. bottom part of structure. For this calculation the moment may be neglected and the check is done using equation:

$$N_d < f_{yd} \times A_{s2}$$ where:

N_d- axial force in the wall of structure (bottom part)
A_{s2} – cross section area of bottom part of the structure
f_{yd} – yield point of steel

Swedish Design Method takes into consideration relative soil and structure stiffness and gives possibility to calculate secant modulus of soil E_s by three different methods- simplified, precise or just set.

The method allows designing bolting connection. It takes into consideration fatigue influence during dimensioning of structure.

The basic results are:

- Maximum and minimum stresses in steel structure
  $\sigma_{max} = 244{,}2\ MPa < R = 315{,}0\ MPa$
  $\sigma_{min} = -244{,}2\ MPa < R = 315{,}0\ MPa$
- Avarage stresses under concrete footings
  $\sigma_{max} = 258{,}0\ kPa$

4. CONCLUSIONS

The use of corrugated steel plate structures to built animal passings over E20 railway line is fast in construction and allows for for non–stop traffic what limit negative construction impact on environment and save costs. Computer visualization of the overpasses shows their aesthetic appearance.

REFERENCES

1. Janusz L., Bednarek B, Zouhar J, Sana M.: *The biggest animal overpass made of CSPS in the world. 11 Mezinarodni Sympozium MOSTY 2006*, Brno, ISBN 80-86604-05-5.
2. Janusz L., Bednarek B, *Największe na świecie przejście dla zwierząt nad autostradą wykonane z konstrukcji z blach falistych.*, Warszawa 2005 Materiały Budowlane, nr 9/2005, ISDN 0137–2971
3. Pettersson L., Sundquist H.: *Dimensionering av rörbroar*, Stockholm, TRITA-BKN 2000.

ELEMENTY PROCESU PROJEKTOWANIA KONSTRUKCJI ŁUKU STALOWEGO Z PODATNEJ BLACHY FALISTEJ NAD DWUTOROWĄ ZELEKTRYFIKOWANĄ LINIĄ KOLEJOWĄ

Streszczenie

Artykuł pokazuje proces projektowania konstrukcji podanej – konstrukcji łukowej o dużej fali jako przejścia dla zwierząt ponad zelektryfikowaną dwutorową linią kolejową . Opisuje procedury zaczynając od programu funkcjonalno użytkowego w którym znajdują się wszystkie założenia projektowe poprzez część obliczeniową po produkt końcowy dokumentację techniczną.

Słowa kluczowe: Konstrukcja łukowa z blach falistych, projekt, przejście dla zwierząt, zelektryfikowana linia kolejowa, duża fala