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THE COMPARISON OF TEMPERATURE LOADING OF SUPPORTING CONSTRUCTION OF BRIDGES

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Abstract

This paper will compare the effects of temperature changes on the superstructures of bridges, above all the effect of temperature gradient. The loadings according to standards ČSN 73 6203, ENV 1991-1-5 and DIN 1072 will be compared here. With respect to a variety of design processes, the comparison will be made without any coefficient of loading, combination or material. Besides the theoretical comparison, the comparison on exact constructions will be made.

Keywords: temperature; temperature loading; bridge; temperature uniform component; temperature difference component

1 The comparison of loading

All the compared standards divide the loading of the superstructure by temperature minimally in to two basic effects - the uniform temperature component and temperature difference components. The standard EN 1991-1-5 takes into account, apart from loading by a temperature gradient in the vertical direction, loading by a temperature gradient in the horizontal direction. This is used for complicated construction where these loadings do not produce inconsiderable effect.

For the uniform temperature every standard has a different technique for obtaining the temperature differences, but the final temperature values do not differ too much.

For temperature differences the standards generally take nonlinear temperature gradient in the vertical direction. For simple constructions it is possible, according to standards ČSN and EN, to use an easier linear gradient. The standard DIN uses this easier linear gradient in all cases of superstructures.

2 Analysis

The Comparative analysis has been made on two bridges. The first bridge is a construction on the D8 motorway, SO 217 – Border Bridge. The bridge crosses the border with Germany, which is created by a deep valley with the Border Brook. The bridge construction forms a superstructure of a continuous girder. It is supported by seven

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supports, two abutments and five piers. The support structure is made as a steel-concrete box girder with a composite concrete slab. Each direction of the motorway has one superstructure with its own piers (Fig. 1). The abutments are the same for both girders. The width of one construction is 14.5m and the construction depth is 3.70m. The length of the bridge is ca. 430m. The continuous girder has spans 58.40 + 73.00 + 73.00 +73.00 + 73.00 + 58.40 m.

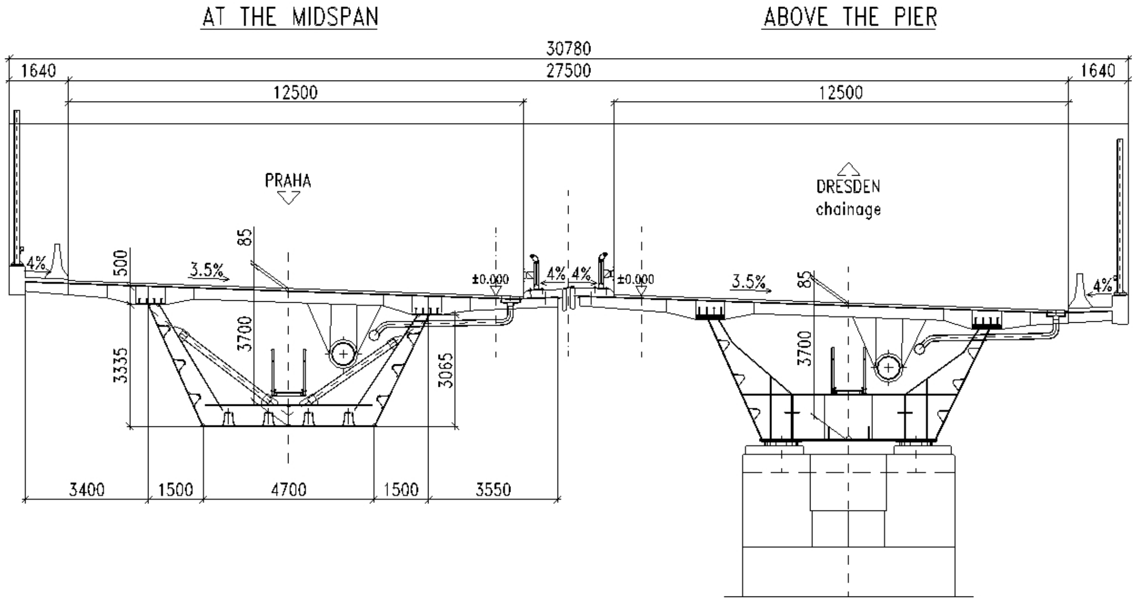

Fig. 1 D8 - Sample cross section

As the superstructure is a statically indeterminate construction, a continuous beam, which is fixed in two middle piers, the uniform temperature component causes only free displacements and produces a normal force in the span between the piers with a straight seated bearing. This force is dependent on the piers stiffness. Owing to the height of the piers of over 40m, this temperature component has no effect on the construction design. Therefore this effect is not being solved here.

Second construction is a bridge over the motorway D11. It transfers the 3rd class road over the motorway in a flatland near Kolín. The bridge construction forms a continuous prestressed concrete slab (Fig. 1). It is supported by five supports, two abutments and three oval piers. The deck is only locally supported above the piers. The construction's width is 10.0m and the construction depth is 1.00m. The length of the bridge is ca. 60m. The continuous girder has spans 12.0 + 17.0 + 17.0 +12.0 m.

This superstructure is fixed only in the middle pier, so the continuous beam has a free displacement and does not produce normal forces.

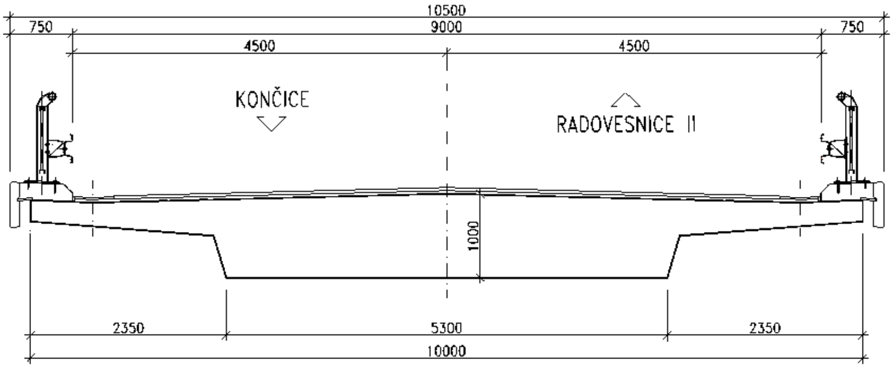

Fig. 2 D11 - Sample cross section

The analysis of temperature difference components is made on a beam model. The temperature gradient is implemented by cross-section rotation. The cross-section rotation is solved for each cross section of the superstructure. The superstructure is loaded by the continuous cross-section rotation. This deformation has got the same effect as the temperature loading.

3 Comparison of results

In this chapter the moments from temperature loading are compared. The bending-moment envelopes for maximal and minimal moments are created (see Figures below).

3.1 Bridge on D8 – composite beam

According to the standards ČSN and EN, which have almost the same temperature distribution for a composite bridge, there will be only a one-side effect and consequently only the plus or minus moment. The calculation confirmed this hypothesis and the temperature difference component caused only one-side cross-section rotation, by which the continuous beam was loaded. In contrast, the DIN standard, as it is clear from the temperature gradient, will cause both plus and minus cross-section rotation. The calculated moments are shown in figures 3 and 4.

Loading with cooling according to the standard DIN will cause only minus moments, whereas the other two standards produce plus moments (Fig. 4). The standard DIN will produce a minimal moment –11MNm in contrast to a zero moment by loading according to standards ČSN and EN.

Comparing maximal moments caused by the heating difference component (Fig. 3), no great differences in values appear. Loading according to ČSN and EN causes almost the same moments although the temperature gradient of these standards is vastly different. The difference between the moments takes ca. 1%. The loading according to EN produces about 15% lower values, but the design according to EN uses many more coefficients than the other compared standards. The resulting effect of loading according to this standard could be the same or worse.

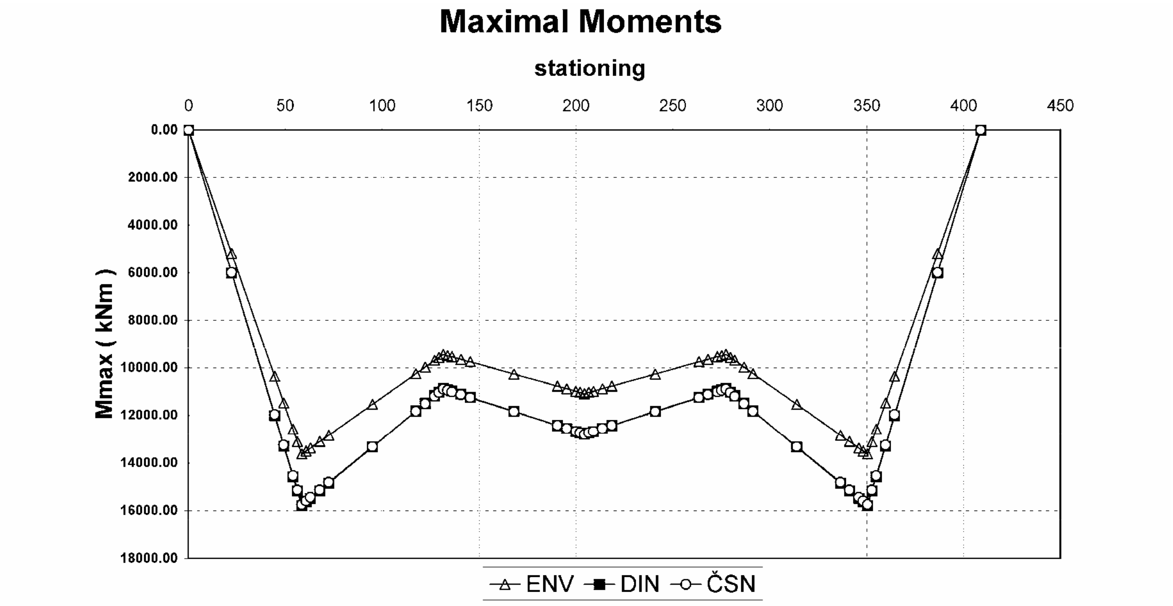

Fig. 3 D8 - Maximal moments from temperature loading

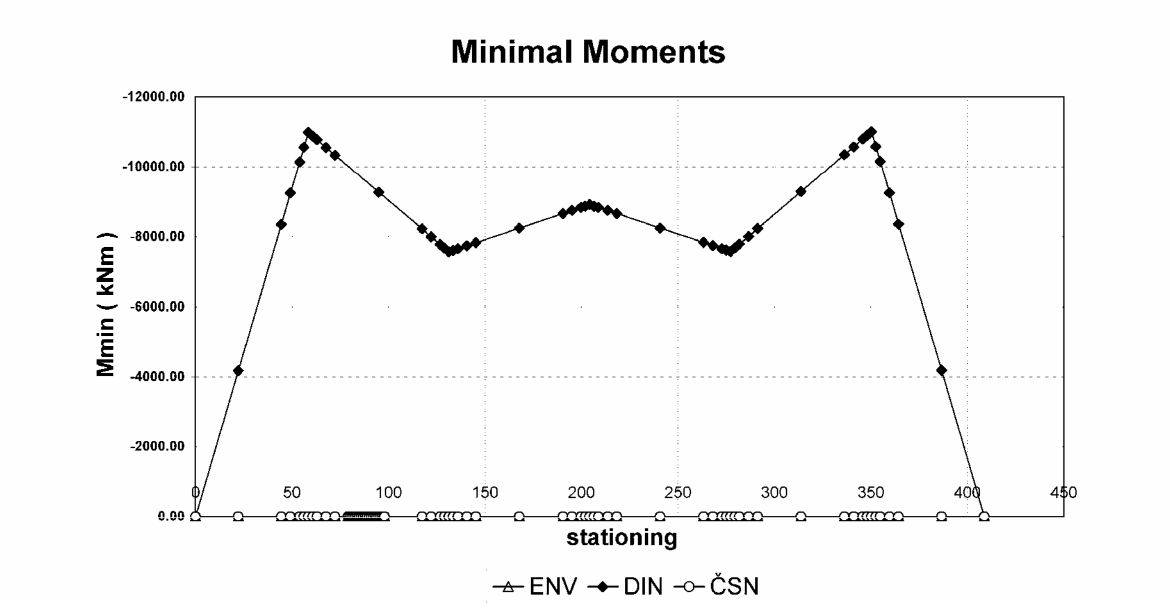

Fig. 4 D8 - Minimal moments from temperature loading

3.2 Bridge on D11 – prestressed concrete slab

Two different temperature loadings were used (according to ČSN) for the concrete slab - one loading with linear temperature gradient and second loading with nonlinear temperature gradient.

The temperature loading according all the comparison standards produce plus and minus moments on bridge of concrete slab. According to the standard ČSN – nonlinear loading - and EN causes almost the same maximal moments, according to ČSN – linear loading – causes lower values of maximal moments. Loading according to standard DIN gives values of maximal moments in 1/3 values according to other standards (Fig. 5).

The minimal moment according to compared standards are not very different. Nevertheless, we must use the easier loading model according to ČSN – linear temperature loading. The values differences are ca. 10%. If we use the more accurate loading model (nonlinear) we get practically zero values of maximal moments.

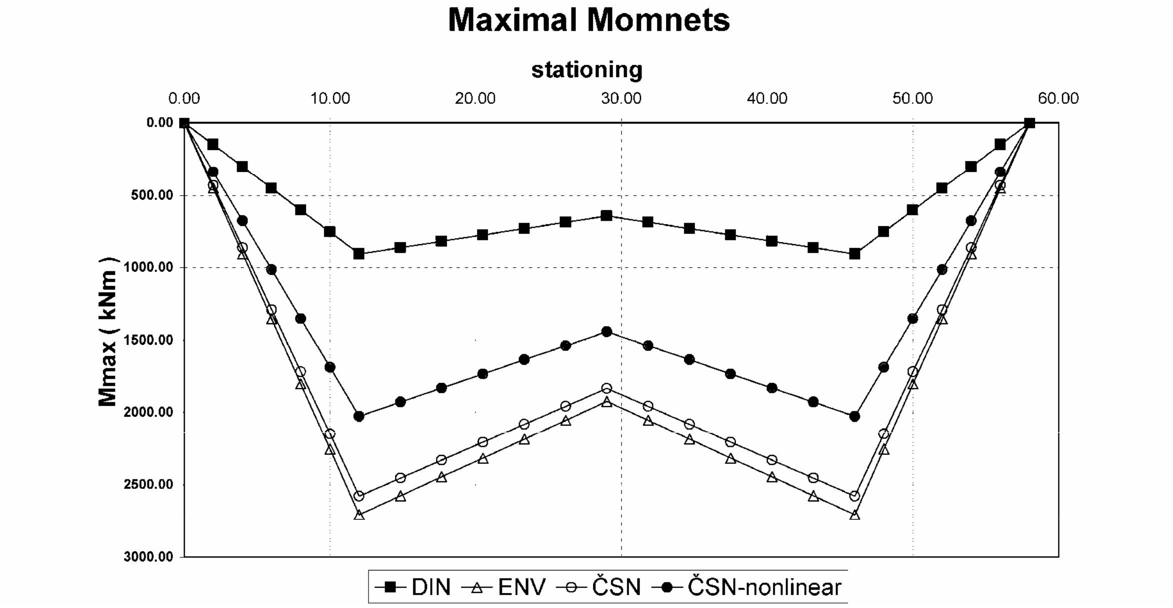

Fig. 5 D11 - Maximal moments from temperature loading

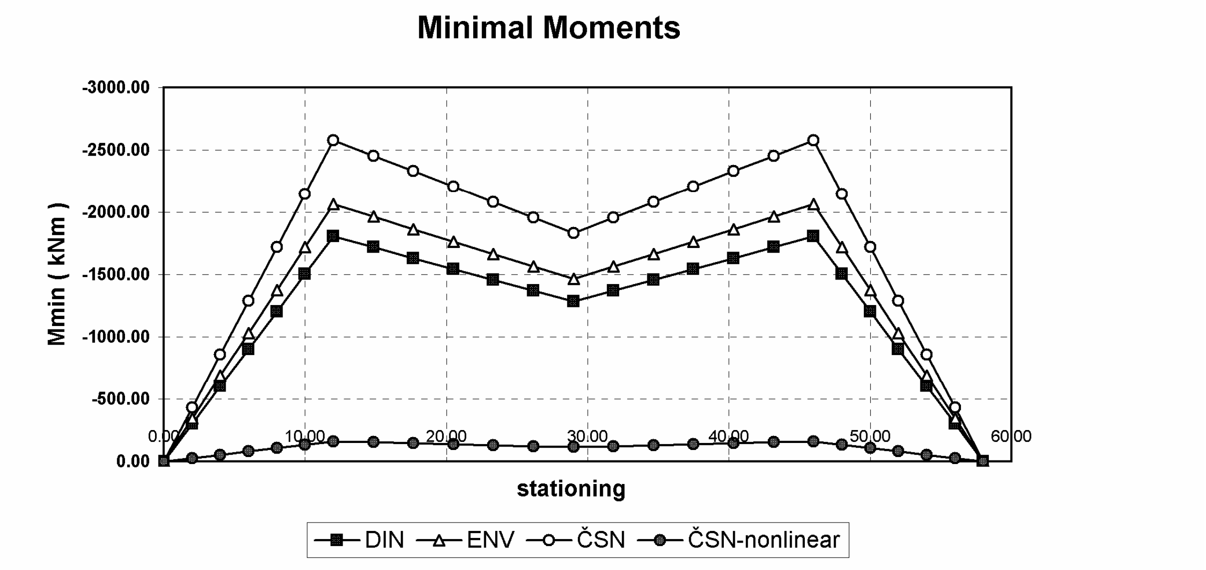

Fig. 6 D11 - Minimal moments from temperature loading

4 Conclusions

It must be mentioned that the comparison of the standards is made only with respect to basic values without any coefficients (loading coefficients or combination coefficients). The final effects from loading by maximum heating by the temperature gradient according to the EN standard can be, in some combinations, higher than those according to other standards although the effect is lower without the coefficients.

Without solutions on some other types of constructions we cannot say, if this difference is valid or if it is relevant only for this type of construction. In addition, we cannot say, without universally measuring temperature gradients on real structures, which standard determines true values or which one is nearer to the truth.

It is necessary to investigate this problem on other construction types. First of all, we must support the theoretical considerations and calculations according to standards by experimental measuring temperature fields on bridge structures on the site. Temperature fields and temperature gradients should be measured during day cycles (24 hours) and year cycles. By evaluation of these cycles it would be possible to fix whether the extreme measured effects do not exceed too much the values given in the standard, or it would be possible to fix the frequency of such exceeding.

It would be possible to fix how precisely and how reliably the individual standards give the temperature gradients for bridge construction design.

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References

[1] ČSN 73 6203 Zatížení mostů (včetně změny a a změny b)
[2] ČSN P ENV 1991-2-5 Eurocode 1: Action on Structures - Part 1-5: General Actions - Thermal Actions
[3] DIN 1072 Strassen- und Wegbrücken – Lastannahmen
[4] Římal J.: Charles bridge in Prague – Measurement of temperature Fields. International Journal for Restoration of Buildings and Monuments, Freiburg 2003, vol. 9, no. 2, pp. 585-602.
[5] Římal J.: Charles bridge in Prague – Measurement of temperature Fields. International Journal for Restoration of Buildings and Monuments, Freiburg 2004, vol. 10, no. 3, pp. 237-250.