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NUMERICAL AND EXPERIMENTAL INVESTIGATIONS OF WEB SHEETS IMPERFECTION CHANGES IN THE PROCESS OF TECHNOLOGICAL PRESTRESSING OF GIRDERS

The essential problem in the process of technological prestressing is the imperfection of web sheets. These elements made of relatively large sheets (about 2 meters high) show significant imperfections of the shape and flatness. Initial deflections have the value equal several times the web thickness, but they tend to grow in the process of straightening. Such a case can particularly occur when stresses that compress the shield of the web sheet between diaphragms are close to the critical buckling stress.

Experiments were carried out in a real object. The box girder having 11.0 m span and 1.8 m in its height was prestressed by welding the straps on the bottom flange and on the web in the vicinity of the bottom flange. Results of performed investigations are the subject of the paper.

1. Introduction

Travelling crane bridges, after multiyear operation usually become permanently deformed. One of the methods of regeneration (straightening) of such objects is the method of technological prestressing. The method consists in welding the straps along the length of the girders and making use of the weld

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shrinkage phenomenon. This technology has been applied in industry and more then ten crane bridges have been straightened in Poland with considerable economic effects.

The web sheets of large box girders have always inaccuracies of shape and flatness. When the web sheets are of 2 metres in their height, the imperfection could reach the value as high as a several times the sheet thickness. The results of technological straightening are changes of imperfections. Dimensions of imperfections as well as their direction (inside or outside the crossection) are the significant factors in the operation of such structure. Excessive deflections could suggest the lost of local stability, or can result in the reduction of the transverse rigidity of the structure and then its destruction under the boundary loads.

In this paper, the numerical analysis of changes of web sheets imperfections is presented. The analysis is based on the finite elements method and the comparison with the real variations of imperfections that appear in the technological straightening of the box girder.

2. Description of the model

The numerical analysis was carried out by FEM of the professional programme pack ANSYS 5.4. Calculations have been applied to the girder whose material properties and geometric characteristic are described below:

- Young modulus $E = 2.06 \cdot 10^5$ MPa,
- yield point $R_e = 300$ Mpa,
- width of the girder flanges $B = 650$ mm,
- thickness of the flanges sheets $g_p = 14$ mm,
- height of webs $H = 1800$ mm,
- thickness of webs sheets $g_s = 10$ mm,
- distance between webs $t = 305$ mm,
- length of the girder $L = 10000$ mm,
- distance between diaphragm sheets $a = 930$ mm.

The discrete model of the girder comprises ¼ part of the real structure because the real girder has two symmetry planes. Welds were also taken into account in the numerical model, and have been divided into elements having material properties the same like properties of the girder sheets. Four-node shell finite elements (SHELL 43) of six degrees of freedom in each node were applied in calculations. The partition of the model is presented in Fig. 2.

The load of the girder was obtained by the simulation of welding process of straps parallel to the axis of the girder. In the process of simulation, relevant temperatures have were to all nodes that belonged to elements of the weld. In the next step, the structure was cooled to the ambient temperature [10].

3. Straightening of the girder in the horizontal plane

In the aftermath of welding the side central strap on the web (strap "3" – Fig. 1), the girder was straightened in the horizontal plane. Thickness of the strap was g_n = 10 mm , width b_n = 200 mm, and the throat thickness of the weld a = 6 mm. It was assumed that the web sheets between diaphragms had initial deflections 5 mm, 10 mm and 20 mm.

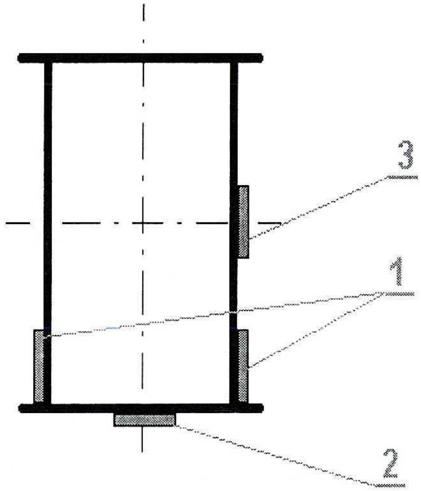

Fig. 1. Crossection of the box girder with straps (1 – bottom side strap, 2 – bottom strap, 3 – central strap)

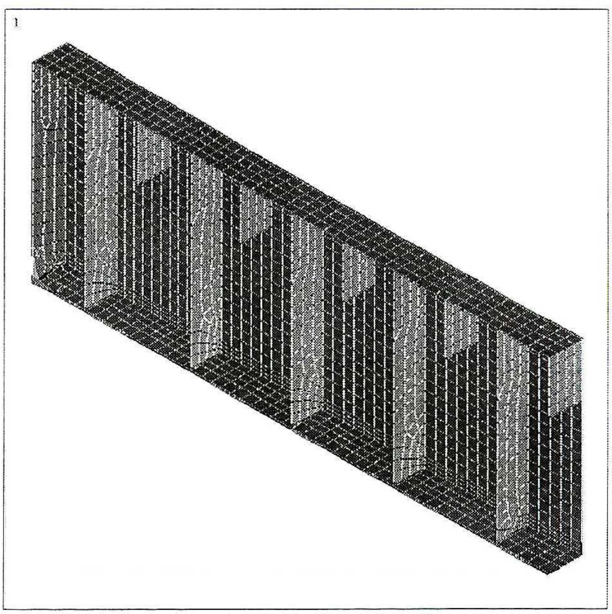

Fig. 2. The model of the girder with partition for elements – the view from inside the girder on diaphragms

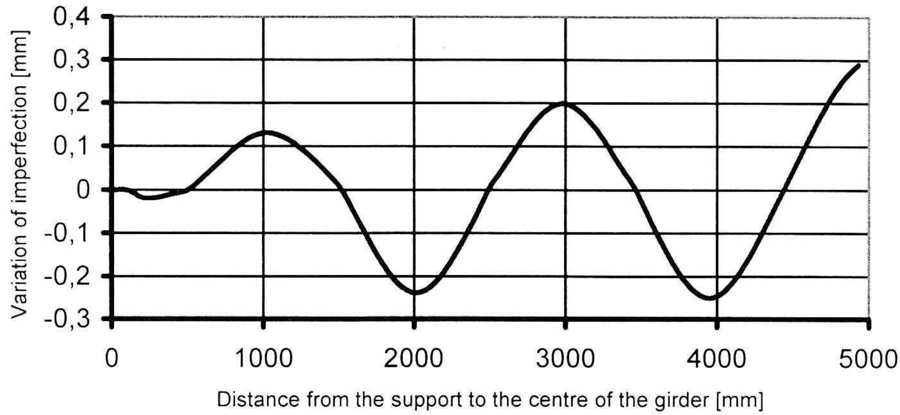

Fig. 3. Variations of imperfection of webs on the length of girder – horizontal section at the half of the web heigth

The result of numerical calculations is the distribution of stresses and deformations of the structure. Fig. 3 presents the variability of imperfection of the web plates between diaphragms in the horizontal section made at the half of the height of the girder. It can be seen that in each case the value of imperfection is reduced, and its final value does not exceed 0.3 mm, i.e. the sheet of the web is getting more flat.

4. Straightening of the girder in the vertical plane

Straightening of the girder in the vertical plane is the result of welding the bottom strap to the bottom flange (strap "2" in Fig. 1). Dimensions of the strap were: thickness g_n = 10 mm, width b_n = 200 mm, throat thickness of the weld a = 6 mm. The pattern of deformation of the surface of the girder webs is presented in Fig. 4. Denoted are displacements UX of webs in direction perpendicular to their surface. It could be seen in the Figure that all imperfections were increased i.e. the convex parts moved outside the girder and the concave parts inside the girder. The maximum absolute values of calculated deflections were within the range 1.2—2.5 mm.

Fig.5 is presents the diagram of imperfections of web sheets before welding the prestressing straps (light line) and after welding the straps (thick line). The section of the girder was made at the half of webs height.

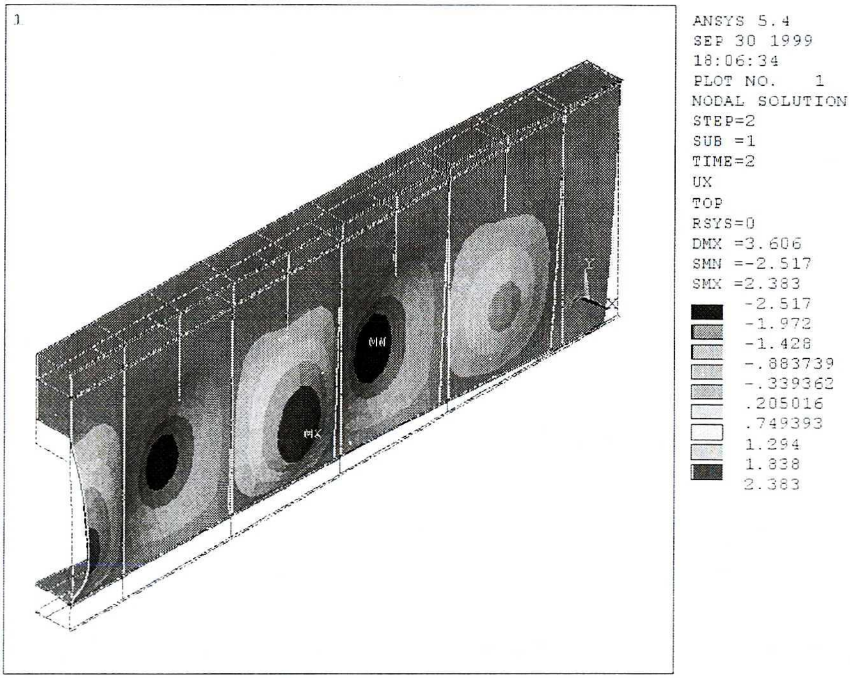

Fig. 4. The chart of deformations in direction perpendicular to the web

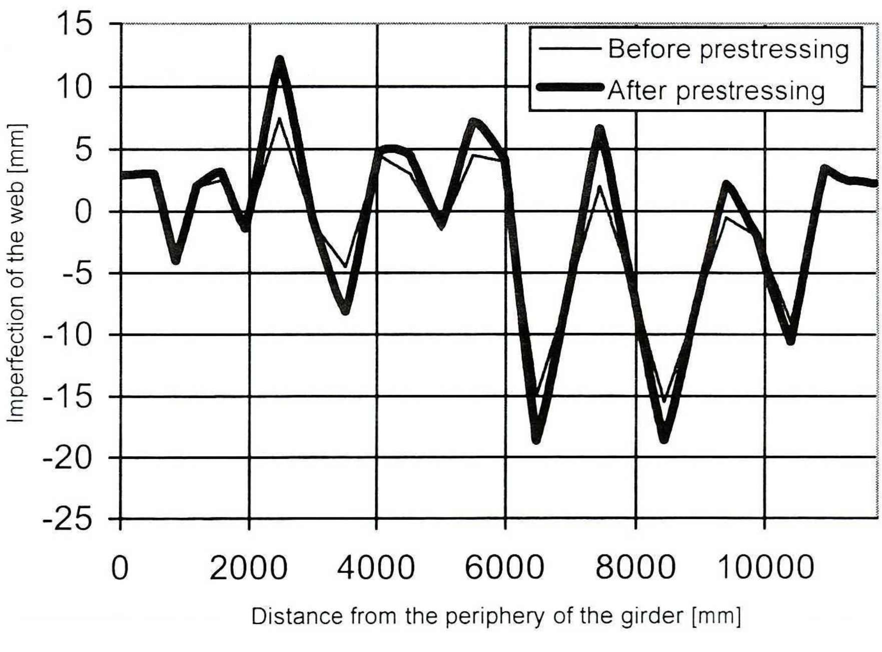

Fig. 5. Imperfections of web sheets before welding prestresssing straps (light line) and after welding prestressing straps (thick line)

5. Concluding remarks

Results of numerical investigation reveal the following regularities:

- in the process of straightening the box girder in the vertical plane (welding the straps "1" and "2" – Fig. 1) imperfections of web sheets were always have been increased, both outside and inside the section of girder,
- in the process of straightening the box girder in the horizontal plane (welding the strap "3" – Fig. 1) imperfections on the opposite web were reduced.

Experiments with the real girder of dimensions analogous to the calculated one were performed in the Sendzimir Steelworks in Kraków. In the process of technological prestressing, the geodesic measurements of web sheets deflections was made. The provisional qualitative analysis showed conformity with hereby presented results of numerical calculations.

Fig. 6 is presents the comparison of results obtained from numerical calculation by the finite elements method with results of geodesic measurements of the real girder after prestressing process.

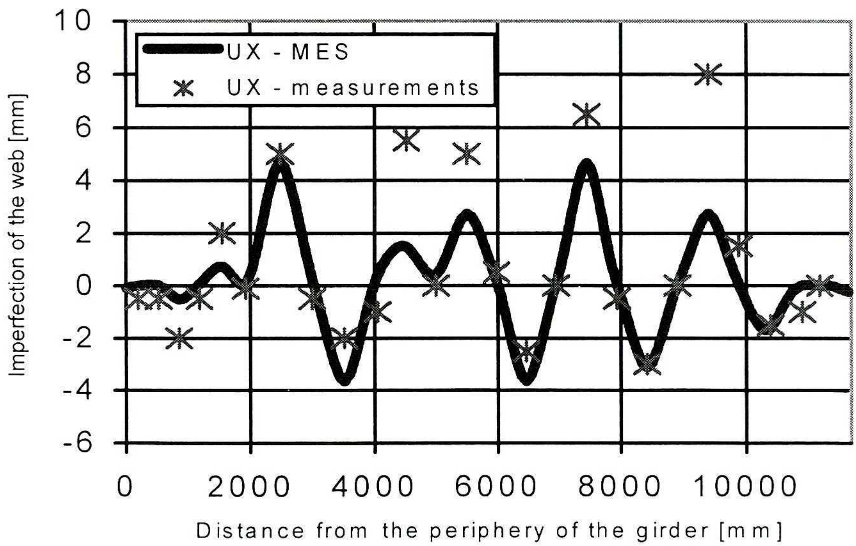

Fig. 6. Comparison of numerical calculation results with experimental data

In the case of the load of the girder close to the critical one, deflections of the real girder are greater then those resulting from numerical calculations. This observation proves that there is local loss of stability, and the buckled area is formed in that region.

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REFERENCES

[1] Blum A., Dzik S., Siemieniec A.: Badanie wartości sił wewnętrznych w procesie spawania nakładek sprężających. XV Sympozjum Mechaniki Eksperymentalnej Ciała Stałego, 1992.

[2] Dzik St., Obrzud K., Wolny St.: Wpływ sprężania na stan naprężenia i odkształcenia skrzynkowego dźwigara suwnicy. Mechanika, tom 13, z. 4, 1994.

[3] Blum A., Orłoś Z.: Modelowe badania efektu sprężania technologicznego skrzynkowych dźwigarów suwnic pomostowych. Materiały XXXV Sympozjonu „Modelowanie w Mechanice", 1996.

[4] Kubiak T., Młotkowski A.: Analiza stanu naprężeń i odkształceń metodą elementów skończonych w prostowanych dźwigarach skrzynkowych. Materiały X Konferencji Naukowej Problemy Rozwoju Maszyn Roboczych, 1997.

[5] Kubiak T., Młotkowski A., Niezgodziński T., Blum A.: Stateczność dźwigarów skrzynkowych sprężanych metodą spawania nakładek. Materiały XI Konferencji Naukowej Problemy Rozwoju Maszyn Roboczych, 1998.

[6] User's Guide ANSYS 5.4, Ansys, Inc., Houston, USA.

[7] Kubiak T., Młotkowski A., Niezgodziński T.: Wpływ rzeczywistych imperfekcji na odkształcenia dźwigarów sprężanych technologicznie. Materiały XII Konferencji Naukowej Problemy Rozwoju Maszyn Roboczych, 1999.

[8] Blum A., Kubiak T., Niezgodziński T.: Obliczenia stanu naprężeń metodą elementów skończonych w dźwigarach prostowanych technologicznie. Materiały XII Konferencji Naukowej Problemy Rozwoju Maszyn Roboczych, 1999.

[9] Kędziora S., Kubiak T., Młotkowski A.: Nieliniowa analiza stanu odkształcenia i naprężenia w dźwigarze skrzynkowym z imperfekcjami kształtu. Materiały XII Konferencji Naukowej Problemy Rozwoju Maszyn Roboczych, 1999.

[10] Kubiak T., Niezgodziński T.: Numeryczny model efektu spawania nakładek w dźwigarach skrzynkowych. Materiały XXXVIII Sympozjonu „Modelowanie w Mechanice", 1999.

Analityczne i eksperymentalne badania imperfekcji blach środnikowych dźwigarów skrzynkowych wywołanych procesem technologicznego prostowania dźwigarów

Streszczenie

Podczas sprężania technologicznego istotnym problemem jest zachowanie się imperfekcji blach środników. Blachy te o stosunkowo dużych rozmiarach (wysokość około 2 metry) wykazują znaczne imperfekcje płaskości i kształtu-wstępne ugięcia maja wartości równe kilku grubości blachy środnika. W czasie prostowania wartość ugięć powiększa się; występuje to szczególnie wtedy, gdy naprężenia ściskające tarczę blachy środnika między przeponami osiągają wartości bliskie wartościom krytycznym na wyboczenie.

Przeprowadzono badania doświadczalne na rzeczywistym obiekcie. Dźwigar o przekroju skrzynkowym posiadający rozpiętość 11,0 m i wysokość 1,8 m poddano sprężaniu poprzez przyspawanie nakładek na pasie dolnym i na środniku przy pasie dolnym-spowodowało to ugięcie dźwigara w płaszczyźnie pionowej. Wyniki przeprowadzonych badań stanowią treść artykułu.