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RAILWAY GRADE SEPARATION MADE OF CORRUGATED STEEL PLATE STRUCTURE - LONG TERM RESEARCH

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Abstract

This research presents the results of long-term measurements of stresses in a flexible steel structure used to build an grade separation under railway line. The structure has a pipe-arch shape and is placed directly on the ground and backfilled with sand-gravel mix. Strains were measured with use of electric resistance wire strain gauges. Tests were carried out during the construction time and then systematically (a few times a year starting from 1998) until end 2006. On the basis of tests results changes in structure's internal forces distribution have been described. It has been affirmed that distribution of stresses changed slightly everywhere but haunch area where the changes were significant. Short discussion of results is presented

Key words : flexible structures, long-term research, change of stresses in time

1. INTRODUCTION

Distribution of internal forces in flexible steel structure is significantly connected to state of the backfill around the structure. Long-time service under dynamic life load can lead to changes in the surrounding ground. As a result of external loads change in compaction degree of soil may occur. This can result in change of stress level in the steel structure. The second factor that can change distibution of internal force is potential relocation of steel structure in the ground.

Above mentioned processes are naturally long-term and in general slow-changing activities. Knowledge of changes in distribution of internal forces in the steel structure caused by numerous changing dynamic load is crucial because of two reasons:

- enables to estimate permanent load-capacity of the structure (after theoretically infinite time),

- shows processes that occur in the structure and in the surrounding ground as an effect of load influence (including service live loads).

Researches in this matter have been carried for many years, and some results of long-term test can be found e.g. in the following [1,2].

In this research authors present test results of stresses' distribution in steel structure of 150*50 mm corrugation with steel grade S235 JRG, that has been intensively used for 9 years (since 1998) under double track railway line with heavy traffic. Analysis of structure's performance includes results of tests carried out during backfilling of the structure and research made duringtrial static and dynamic load before the real service of the structure. Some of the results are described in paper [3],[4],[5] .

2. DESCRIPTION OF THE FLEXIBLE STEEL STRUCTURE

The tested structure is situated over the street and under double-track main railway line. Skew angle of intersection between the street and railway line is 73^{o}. Grade separation consists of two parts. One is used to take the traffic road, the other one for the sidewalk. Both structures are flexible corrugated steel culverts with corrugation 150*50 mm shaped as closed pipe -arch (the bigger one) and pedestrian underpass (the smaller one) (Figure 1). The pipe-arch structure was a subject of the tests. It has the following dimensions: span B=8,90 m, rise H=6,72 m (Figure2). Length of the structure in the lowest point is 39,88 m. The depth of cover above the structure (from rail's head) is 2,67m. The rails are placed on ballast through concrete sleepers. Geometry of the structure is shown in the Figure 2. Due to a need to maintain a constant traffic on the railway line the concrete support walls remained not dismantled.

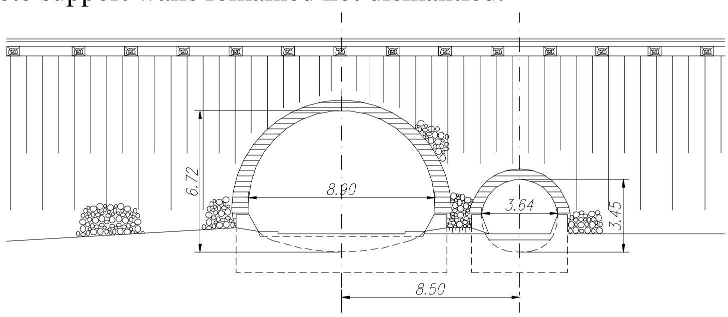

Figure 1. General view of the grade-separation

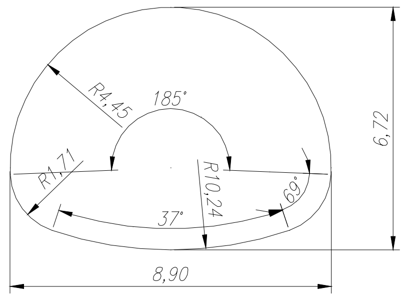

Figure 2. Cross-section geometry of the structure

Corrugated steel plate with thickness of 7 mm and corrugation of 150 (length) x 50 (height) mm has been used. Plate fulfills requirements of the Swedish norm SS–EN 10025, defined as Fe 3600 B FN. The steel yield point is f_Y=245 MPa. Plates are connected with bolts of class 8.8.
In the subsoil under the structure loams occured. The structure has been settled directly on the ground using a „sand pillow" with thickness of 40 cm. Between the subsoil and the „sand pillow" a geofabric with density of 250 g/m^2 has been placed. The ground has been drained with use of three corrugated pipes, situated on both sides and in the structure's centreline under the bottom plate. The whole backfill is mixture of sand and gravel with ununiform grading of U=5 (mixture of gravel 0÷16 50% + aggregate 25% + sand grade II 25%). The compaction degree of aggregate under the structure (apart from 10 cm top layer) amounted to 98,9%÷99,7%, in the zone approximately 2,0 m around the structure and above 1,0 mm over the structure 98%.

3. RESEARCH DESCRIPTION

The structure was built at break of 1997 & 1998 and put to service in 1998. Before it was put to service the research of structure's steel behaviour had been carried out in the following periods of time:

- backfilling of the structure with soil,
- directly before putting the structure to use with test load.

During backfilling of the structure strain measurements in the steel and entire structure's deformations have been carried out (horizontal and vertical dislocation of particular poitns). During test load dislocation measurement in chosen points (by mechanical sensors and total station, strain measurements of structure deformation, and settlement of whole structure) have been carried out.

After putting the structure to use systematic measurements of changes in the steel stresses started. The research is still beeing continued. Number of measurements was from two to four times a year spread evenly each year. Since the structure has been put to use 9 years ago, 30 measurements of coating's deformation have been made.

For measurement of strains electric resistance wire strain gauges with measurement length of 6mm and resistance of 120Ω have been used. They were located in transverse centreline of the steel structure in 10 different locations. Placement of electric resistance wire strain gauges is shown in the Figure 3. While measuring a Hottinger Baldwin Messtechnik – UPM60 amplifier was used.

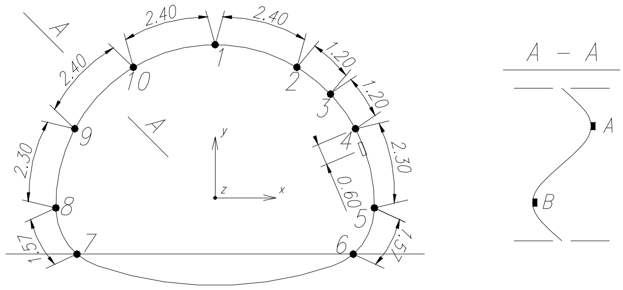

Figure 3. Locations of electric resistance wire strain gauges

4. MESUREMENTS DURING CONSTRUCTION WITH TEST LOAD

Because distribution of stresses during backfilling and behavior of the flexible steel structure during test loading are considered to be a good starting point for the test of stresses changes in time, crucial results and conclusions of the research carried out before putting the structure to use are presented below. During construction of the structure stresses have been measured in above described locations. During test loading stresses and deformations were measured.

The most important results and conclusions from the research are [5]:

a) During backfilling the biggest stresses occured in the crown (location 1) and reached the level of 240 MPa. In other measured points they never exceeded 150 MPa, and values of stresses in particular locations after complete backfilling were between 30 MPa in location 6, and 110 MPa in location 2, up to the mentioned maximum value of 240 MPa in location 1.

b) Measured increase of stresses from railway load reached few MPa. Maximum increase of normal stresses reached 6,5 MPa, but in most research locations it didn't exceed 2÷3 MPa.

c) The most significant vertical defromations didn't exceed 0,45 mm, which gives 1/20000 of the span. The biggest horizontal deformation was 0,33 mm (in span). Permanent deformations were in the range of the measurement error. The whole structure's settlements were not big,too. Maximum value of measured settlement didn't exceed 0,25 mm. After unloading the structure returned to its origin location.

d) Conclusions of research with test loading confirmed conclusions from theoretical and other analisys which have been made so far, that in this kind of structures participation of steel structure in carrying the load is very small. Load capacity of the structure as a whole is the effect of equilibrium of active and passive soil presssure.

5. RESULTS OF LONG-TERM TESTS – DISCUSSION

The stresses were calculated based on assumption that modulus of elasticity of steel equals E = 205000 MPa. Based on strains on pitch and bottom of corrugation normal and bendig stresses were calculated as follows:
Normal stresses

$$\sigma_N = \frac{\sigma_A + \sigma_B}{2} \tag{1}$$

Bending stresses

$$\sigma_M = \frac{\sigma_A - \sigma_B}{2} \tag{2}$$

where: σ_A, σ_B – corresponding normal stresses at pitch and bottom of corrugation (Figure 3).

Distribution of bendig and normal stresses from construction loads during calculated as above is presented in Figure 4 ([5]).

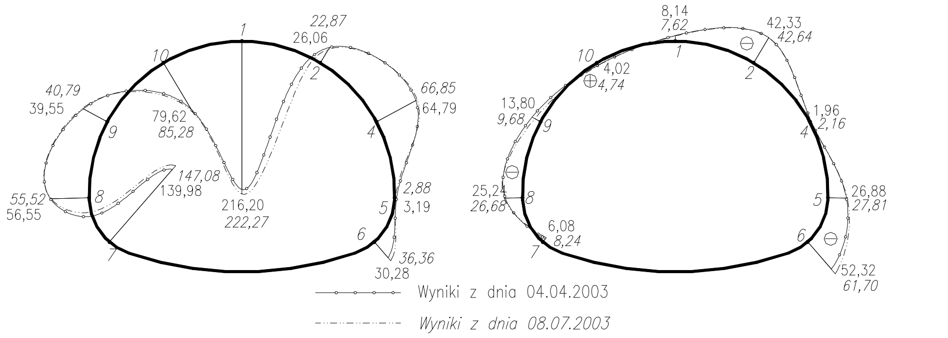

Figure 4. Distribution of stresses in the structurel [MPa]: a) Bendig stresses; b) normal stresses ("+" compression, "-" tension;bending stresses located at tensioned fibres)

Figures 5 and 12 present results of long – term measurements of changes of stresses at selected points. They are supplemented by trend lines.

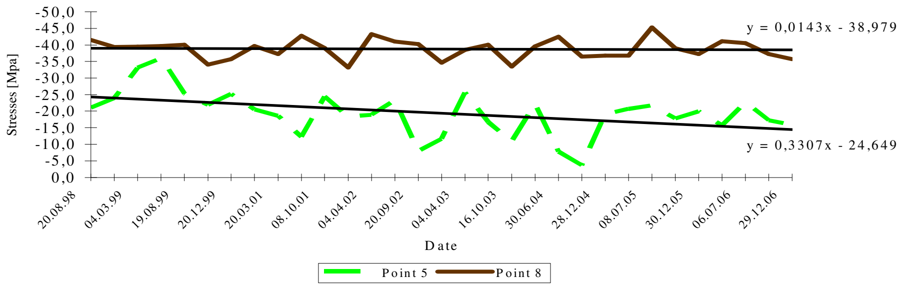

Figure 5. Changes of normal stresses above haunches (point 5 and 8)

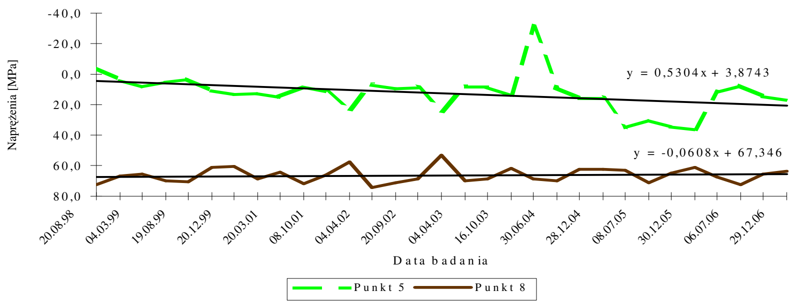

Figure 6. Change of bending stresses (point 5 and 8)

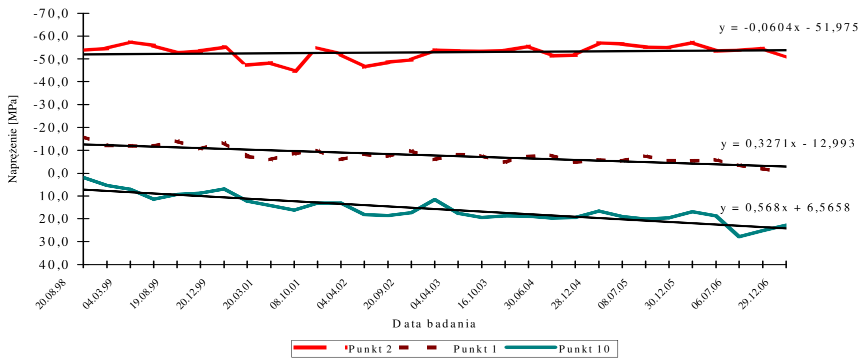

Figure 7. Changes of normal stresses at the crown (point 1, 2 and 10)

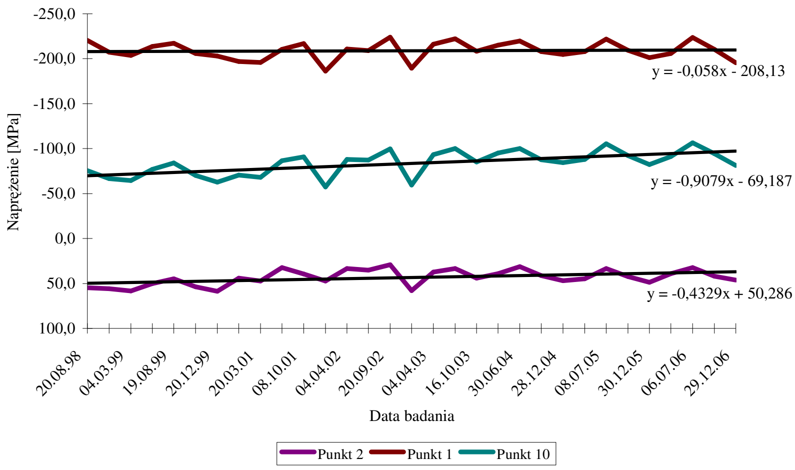

Figure 8.Change of bending stresses at the crown (points 1, 2 and 10)

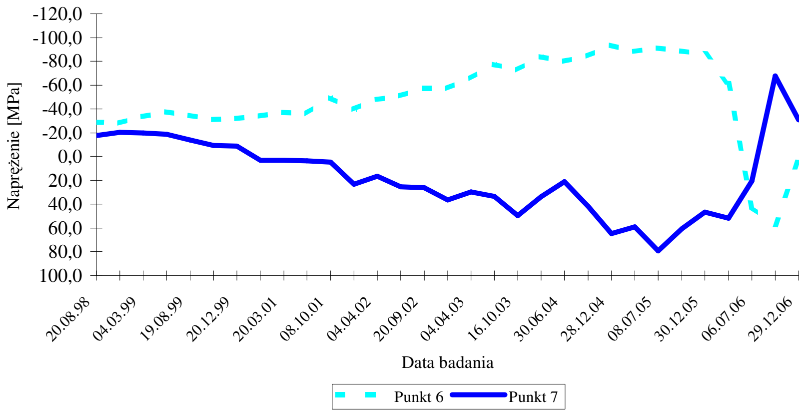

Figure 9. Change of normal stresses at haunches (point 6 and 7)

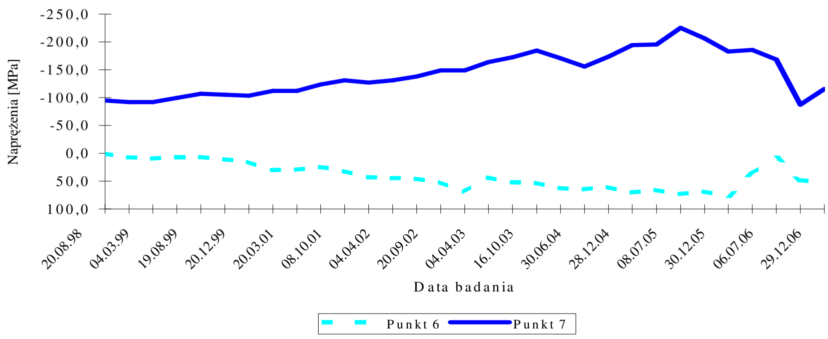

Figure 10. Change of bending stresses at haunches (point 6 and 7)

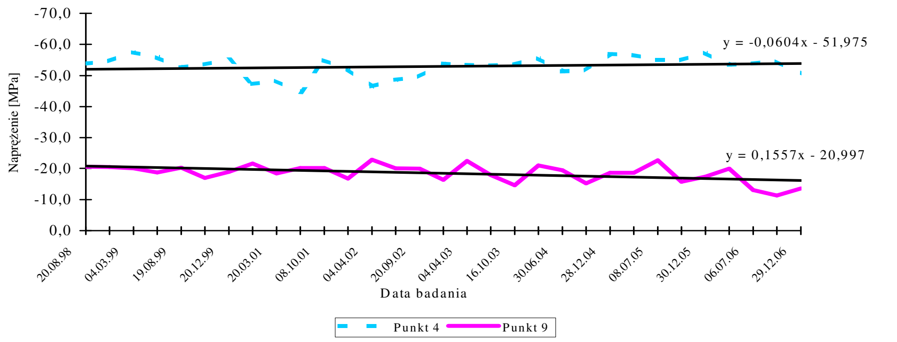

Figure 11. Change of normal stresses at side plates (points 4 and 9)

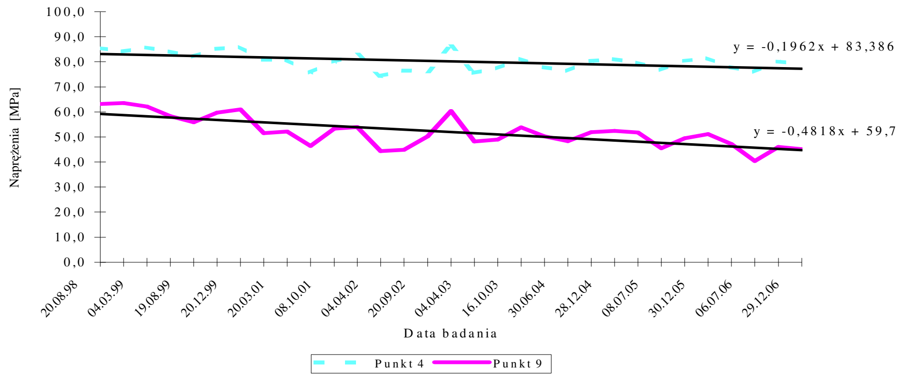

Figure 12. Change of Bending stresses at side plates (points 4 and 9)

An analysis of the presented results allows to conclude as follows:

- changes occured in the stress level of the structure over observation time: based on time when measurements were taken it could be concluded that these changes are caused by thermic deformations of the structure (measurements taken in spring, winter, fall and summer).

- At the crown of the structure (points 1,2 and 10) slight increase of bending moments with decrease of normal forces were noticed;

- a slight reduction of both bendig moments and normal forces were observed ta side (points 4 and 9)

- slight increase of bendig moments and normal forces located slightly above haunches (points 5 and 8)

- big changes in the chaunch (points 7 and 6). Over first 6 years of service a substantial increase of internal forces was noticed. It concerns both normal forces and bending moments. The increase of bending stresses was over 50 MPa and normal stresses (hoop stresses) increased by 40 MPa (point 6) and approximately 60 MPa (point 7). After that period of time a substantial reduction of normal (thrust) force was recorded leading to change of its' direction. An absolute change of stresses from normal force in both points was from 140-160 MPa. A year after the internal forces reached their maximum values a rapid decrease of those has been noted connected to a change of direction of action. After recent measurements the direction and values of internal forces are geeting close to those recorded at the beginning of the measurements (1998).

6. CONCLUSIONS

The long term measurements carried after completion of the construction stage indicato that ther are minor changes of stresses in the steel structure and a certain equilibrium state has been reached. The exception is haunch area where a substantial change of stresses occurred over time. Observed increase of bending stresses with change of direction of normal stresses at haunches with stable level of stresses in the remaining part of the structure indicate a probable slight settlement of the structure or increased active pressure from soil in haunch area. To explain this we should recall that the structure is located very close to old concrete walls that remained in the backfill from the old viaduct. The distance from haunches to the concrete walls is about 80 cm. During long term consolidation of soil in the at haunch area together with slight settlements could cause an increase of active pressure onto the structure. After a period of time steel structure deformed slightly to seek another position to reach state of equilibrium in order to limit strains in the steel wall. After thst in again reacted to earhe pressure. That could explain the change of direction of stress from bending and normal forces. An increase of streeses in haunch area during long-term tests was also observed by Vaslestad [3]. A detailed explanation of this phenomenon requires further tests.

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WIELOLETNIE BADANIA KONSTRUKCJI Z BLACH FALSTYCH POD LINIĄ KOLEJOWĄ

Referat prezentuje wyniki wieloletnich badań konstrukcji z blach falistych użytej do budowy wiaduktu kolejowego. Konstrukcja ma kształt łukowo-kołowy
(kroplisty). Posadowiona jest bezpośrednio na podłożu gruntowym i otoczona została mieszanką żwirowo-piaskową. W trakcie badań dokonano pomiarów tensometrycznych. Badania wykonano w trakcie wznoszenia konstrukcji i następnie systematycznie (parę razy do roku) aż do końca 2006 roku. W oparciu o wyniki pomiarów określono zmiany w rozkładzie naprężeń w powłoce stalowej. Na tej podstawie stwierdzono, że zasadniczo zmiany naprężeń w powłoce są niewielkie, z wyjątkiem strefy pachwinowej, w której nastąpiła istotna ich zmania. Dyskusja wyników załączona została w końcowej części referatu.

Słowa kluczowe: konstrukcje podatne, badania wieloletnie, zmiany naprężeń w czasie