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Vertical displacements of a steel-concrete railway superstructure, 51m long, under the 250KN mobile axle load, for speed ranging between 1...150m/s.

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Summary

Objectives:

The paper analyses the vertical displacements of a railway bridge superstructure, steel-concrete composition, 50m span, under the the 250KN mobile axle load.

Work method:

The running track of the bridge has a special structure: the rails are continuously fixed into the concrete slab using the Edilon corkelast material.

In order to determine the impact of the increased speed upon the vibrations and deflections of a mixed section railway bridge superstructure, this superstructure has been carried into the SAP2000 finite element calculation programme.

Sixteen non-linear dynamic analysis have been performed with the 250 KN mobile axle that covers the analyzed model with speeds from 1, 10, 20, 30... 150m/s (3.6...540km/h).

Conclusions:

Based on the results presented in this paper, we can say that, for the high speed trains that run at a speed that is close to 60m/s on this superstructure, it is possible that the vibrations and vertical deflections will be amplified. This amplification will be reached if the frequency with which the axles of the train get to L/2 is close to the own frequency of the first vibration mode of the analyzed structure.

The increase of the running speed of the mobile axle determines the increase of the amplitude of the vibrations, but this does not necessarily lead to a continuous increase of the recorded deflections of the superstructure.

The behaviour of the analyzed model from the point of view of the vibrations and of the deflection pattern corresponds to the known theoretical models.

The paper has a theoretical importance because it studies the behaviour of this type of structure in response to a single mobile axle.

KEYWORDS: superstructure vibration, mobile load, high speed, deflection

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1. INTRODUCTION

In order to understand the behaviour of a superstructure under the action of high speed trains, first we need to determine the dynamic answer to the load of one mobile axle. The load with the 250KN mobile axle of the considered model has been chosen in order to be able to make observations regarding the superstructure displacement answer to speeds exceeding the common speeds presently reached on the Romanian railways.

2. OBJECTIVES

To determine the influence of the increased speed of the mobile axle upon the vibrations and deflections recorded in the analyzed superstructure.

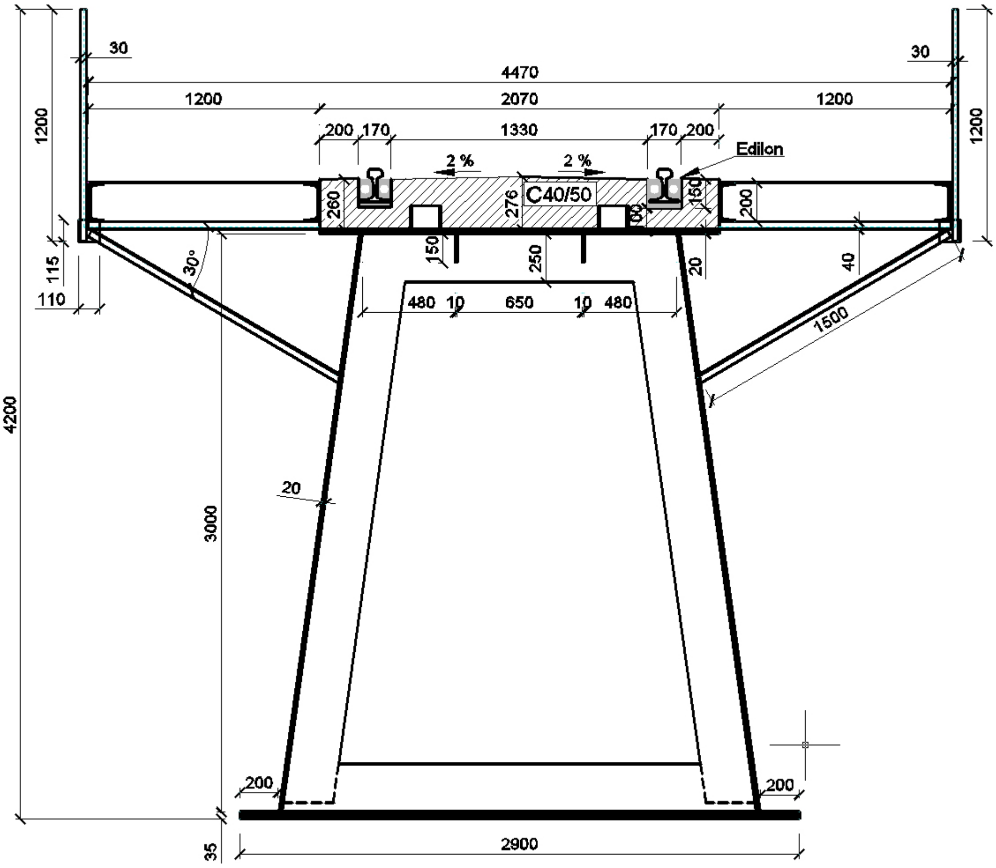

Figure 1. Cross section of the superstructure.

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3. WORK METHOD

In order to determine the impact of the increased speed upon the vibrations and deflections of a mixed section railway bridge superstructure, with a 50m span and the cross section as seen in Figure 1, this superstructure has been carried into the SAP2000 finite element calculation programme.

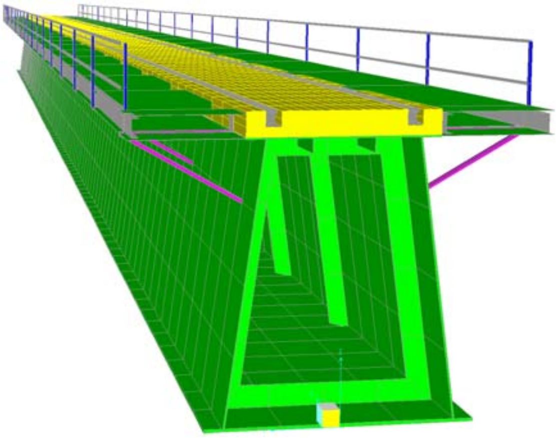


Figure 2. Structure analyzed with the SAP2000 programme

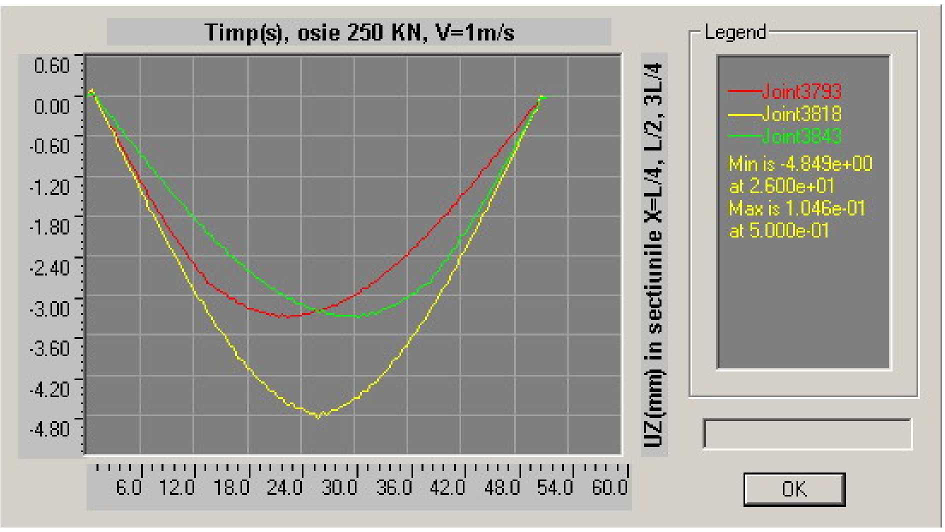
It is important to know the deflections recorded under the action of a mobile axle, in the dynamic analysis for regular or high speed trains, because the second axle of the train will follow a path that has been deformed by the first axle.

In order to obtain results that are as close to reality as possible, we have considered a space moulding of the structure was necessary, with all the comprised elements, instead of making the analysis for a free beam having an equivalent rigidity.

The box section and the sidewalk panes are made of “shell” plane elements, the rails and the linear elements of the sidewalks have been inserted as “frame” rod type elements, the concrete slab the rails are fixed into has been inserted as “solid” type elements.

The analyzed superstructure is 51m-long and it has been divided into 0.5m-long elements along the way, obtaining 103 characteristic sections, as seen in Figure 2. The dynamic analysis have been made considering the P=250KN constant force, charging the structure in 104 load steps. The vertical deflections of the superstructure have been recorded at the rail level, for all of the 104 load steps.

The dynamic analysis have been made using the direct integration method. The vertical deflections obtained in 3 sections, situated at L/4(red), L/2(yellow), and 3L/4(green), are represented in the graphics below.

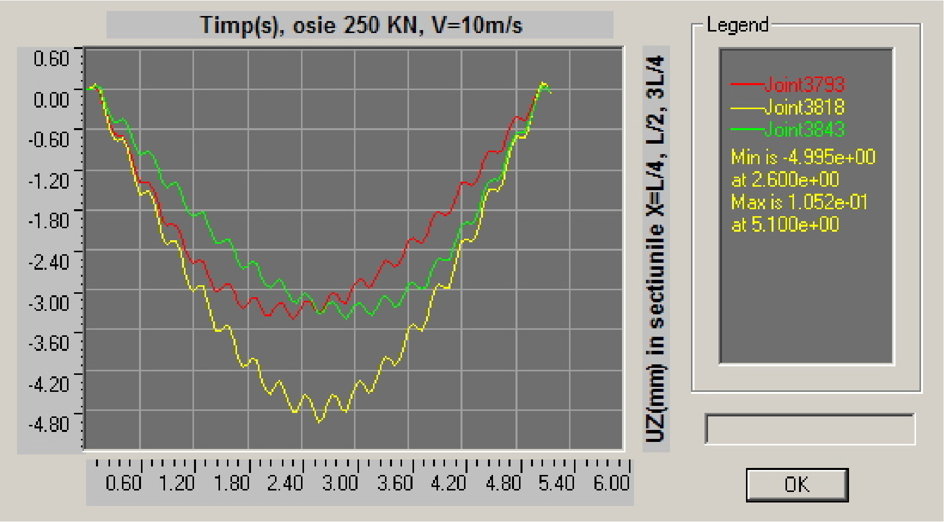


Min is -4.849e+00
at 2.600e+01
Max is 1.046e-01
at 5.000e-01

Figure 3. Vertical displacements UZ(mm), P=250KN, V=1m/s (3.6km/h)

In Figure 3, at the speed of 1m/s the vibrations are almost inexistent.

The maximum value of the recorded deflection of the superstructure is 4.849mm and it is reached in the L/2 section, at second 26.



Min is -4.995e+00
at 2.600e+00
Max is 1.052e-01
at 5.100e+00

Figure 4. Vertical displacements UZ(mm), P=250KN, V=10m/s (36km/h)

In Figure 4, the speed is 10m/s, vibrations start to appear in the superstructure. The superstructure is loaded for 5.1s, the maximum recorded deflection is 4.995mm.

Vertical displacements of a steel-concrete railway superstructure, 51m long, under the 250KN mobile axle load, for speed ranging between 1...150m/s

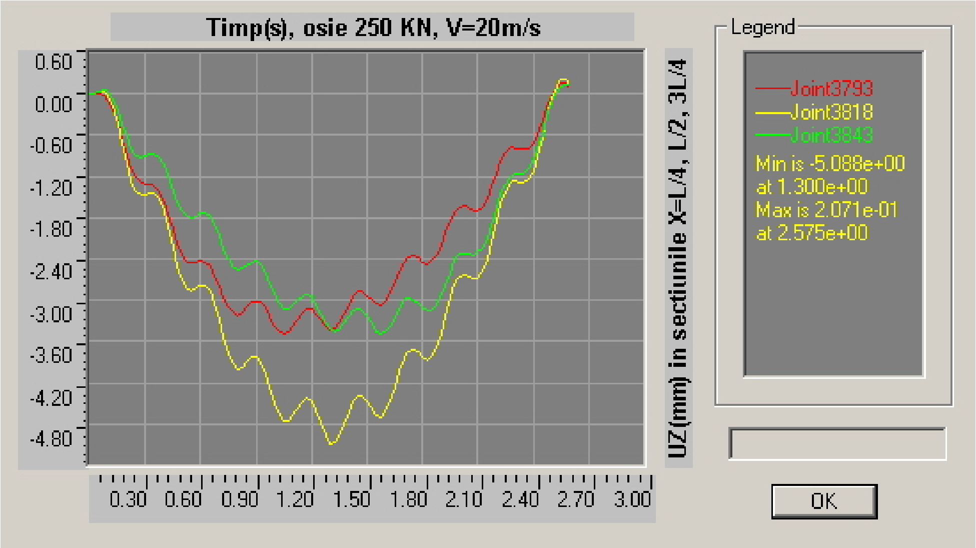


Figure 5. Vertical displacements UZ(mm), P=250KN, V=20m/s (72km/h)

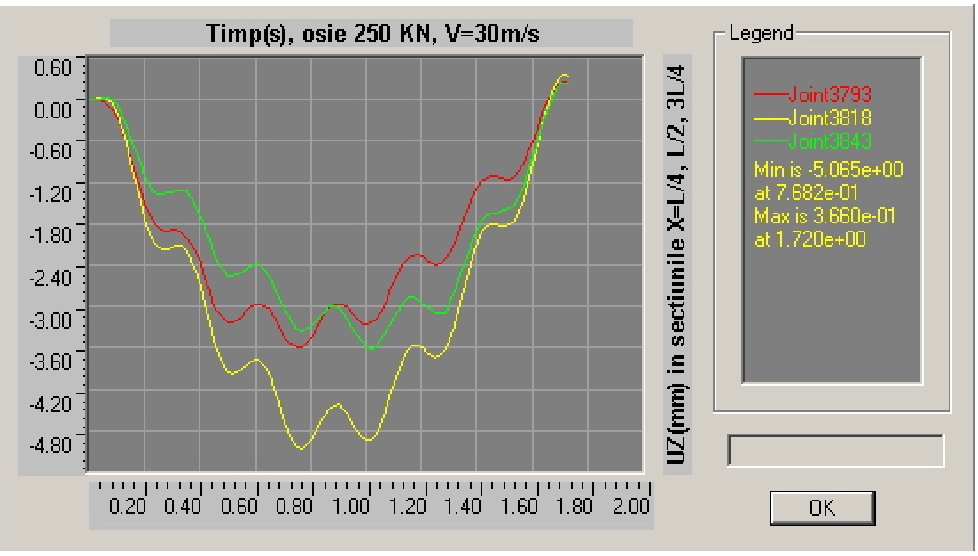
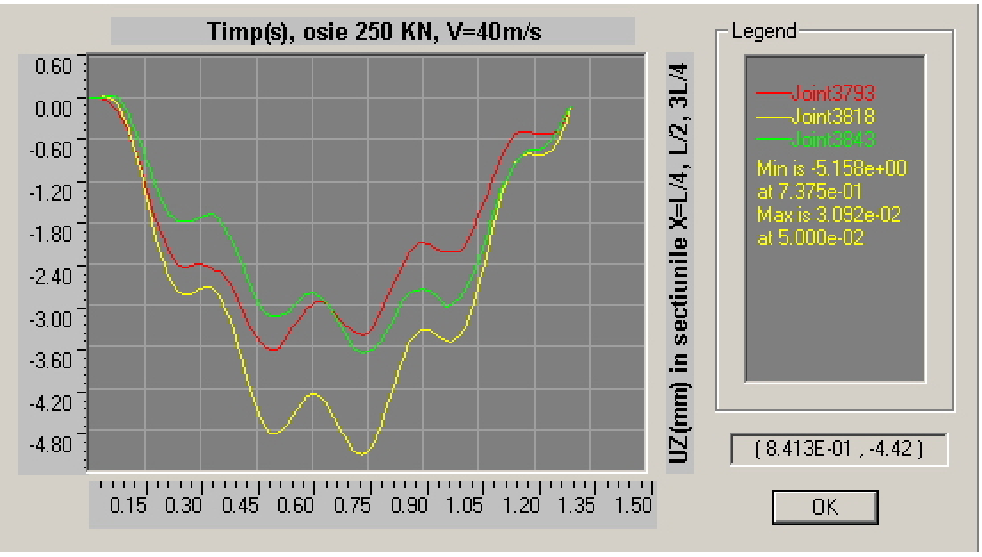


Figure 6. Vertical displacements UZ(mm), P=250KN, V=30m/s (108km/h)

In Figure 5, the 250KN axle will cover the 50m superstructure at 20m/s and the maximum midspan deflection is 5.088 mm.

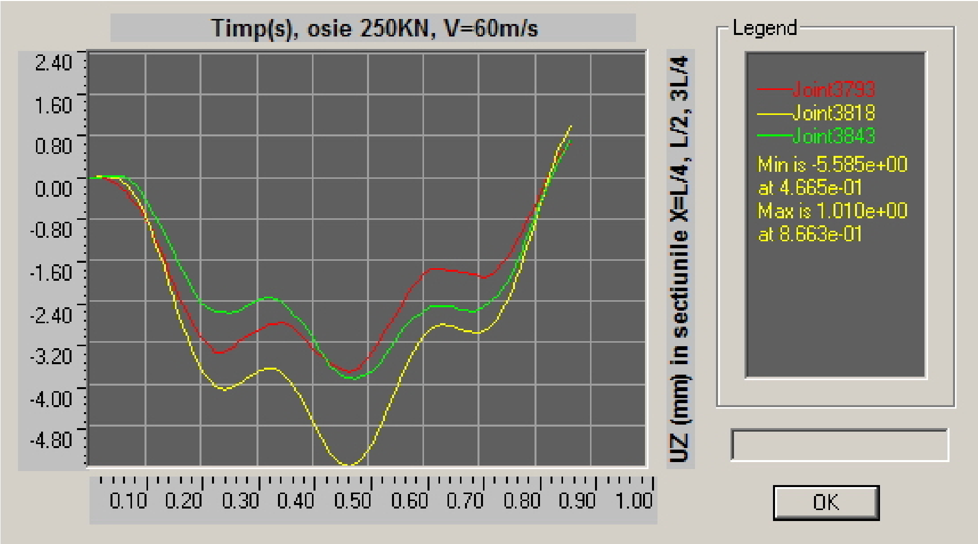
In Figure 6, the 250KN axle will cover the 50m superstructure at 30m/s and the maximum midspan deflection is 5.065 mm.



Min is -5.158e+00
at 7.375e-01
Max is 3.092e-02
at 5.000e-02

(8.413E-01 , -4.42)

Figure 7. Vertical displacements UZ(mm), P=250KN, V=40m/s (144km/h)



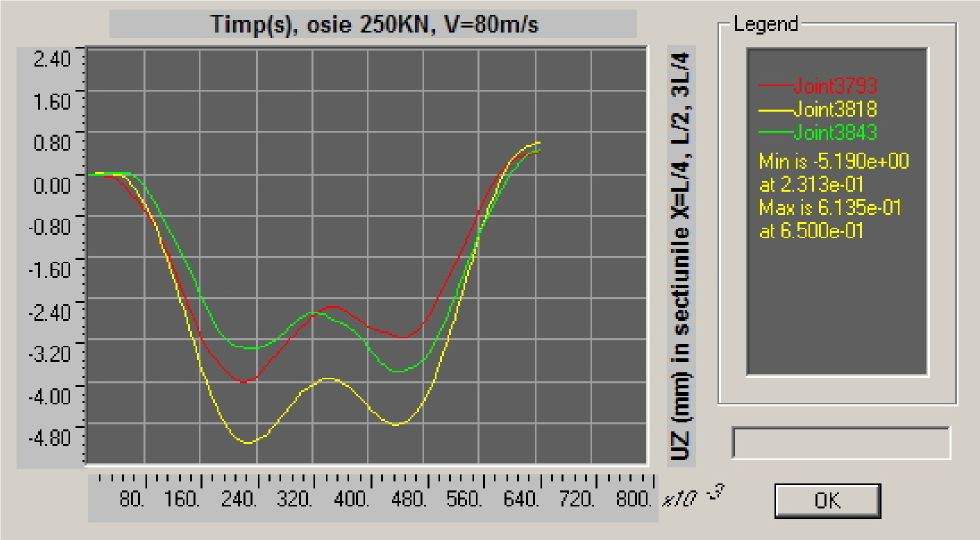
Min is -5.585e+00
at 4.665e-01
Max is 1.010e+00
at 8.663e-01

Figure 8. Vertical displacements UZ(mm), P=250KN, V=60m/s (216km/h)

In Figure 7, the 250KN axle will cover the 50m superstructure at 40m/s and the maximum midspan deflection is 5.158 mm.

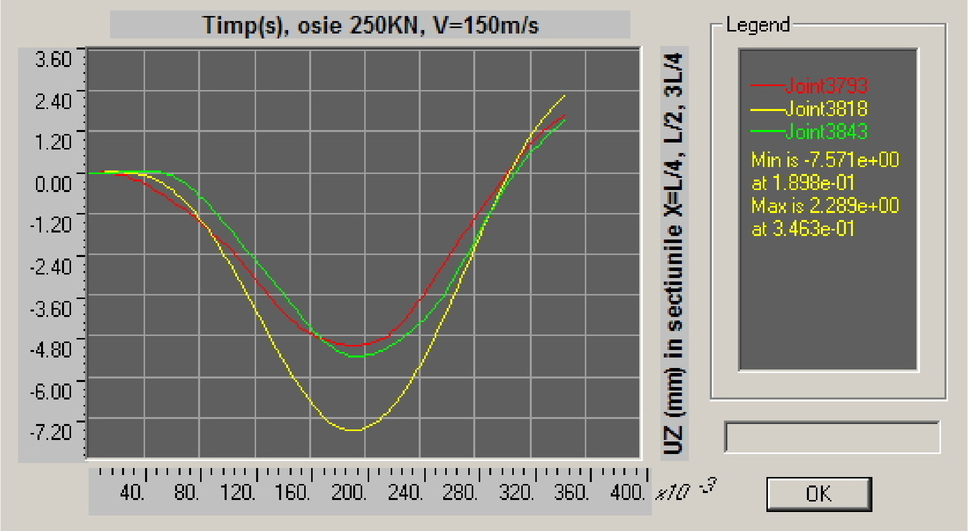
In Figure 8, the 250KN axle will cover the 50m superstructure at 60m/s and the maximum midspan deflection is 5.585 mm.

Vertical displacements of a steel-concrete railway superstructure, 51m long, under the 250KN mobile axle load, for speed ranging between 1...150m/s



Min is -5.190e+00
at 2.313e-01
Max is 6.135e-01
at 6.500e-01

Figure 9. Vertical displacements UZ(mm), P=250KN, V=80m/s (288km/h)



Min is -7.571e+00
at 1.898e-01
Max is 2.289e+00
at 3.463e-01

Figure 10. Vertical displacements UZ(mm), P=250KN, V=150m/s (540km/h)

In Figure 9, the 250KN axle will cover the 50m superstructure at 80m/s and the maximum midspan deflection is 5.190 mm.

In Figure 10, the 250KN axle will cover the 50m superstructure at 150m/s and the maximum midspan deflection is 7.571 mm.

4. OBSERVATIONS

The featured graphics allow us to notice that, as the speed increases from 1 to 150 m/s, the time needed to cover the 51m-long superstructure decreases from 51 seconds to 0.34s and the amplitude of the vibrations increases. However, the maximum reached deflections of the superstructure do not compulsorily grow together with the increase of the speed. They are influenced by the vertical position of the mid-span section within the current oscillation. Thus, if the moment the axle gets near the mid-span this section is in a position of minimum of the current oscillation, then the deflection is maximum and it is obtained from static load (that can be considered the maximum value obtained at V=1m/s, where no vibrations have been recorded) to which we add the deflection difference of the current oscillation.

The deflections recorded in the L/4, L/2, and 3L/4 sections normally grow together with the increase of the speed, but there are also speeds for which the maximum deflections obtained are lower than the ones recorded at inferior speeds. The section where the maximum deflections have been obtained is near the mid-span section, but it is not compulsory that it be in this section, as seen in Figure 11.

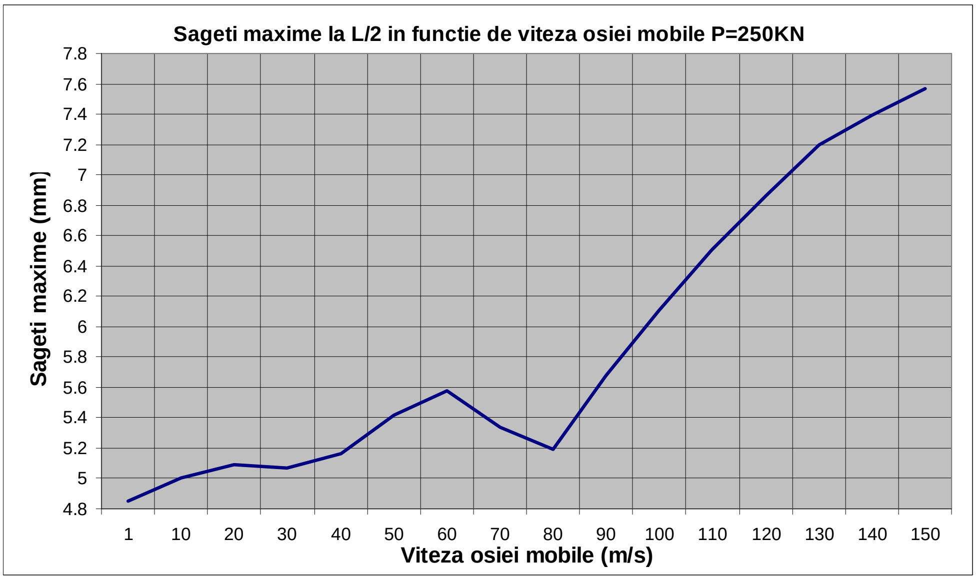


Figure 11. Maximum vertical deflections(mm) recorded at the track level, mid-span of superstructure, for a 250KN mobile axle, speeds V=1…150m/s (3.6…540km/h)

Table 1. is presented below. It features the centralization of the results obtained in the dynamic analysis made with the 250KN mobile axle that covers the 51m-long superstructure, with speeds ranging from 1-150m/s (3.6-540km/h).

Table 1. Maximum deflections recorded at the rail level.

The speed of the mobile axle P=250KN	Maximum deflections UZ (mm) measured in the L/4, L/2, and 3L/4 sections, and the position of the axle on the bridge (the covered distance) at the moment when the maximum value is recorded.						Maximum deflection measured in the rail, the covered distance and the section where the maximum value was recorded.		
V m/s (v km/h)	X=L/4 (13m)		X=L/2 (25.5m)		X=3L/4 (38m)				
	UZ(-) mm	Dist m	UZ(-) mm	Dist m	UZ(-) mm	Dist m	UZ(-) mm	Dist m	Sect m
1m/s (3.6)	3.33	22.5	4.85	26.0	3.32	30.5	4.85	26.0	25.5
10 (36)	3.43	23.0	5.00	26.0	3.43	29.0	5.00	26.0	25.5
20 (72)	3.49	21.0	5.09	26.0	3.48	31.5	5.10	26.5	26.0
30 (108)	3.59	22.5	5.07	23.0	3.61	30.5	5.09	23.0	22.5
40 (144)	3.65	20.0	5.16	29.5	3.70	29.5	5.19	29.0	28.5
50 (180)	3.82	24.0	5.42	24.0	3.62	24.5	5.47	24.5	24.0
60 (216)	3.77	28.0	5.58	28.0	3.89	28.5	5.62	28.0	27.5
70 (252)	3.72	16.0	5.34	31.5	3.97	32.0	5.38	31.5	27.5
80 (288)	4.02	18.0	5.19	18.5	3.81	35.5	5.24	18.0	23.0
90 (324)	4.26	20.0	5.68	20.0	3.71	20.5	5.72	20.0	23.5
100 (360)	4.47	21.5	6.11	21.5	4.04	22.5	6.14	21.5	24.0
110 (396)	4.64	23.0	6.51	23.5	4.36	23.5	6.54	23.5	23.0
120 (432)	4.79	25.0	6.86	25.0	4.65	24.5	6.90	25.0	24.5
130 (468)	4.90	26.5	7.20	26.0	4.93	26.0	7.20	26.0	25.5
140 (504)	5.00	28.0	7.39	27.5	5.18	28.0	7.43	27.5	27.0
150 (540)	5.08	29.5	7.57	28.5	5.42	29.0	7.59	28.5	26.5

5. CONCLUSIONS

Based on the results presented in this paper, we can say that, for the high speed trains that run at a speed that is close to 60m/s on this superstructure, it is possible that the vibrations and vertical deflections will be amplified. This amplification will be reached if the frequency with which the axles of the train get to L/2 is close to the own frequency of the first vibration mode of the analyzed structure.

The maximum deflection in the case of the analyzed superstructure is 7.59mm. This value has been reached for the speed of 150m/s (540km/h) the moment the axle had covered 28.5 of the 51m (it has been recorded in the section placed at 26.5m from the first joint).

The increase of the running speed of the mobile axle determines the increase of the amplitude of the vibrations, but this does not necessarily lead to a continuous increase of the recorded deflections of the superstructure, Figure 11 and Table 1.

The behaviour of the analyzed model from the point of view of the vibrations and of the deflection pattern corresponds to the known theoretical models.
The data offered by this paper are of interest because the second axle of the train will enter the superstructure on a deformed path that records vibrations similar to the ones featured by the graphics Figure 3 – Figure 10, according to the running speed.

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