THE STUDY OF THE BUCKLING PHENOMENON OF INDUSTRIAL RAILWAYS IN THE JIUL VALLEY

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Abstract: The compression load of straight bars, for which the cross-sections are smaller compared to their length, causes a phenomenon of bending along the longitudinal axis. Upon reaching a certain level, called the critical level of the stresses, the bending deformations begin to increase beyond the bearing limit of the bar. It yields instantly, due to an unstable elastic deformation state, although the material's resistance limit has not been exceeded. The irreversibility of the phenomenon is dangerous especially for the railway tracks and is not fully mastered by calculation methods. They can eventually establish the level of the critical demand, which has values specific to each rail configuration. It is accepted that for loads lower than this level, buckling of the respective rail does not occur. The longitudinal tension in the railway tracks occurs due to the expansion caused by their heating under the action of the sun's rays, but also due to the friction between the rails and the train wheels. This paper proposes the realization of a study model of the buckling of the railway tracks. This model is represented by an assembly, built in the SOLIDWORKS application for which a Buckling simulation was made. The imposition of two distinct temperatures on the rails and crossties is the source of the model's request. The increase in the temperature of the component parts of the assembly causes their expansion, so implicitly the appearance of some longitudinal deforming forces, specific to the buckling phenomenon.

Key words: Buckling, railway, assembly, simulation, frequent

1. GENERAL PRESENTATION OF RAILWAY TRANSPORT

Railway transport involves a complex of well-correlated and coordinated work processes, which carry out the punctual, safe and regular transport of goods and people. A train is a railway vehicle consisting of two or more wagons linked together in certain ways and set in motion by one or more locomotives. The railway represents the infrastructure of railway transport. It consists of understructure and superstructure, with the railway superstructure (figure 1) placed on the understructure.

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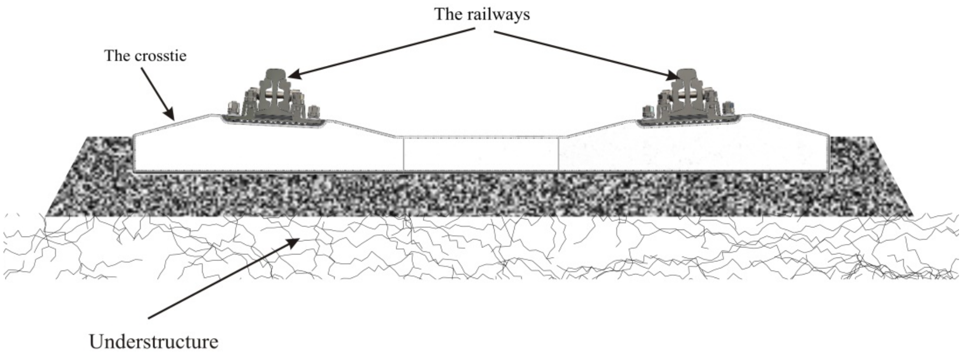


Fig. 1. Railway superstructure

Two rails placed in parallel at an equal, constant distance, called gauge, form the railway (figure 2).

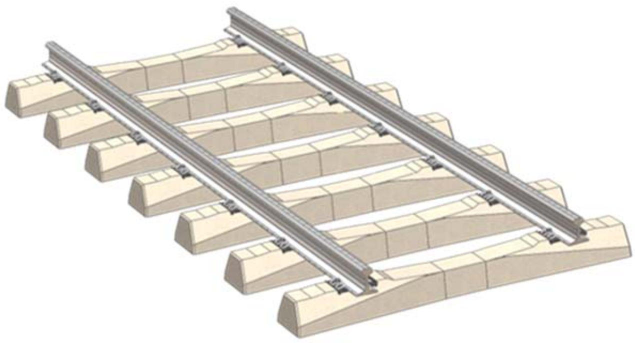


Fig. 2. The railway

The traverse can be made of wood or reinforced concrete. The prestressed reinforced concrete crossties (figure 3 and 4) have a longer service life than the wooden crossties. But these are more expensive, harder to handle and more fragile.

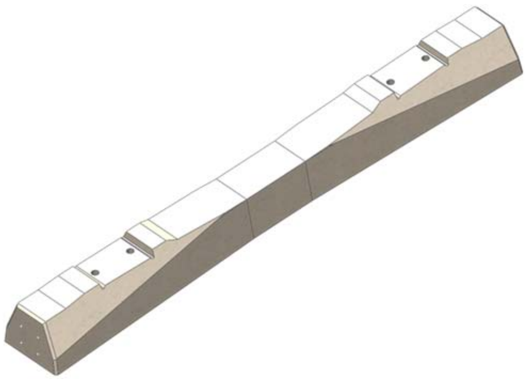


Fig. 3. Prestressed reinforced concrete crosstie

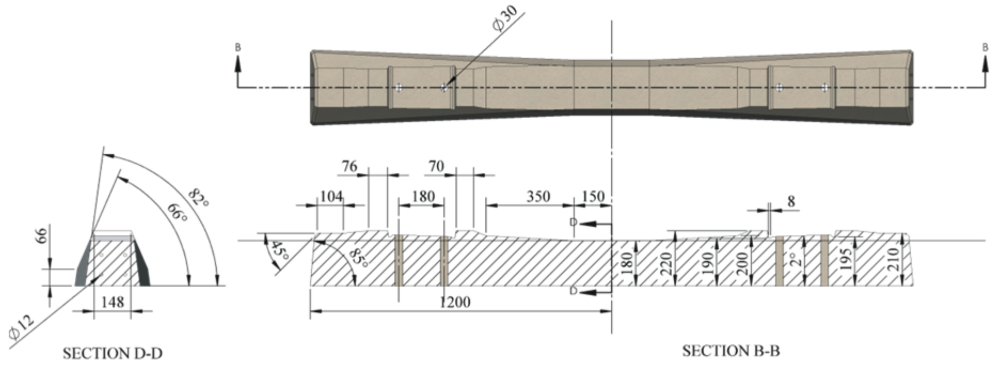


Fig. 4. The elevations of the prestressed reinforced concrete crosstie

2. SIMULATION MODEL OF THE BUCKLING PHENOMENON

In order to simulate the buckling of the railway under the action of temperature, the model in figure 5 was built in SOLIDWORKS. It is an assembly made up of parts, namely two rails and two crossties.

Fig. 5. The assembly of crossties with rails

2.1 The rail of the model

The rail is made out of alloy steel. The mechanical and thermal characteristics of the material from which the rails are made are shown in figure 6 and are automatically provided by the SOLIDWORKS application.

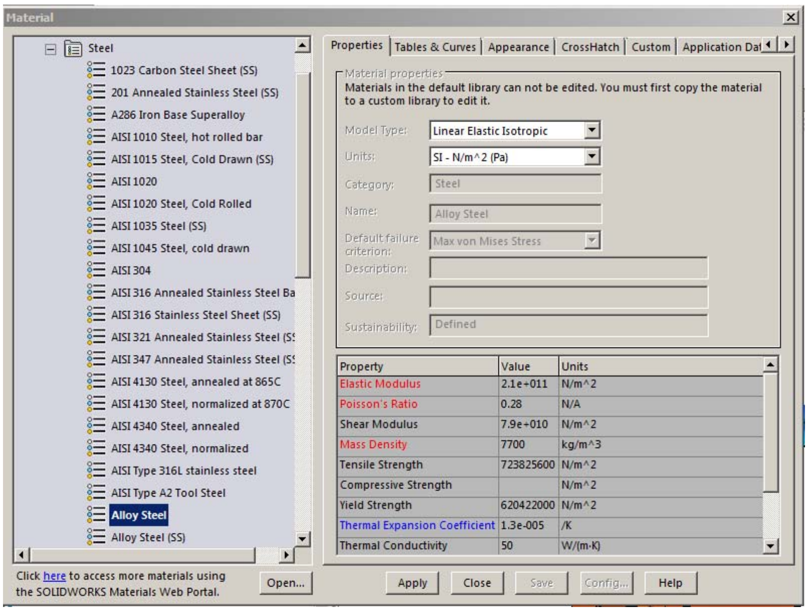


Fig. 6. Characteristics of the material from which the rail is made

2.2 The crosstie of the model

The crosstie is made of concrete, and figure 7 shows its characteristics.

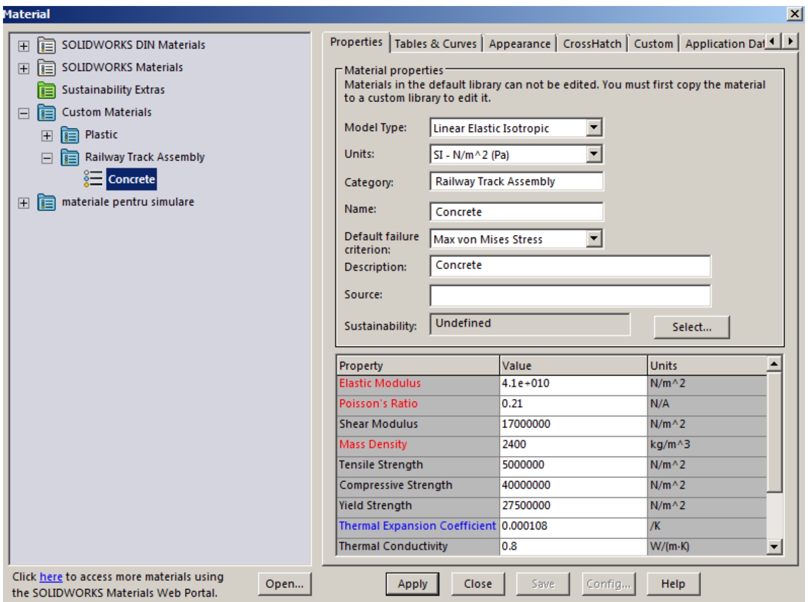


Fig. 7. Characteristics of the material from which the crosstie is made

2.3 Building the model

The model of the railway subjected to the simulation of buckling under the action of temperature consists of, as I mentioned before, two rails and two crossties. Standard geometric links (concurrence and distance) specific to the SOLIDWORKS application were established between them, as can be seen in figure 8.

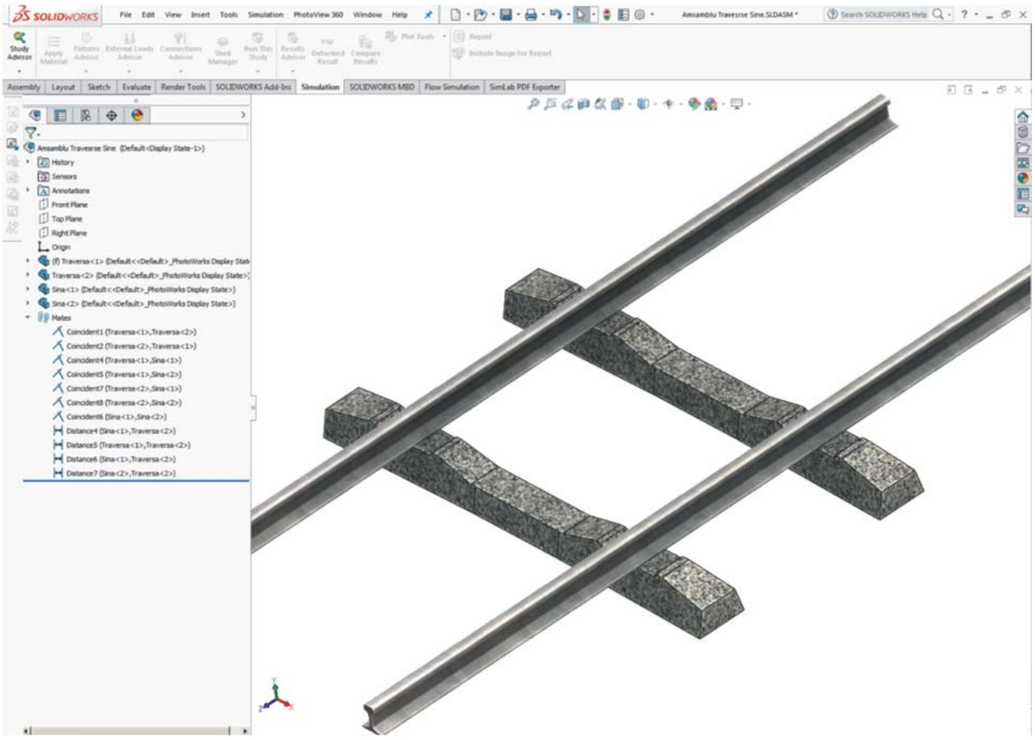


Fig. 8. Establishing the geometric links between the component parts of the assembly

3. MODELING OF THE RAILWAY BUCKLING

3.1. Establishing the buckling simulation parameters

The model presented and built in section 2 was subjected to a Buckling type simulation in SOLIDWORKS as seen in figure 9. In the simulation we considered that the rigid elements in terms of deformation are the crossties, and the assignment of this property is shown in figure 10.

It was considered that the railway tracks are fixed at the ends. Figure 11 shows how to establish this property by assigning the Fixed Geometry feature to the rail end surfaces.

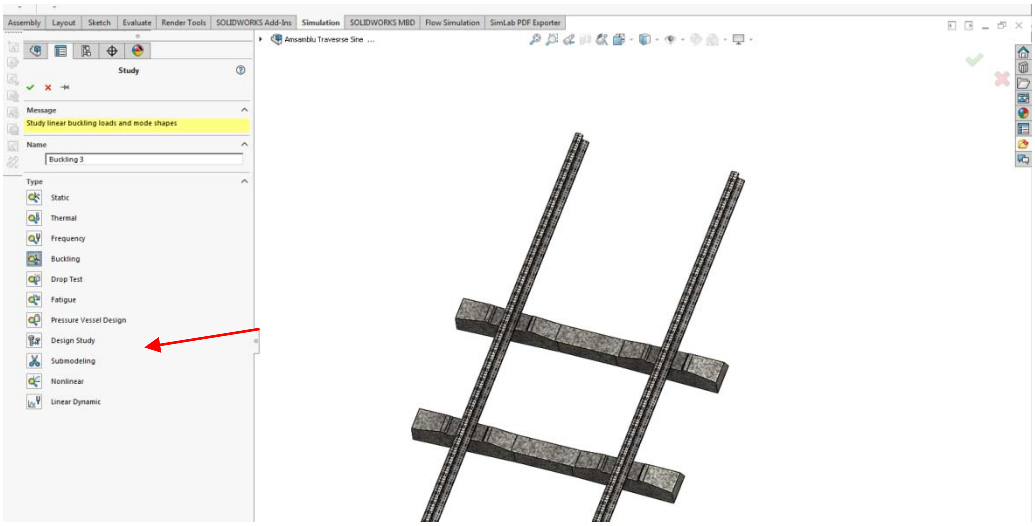


Fig. 9. Establishing the SOLIDWORKS simulation type – Buckling

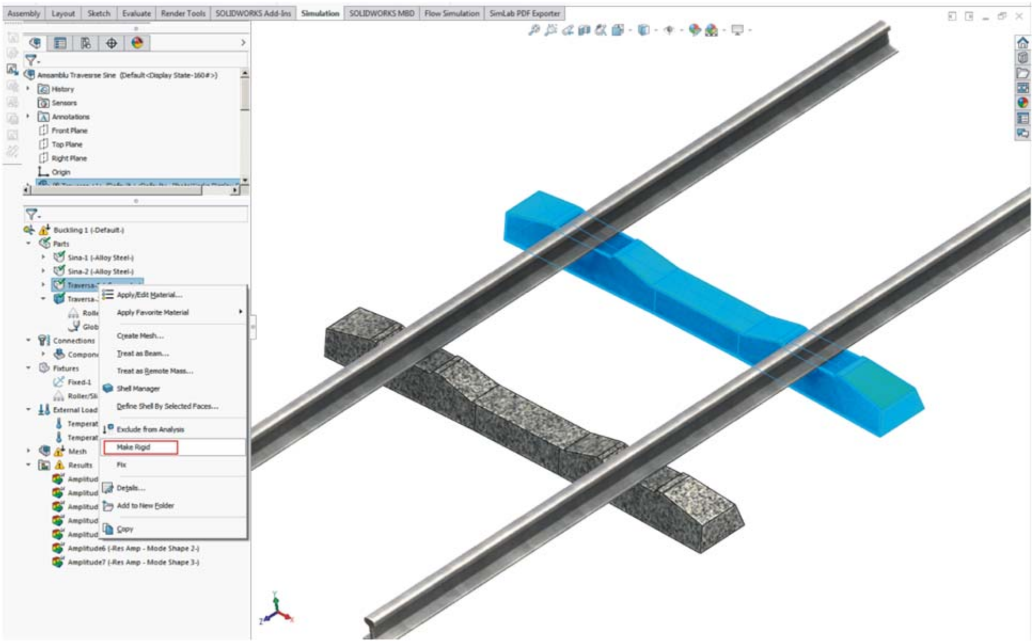


Fig. 10. Establishing the Rigid characteristic for the crossties

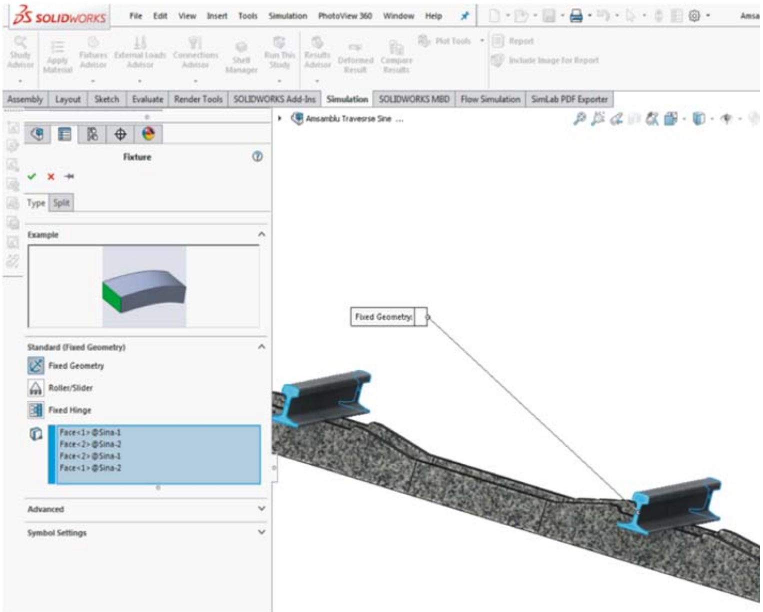


Fig. 11. Assigning the Fixed Geometry feature to the rail track end surfaces

The crosstie - railway assembly can move only in the horizontal plane during the simulation. This aspect was materialized in the simulation setting for the bottom ground contact surfaces of the crossties and for the contact surfaces of the rails and crossties, with a Roller type attaching connection as shown in figure 12.

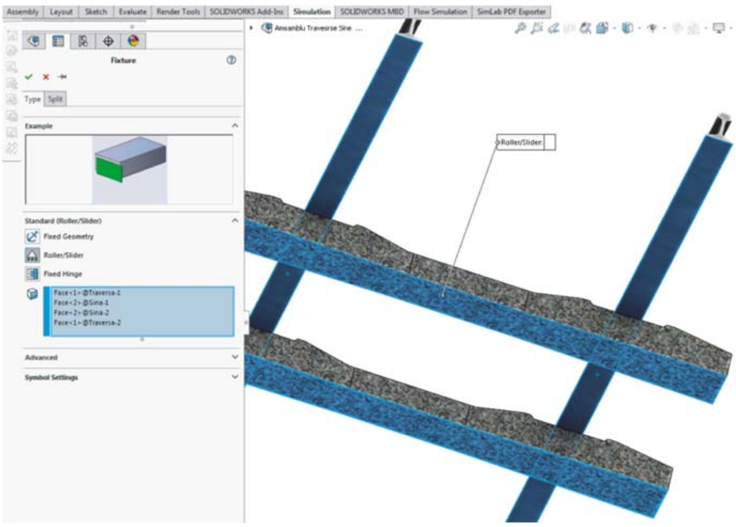


Fig. 12. Establishing the Roller type attaching connection

We simulated the heating of the rails and crossties through thermal stress. The rail has a lower temperature (figure 13) because the material from which it is built has a higher thermal conductivity than the material from which the crossties are built, which were imposed a higher temperature (figure 14).

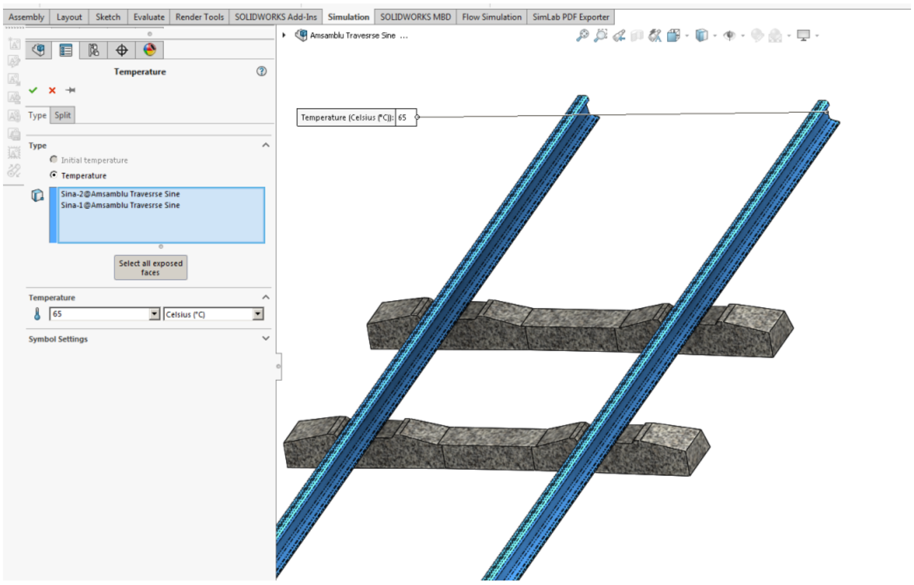


Fig. 13. Imposing the rail temperature

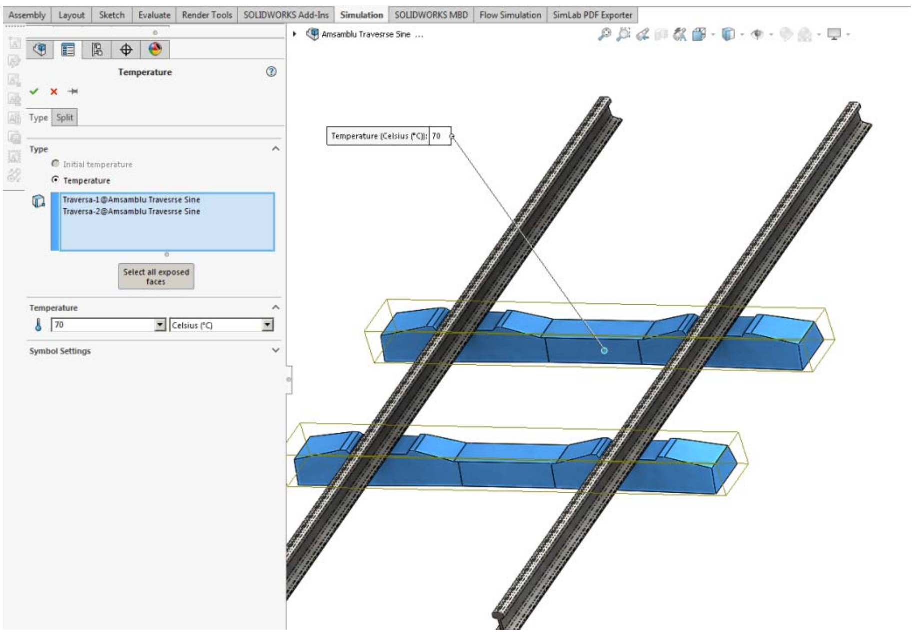


Fig. 14. Imposing the temperature of the crossties

3.2. Establishing the properties of the Buckling simulation, discretization of the model

The simulation properties were set as seen in figure 15. Accessing the option causes the window in figure 16 to open where the number of buckling modes was set to 17.

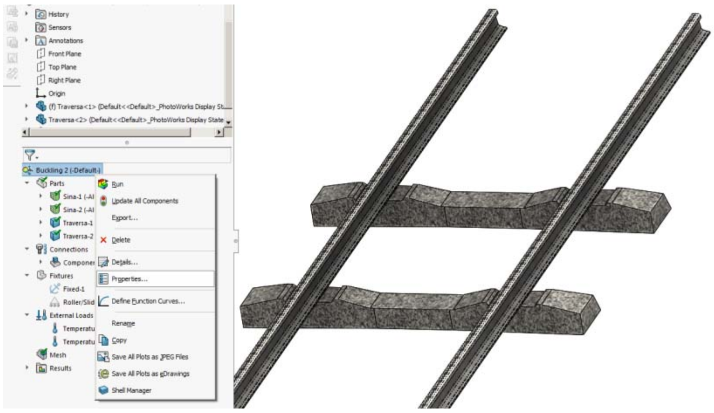


Fig. 15. Accessing the simulation options

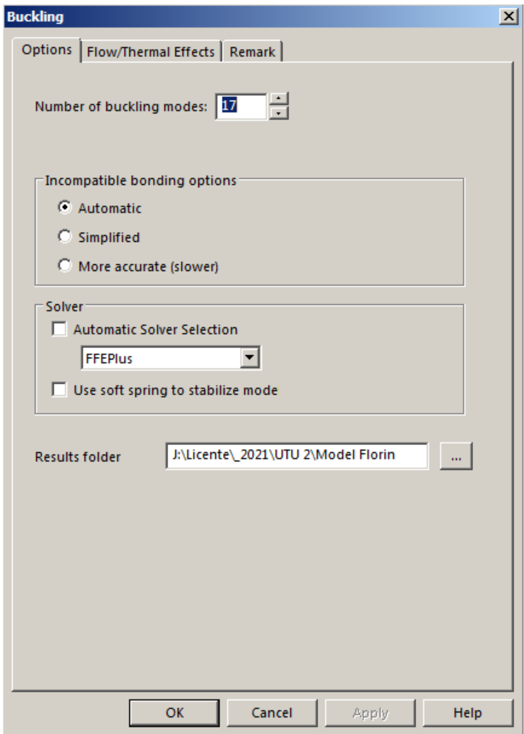


Fig. 16. Establishing the number of buckling modes

The simulation assumes in a first stage the discretization of the assembly subjected to the simulation. Different dimensions were adopted for the finite elements of rails and crossties. Figure 17 shows the obtained ensemble.

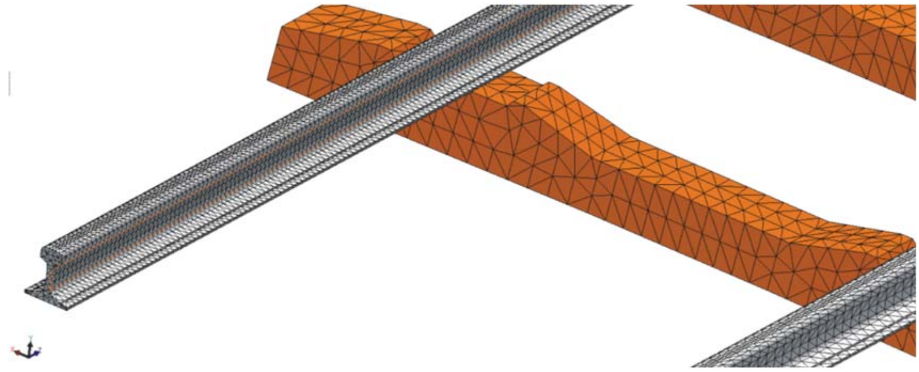


Fig. 17. Discretization of the study ensemble

4. RESULTS OBTAINED AFTER THE SIMULATION

The obtained results are presented in figures 18–34. They indicate the trend or shape of the railway deformation for the 17 buckling modes imposed.

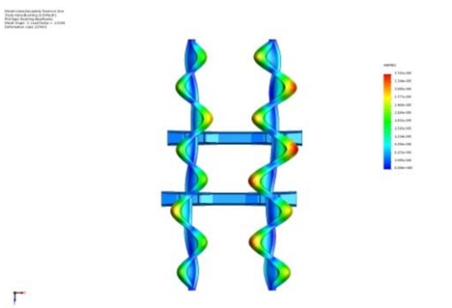


Fig. 18. Deformation of the railway for buckling mode 1

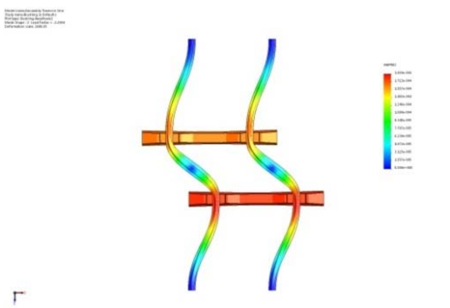


Fig. 19. Deformation of the railway for buckling mode 2

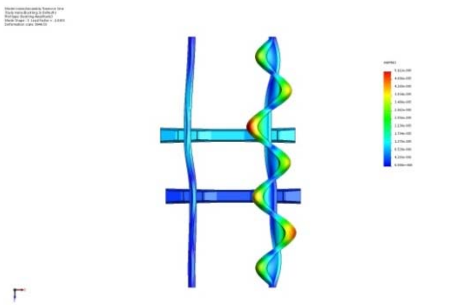


Fig. 20. Deformation of the railway for buckling mode 3

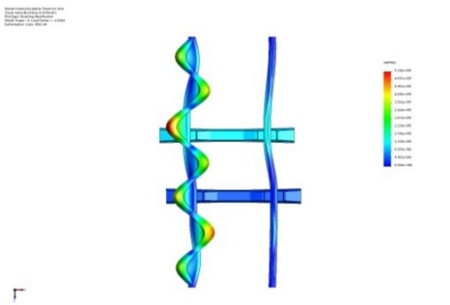


Fig. 21. Deformation of the railway for buckling mode 4

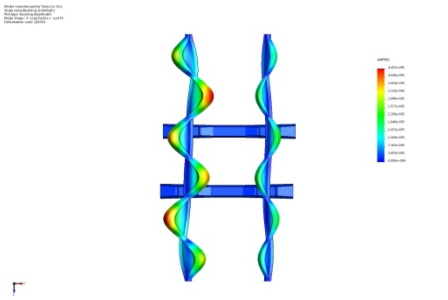


Fig. 22. Deformation of the railway for buckling mode 5

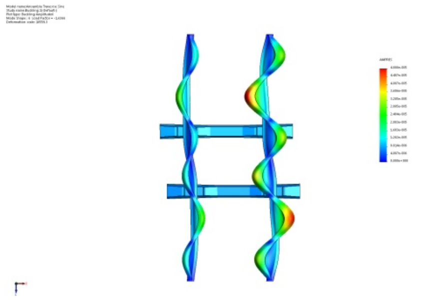


Fig. 23. Deformation of the railway for buckling mode 6

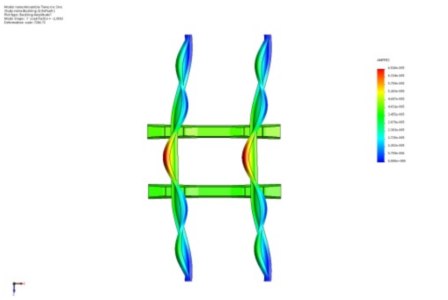


Fig. 24. Deformation of the railway for buckling mode 7

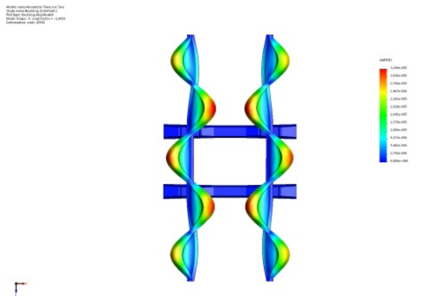


Fig. 25. Deformation of the railway for buckling mode 8

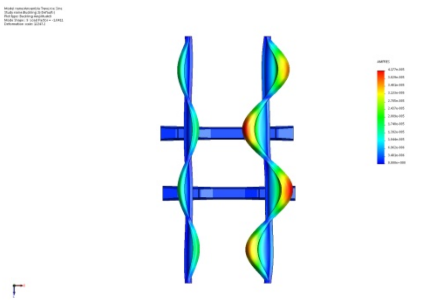


Fig. 26. Deformation of the railway for buckling mode 9

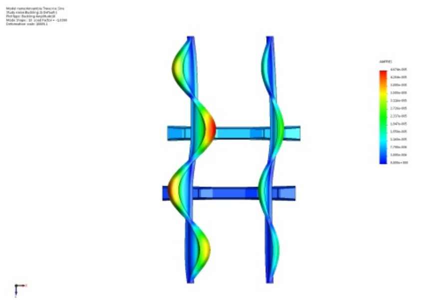


Fig. 27. Deformation of the railway for buckling mode 10

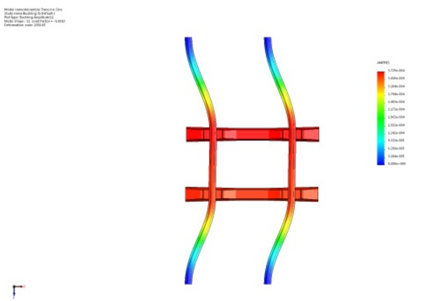


Fig. 28. Deformation of the railway for buckling mode 11

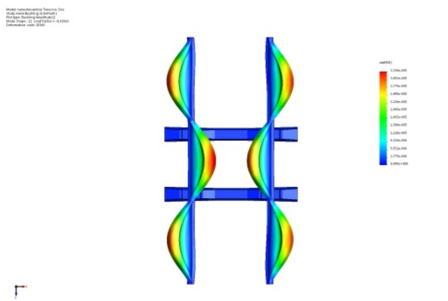


Fig. 29. Deformation of the railway for buckling mode 12

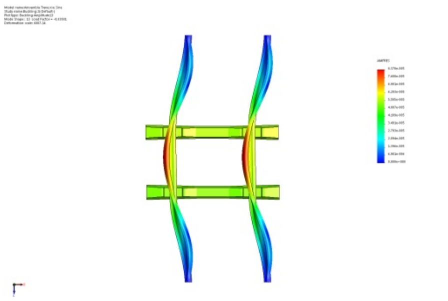


Fig. 30. Deformation of the railway for buckling mode 13

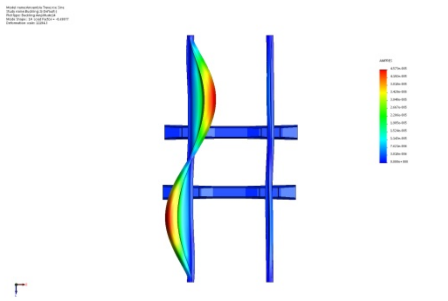


Fig. 31. Deformation of the railway for buckling mode 14

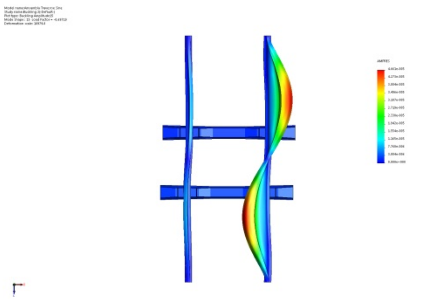


Fig. 32. Deformation of the railway for buckling mode 15

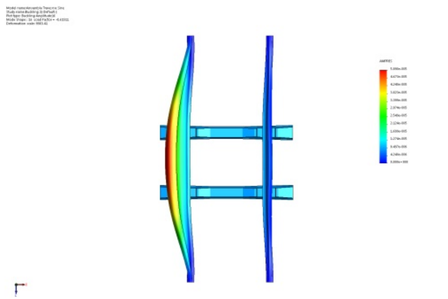


Fig. 33. Deformation of the railway for buckling mode 16

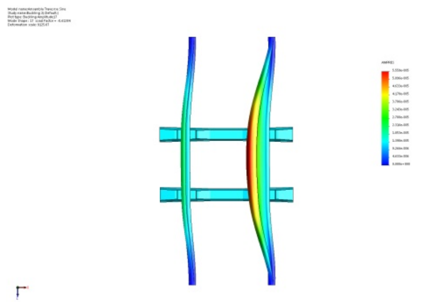


Fig. 34. Deformation of the railway for buckling mode 17

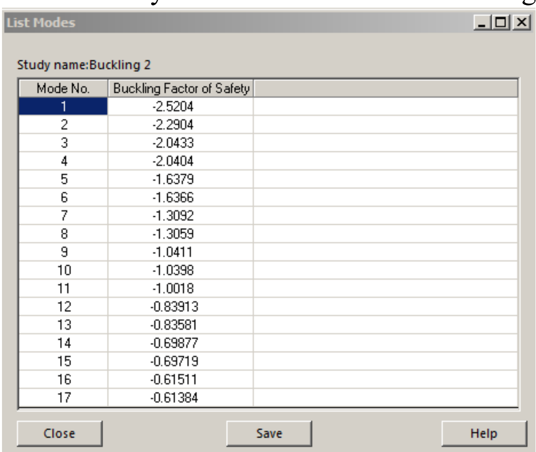
Table 1 shows the maximum buckling amplitudes corresponding to modes 1−17. As can be seen, the table is sorted in ascending order according to the size of the deformation. Thus, it can be noted that the amplitude of the largest deformations due to buckling, correspond to modes 11 and 2.

Correlating this observation with the shapes of the deformations shown in figures 19 and 28 respectively, we can draw the conclusion that the maximum deformations due to buckling correspond to those shapes that show a displacement of the crossties in the plane horizontally. Of these two cases, the maximum deformation occurs when the two crossties move in the same direction.

Table 1 **Maximum buckling amplitudes**

No.	Buckling mode	Deformation [mm]
1	*11*	3.72E-04
2	*2*	1.87E-04
3	13	8.40E-05
4	7	6.90E-05
5	17	5.50E-05
6	4	5.34E-05
7	3	5.10E-05
8	16	5.10E-05
9	6	4.80E-05
10	10	4.60E-05
11	14	4.60E-05
12	15	4.60E-05
13	5	4.40E-05
14	9	4.17E-05
15	1	3.70E-05
16	8	3.30E-05
17	12	3.30E-05

Figure 35 shows the safety factor values for each buckling mode.


List Modes

Study name:Buckling 2

Mode No.	Buckling Factor of Safety
1	-2.5204
2	-2.2904
3	-2.0433
4	-2.0404
5	-1.6379
6	-1.6366
7	-1.3092
8	-1.3059
9	-1.0411
10	-1.0398
11	-1.0018
12	-0.83913
13	-0.83581
14	-0.69877
15	-0.69719
16	-0.61511
17	-0.61384

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Fig. 35. Safety factor values depending on the buckling mode

Analyzing the values in figure 35, shows that the lowest safety factor corresponds to buckling mode 1, despite the fact that this mode does not have the largest deformation of the assembly shape.

CONCLUSIONS

The phenomenon of longitudinal buckling is a specific one, with an irreversible character, involving mechanical yielding under a certain stress. Buckling often has catastrophic consequences for railways. For the study of this phenomenon that can also occur due to an expansion generated by thermal stress, we built a model for simulating the buckling of railway tracks in SOLIDWORKS, performing a Buckling type simulation. In order to obtain a more complete picture of the buckling phenomenon, we set the number of modes to 17. The request of the model is a thermal type and it is obtained by imposing two distinct temperatures on the rails and cross members of the assembly. Increasing the temperature of the component parts of the assembly causes their expansion. Following the dilation, longitudinal deforming forces appear that are specific to the buckling phenomenon.

For the considered model, it is found that the amplitude of the largest deformations due to buckling correspond to modes 11 and 2. From the analysis of the shape corresponding to these modes, it is observed that both show a displacement of the crossties in the horizontal plane. The maximum value of the deformation amplitude is obtained if the two crossties move in the same direction. Buckling mode 1 has the lowest safety factor, although this mode does not determine the largest amplitude deformation of the shape of the assembly under analysis. The presented method can be applied to other railway configurations, which require a different shape of rails, a different shape of crossties, other materials from which they are made, but not least, the imposition of other temperatures as sources of longitudinal stresses.

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