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Study by Numerical Mean of the Behavior of the Twin-Block Sleeper Used In the Superstructures of Railways

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Abstract: *The study of the behavior of a reinforced concrete sleeper is one of the most important researches in the field of transport. Because of the passage repeats trains, degradations are observe throughout the railway on this element. These degradations depend mainly with the mechanical actions due to the traffic which they can threaten comfort and safety of the passengers and require high costs of maintenance to return the way to its initial geometry. Our study consists in working out a three-dimensional nonlinear numerical model based on the MEF and using software ANSYS able to take into account the nonlinear behavior of a Twin-block sleeper. The results of the numerical model will be validated by the experimental results of other studies and consolidated the observations concerning the behavior of the sleeper.*

Keywords: *Twin-block Sleeper, Railway, Finite Element, Nonlinear Static behavior, reinforced concrete.*

1. Introduction

To take into account all expenses which are subject sleepers (random dynamic overloads wheels, wheel flats, crossing hollow welds, shocks), the SNCF requires concrete sleepers able to withstand heavy traffic, fast (200 km / h and above) [1] and withstand a load equal to four times the rated load of the wheels of one axle loaded at 25 t or 440 kN, [6]; to this end both approval tests will be presented.

1.1. Inflection Test under Static Head Positive

It is about an inflection test under static head carried out at the place of a small block. The rise in load will be made by stage of 10 kN starting from 120 kN, each stage of load will be maintained at least one minute (Figure 1), [5].

The experimental load maximum FrB = 588 kN is applied perpendicular to the base of the sleeper, [7]. In the experiments, a steel dish was used to distribute the load to the small block. The supports were regarded as a simple support.

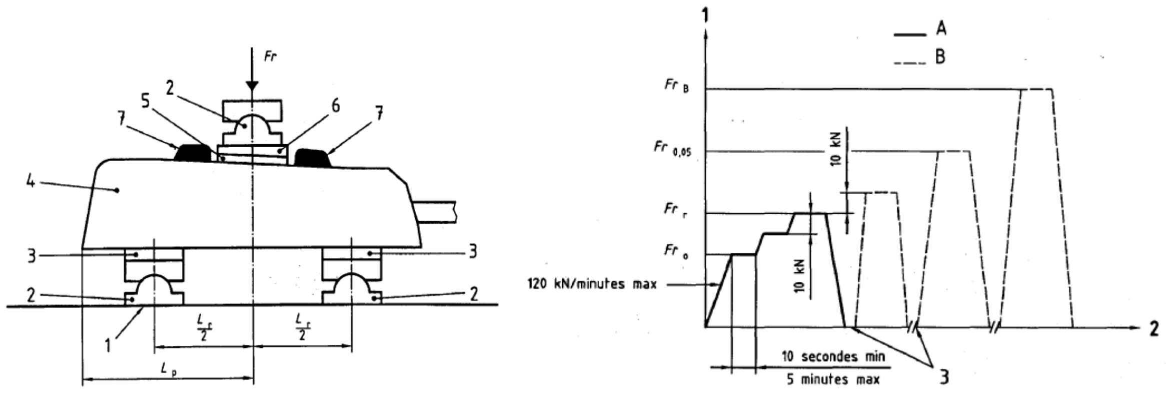


Fig. 1: Inflection test under Static head Positive [5].

1.2. Inflection Test under Static Head Negative

It is about an inflection test under static head carried out to the back of a small block of the same sleeper but for the other side. (Optional Test carried out at the request of the customer), [5].

2. Modeling By MEF, Static Loading and Boundary Conditions

Knowing that the Twin-block Sleeper is symmetrical compared to a plan perpendicular to the brace, a half of the sleeper is treated for the model of finite element [11, 12], adopted by ANSYS 11.0 [2].

The grid of the model is represented by 57477 elements (figure 3). The intermediate size of an element of grid is of 1 cm, which enables us to model our model correctly, the grid is composed of three groups of elements of various materials, the concrete (solid65), brace and the supports (solid45) are built by quadratic elements. Reinforcement is presented by elements bars (link8) [3, 9]. This choice can guarantee a good performance and reduces the computing time and the space of hard drive significantly.

The boundary conditions of symmetry one placed in the plan of symmetrical "OXY", the nodes from this point of view must be blocked in the direction of Z. These nodes were given normal displacements Uz = 0. Concerning displacements of the nodes at the base are simply supports [10].

In the static case the load applied to each node is (Q/N) total load, (N: number of the nodes of the plate act with the loading Q =588 kN), (Figure 2) [10].

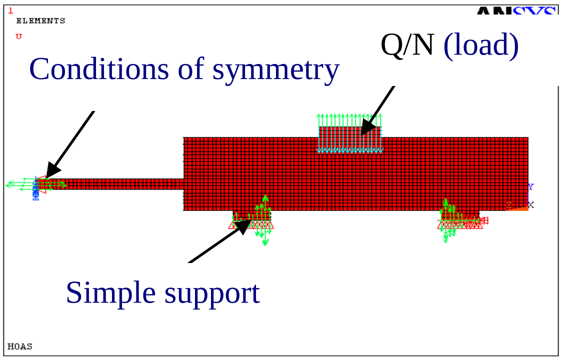


Fig. 2: The limiting loading and conditions

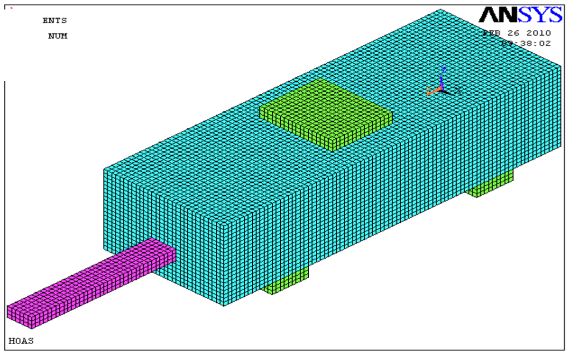


Fig. 3: Grid of a half-model.

3. Results Obtained by ANSYS for the Twin-block Sleeper

The figure 4 presents the distribution of the stress in half-sleeper, under the effect of the external loading. Considering the symmetry of the problem, the stress has also an axial symmetry.

The figure 5 represents the strain of half- sleeper, under the effect of the external loading. Considering the symmetry of the problem, the strain has also an axial symmetry.

The figure 6 represents displacements of half- sleeper, under the effect of the external loading. Considering the symmetry of the problem, displacements have also an axial symmetry.

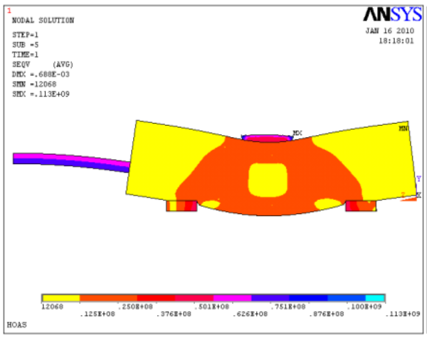


Fig. 4: Stress.

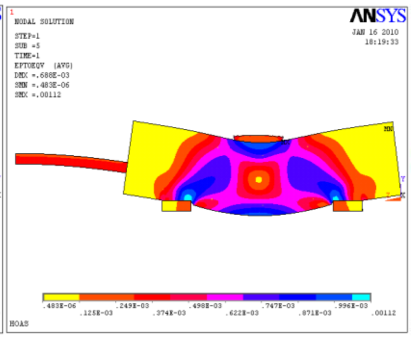


Fig. 5: Strain.

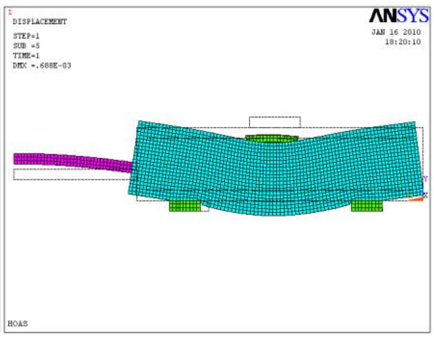


Fig. 6: Displacements.

3.1. The List of the Results Obtained

The results obtained by ANSYS, are given in each node (nodal results). Our objective is to know the nodes most requested and most deformable under this type of loading. This point, one draws all the list from displacements, stress and strain for each step of loading (load step), and for each node then the most unfavorable results are extracted. The results obtained are summarized in table 1.

TABLE I: Results obtained Load, Displacement, stress and strain.

load (N)	Displacement (mm)	stress (N/m^2)	strain (0/$_{00}$)
100000	1,358	4,27E+07	7,33E-03
200000	2,879	5,52E+07	0,01047
300000	3,928	6,41E+07	0,01353
400000	4,668	7,00E+07	0,01669
500000	5,446	7,71E+07	0,02713
588000	7,773	8,13E+07	0,07423

3.2. Diagrams Load- Displacement, Load - strain And Discussions

The figure 7, gives the curve of the variation of the arrow according to the load of the sleeper. One notes three modes of the behavior and the values of these three modes are represented in table 2:

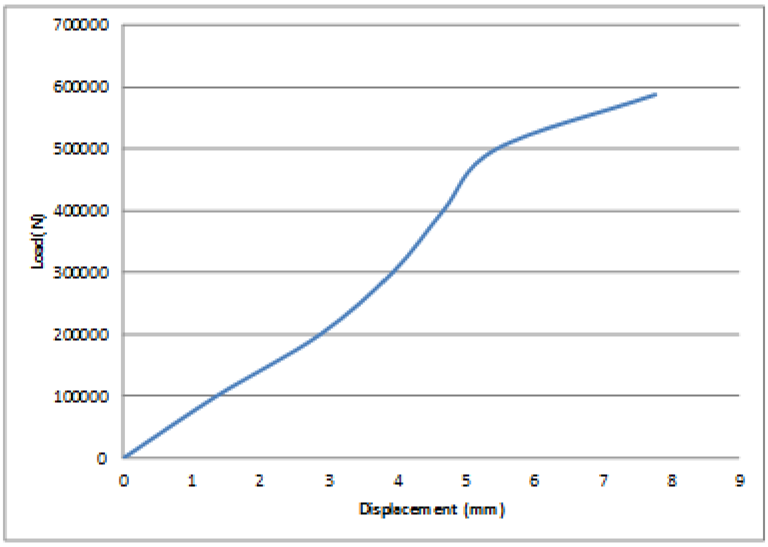
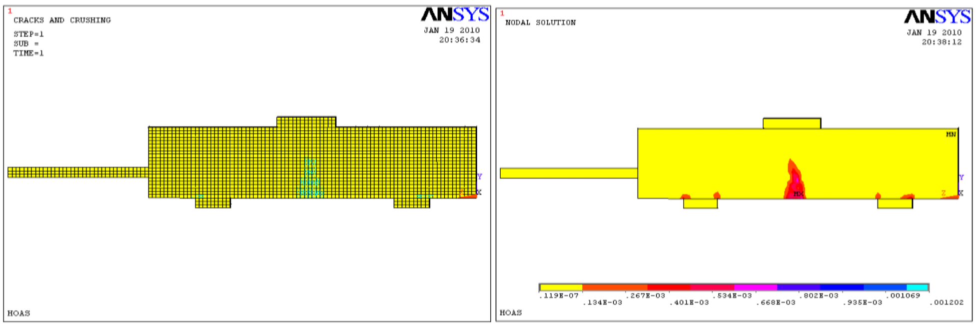
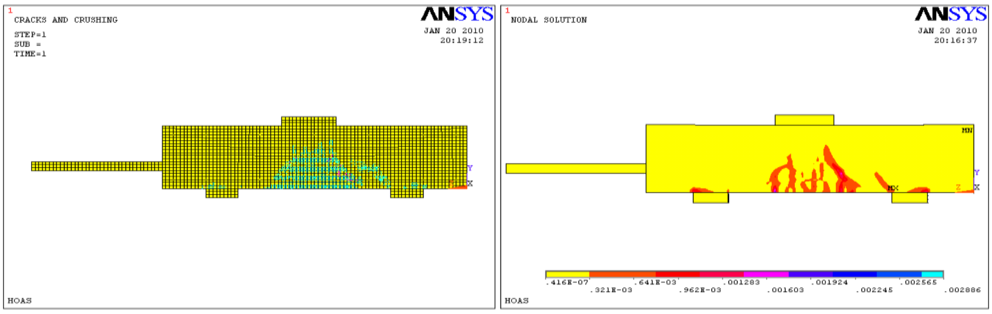


Fig. 7: Curve load-displacement for the sleeper.

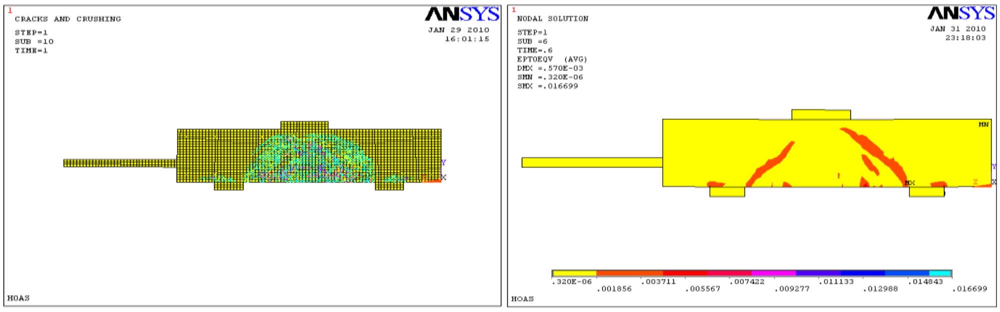
- A mode reinforced concrete not fissured, or the arrow grows linearly with the load until approximately 30% of the maximum loading. This phase extends to 200 kN with the appearance of the first ascending vertical cracks (Figure 8 (a)), the arrow reached is of 2,879 mm; correspondent with an elastic flow of the reinforced concrete sleeper.
- A mode fissured reinforced concrete, linear-parabola, one to note a fast increase in the arrow going up to 5.446 mm with the appearance of the first cracks inclined for a loading of 500 kN (Figure 8 (b)). Until the absolute limit of service; correspondent with an elastoplastic flow of the reinforced concrete sleeper, another important claim which should be mentioned is that steel reached the elastic limit.
- A plastic mode reinforced concrete fissured after the plasticization of steels of inflection and beyond a load of 588 kN, Until the ultimate absolute limit, One observes a quick change of the arrow due to a plastic flow, the arrow reached is of 7,773 mm (Figure 8 (c)).



(a) First cracks to 200 kN.



(b) First cracks inclined to 500 kN.



(c) Cracks with the load 588 kN.

Fig. 8: Progression of the cracks for the sleeper

The figure 9, expresses the curve of the evolution of the strain of the sleeper according to the load. One notices a first linear part of the curve, a radial force between (0 - 200) kN, giving a strain between (0 - 0,01047 ‰). This phase to correspond to the phase of the reinforced concrete not fissured. For load going of 200 kN up to 500 kN, one notices an important strain going until (0, 02713 ‰), it is the phase of the fissured reinforced concrete. Beyond of a load of 500 kN, one notes a very important strain (0, 07423 ‰), it is the part of the plastic fissured reinforced concrete. The values of these three modes are represented in table 2.

The figure 10, expresses the curve of the evolution of the strain of the sleeper according to the constraint. One notices a first linear part of the curve, this phase to correspond to the phase of the reinforced concrete not fissured. A second part linear-parabola, it is the phase of the fissured reinforced concrete. Third part horizontally flattened linaire, it is the phase of the plastic fissured reinforced concrete. The values of these three modes arerepresented in table 2.

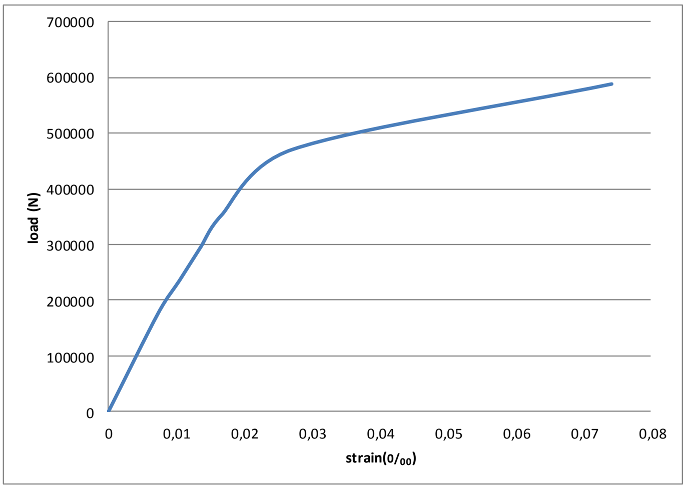


Fig. 9: Curve load- strain.

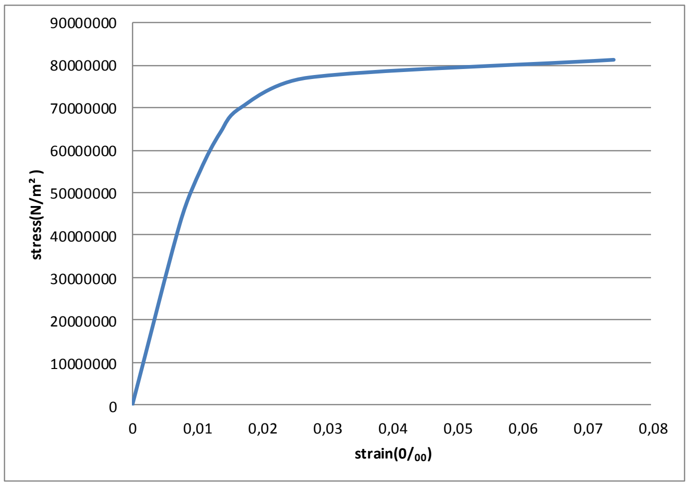


Fig. 10: Curve stress - strain.

TABLE II: who gives the values of the three modes obtained, Displacement, stress and strain.

load (KN)		Displacement (mm)	stress (N/m^2)	strain ($0/_{00}$)
1st crack	200	2,879	5,52E+07	0,01047
1st cracks inclined	500	5.446	7,71E+07	0,02713
final cracks inclined	588	7,773	8,13E+07	0,07423

3.3. Analyzes Results

In light of the results shown by the curves before it, one can a priori initially make the comparison between the values of different the three modes obtained and one finds the four stages of load Fr_0 ; Fr_r ; $Fr_{0,05}$; $Fr_{0,5}$ (ou Fr_B) [5].

- The Fr_0 values = 100 kN (loads designs) will define the stages beyond of which one will have noted under load the appearance of a no initial crack.
- The Fr_r values = 200 kN will define the stages beyond which one will have noted under load the appearance of the first crack.
- The $Fr_{0,05}$ values = 500 kN will define the stages beyond whose a crack at least, will not be closed again after unloading (opening 0,05 mm).
- The values $Fr_{0,5}$ (or Fr_B) = 588 kN will define the stages beyond whose a crack at least will present after unloading an opening ≥ 0,5 mm.

The criteria of acceptance for the static tests under rail are checked:

- $Fr_r > Fr_0 \geq 180$ KN (18 t) ; for the moment of inflection positive
- $Fr_{0,05} > k1S * Fr_0 \geq (234*1.8 = 421$ KN)
- $Fr_{0,5}$ (ou Fr_B) $> k2S * Fr_0 \geq (234*2.5 = 585$ KN)

4. Comparative Study with Other Research

One will take here some experimental results, carried out on reinforced concrete sleeper realized by Kaewunruen, Sakdirat, [7]. [8] These experimental results were used as a basis of comparison for the results obtained by software ANSYS.

Graphics of the figure 11, 12 gives the experimental results charges displacement with the Positive Static Test on Section under Rail.

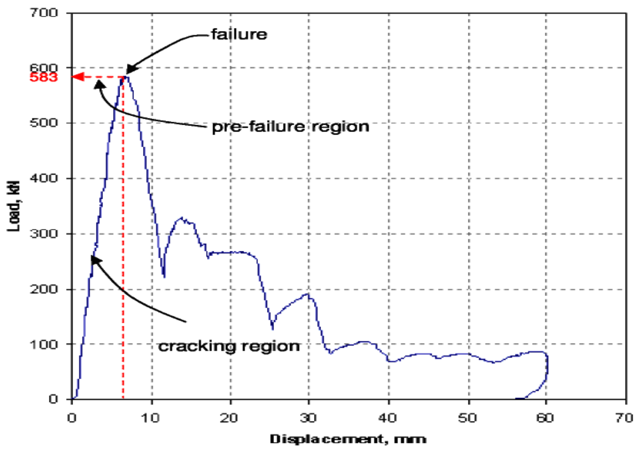


Fig. 11: curve of load-displacement [7].

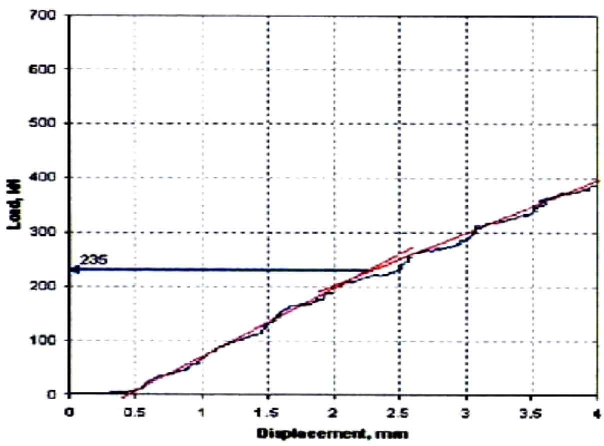


Fig. 12: The load of steel release [7],

4.1. Comparison between Numerical and Experimental Study

The results of the numerical model are compared with the experimental results. Tables 3,4 presenting the whole of the numerical and experimental results of the sleeper.

TABLE III : values of the three numerical, experimental modes of the sleeper.

/	load 1st crack (kN)	Arrow 1st crack (mm)	Load 1st cracks inclined (kN)	Arrow 1st cracks inclined (mm)	load final cracks inclined (kN)	Arrow final cracks inclined (mm)
EXP	200	2,000	500	5.200	583	7,000
NUM	200	2,879	500	5.446	588	7,773

TABLE IV : numerical, experimental results of load-displacements.

Load (N)	Displacement (mm)		Relative error (%)
	NUM (ANSYS)	EXP	
100000	1,358	1,200	11
200000	2,879	2,000	30
300000	3,928	3,200	18
400000	4,668	4,400	5
500000	5,446	5,200	4
588000	7,773	7,000	10

The following curves compare the numerical and experimental results.

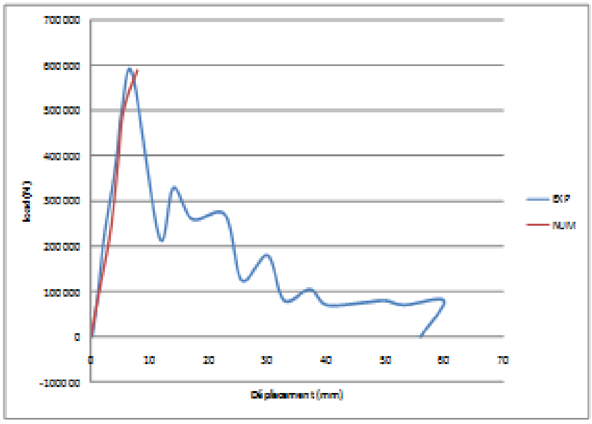


Fig. 13: Comparison of the curves loads arrow with numerical model and model experimental.

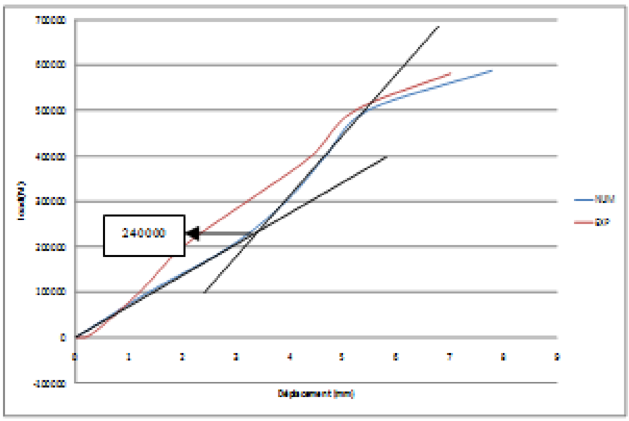


Fig. 14: The load of numerical and experimental steel release.

4.2. Discussions

Graphics of the Figure 13 compare the numerical and experimental results. It is noticed that the total behavior of numerical modeling is very close to that of the tests laboratory with variations on displacements, and this for the various stages of the loading of the sleeper. This shows that the model of finite elements used in this study is adequate. The curve of the experimental results is stiffer than that of the results of the analysis of finite elements by roughly average 13%. On the other hand, numerical calculation detects well a rupture in on this side found values.

In the linear field, the arrow obtained of the load of first crack for the model of finite elements is of 2,879 mm, in comparison with the arrow of 2,000 mm for the experimental results (either a reduction of 30%).

After the first crack, until the absolute limit of service; correspondent with an elastoplastic flow of the sleeper, the experimental curve is even stiffer than the curve of the model of finite elements by 09%. With a load of 500 kN, the arrow obtained is 5,446 mm for model EF and 5,200 mm for the experimentation.

One notes the plasticization of steels and the reduction in the rigidity of the sleeper. The final load is of 588 kN for an arrow of 7,773 mm for model EF is lower than the final load of 588 kN for an arrow of 7 mm for the experimental sleeper (either a reduction of 10%).

The load of steel release was detected numerically by the use of the relation of load-displacement, which be defined like intersection enters stage I and II [4], as represented on the Figure 14. This method provides a load slightly higher which that to find in experiments. Comparisons of the loads of steel release: numerical 240 kN and experimental 235 kN (Figure 12), showed a very good agreement.

5. Conclusions

This research studies the static behavior of a Twin-block sleeper of reinforced concrete, with the use of non-linear material properties and the ANSYS11.0 calculation code. The model of finite element of a reinforced concrete sleeper was developed; the concrete, the plate's steels and the wire of reinforcements were modeled by using elements SOLID65, SOLID45 and LINK8, respectively. The method of iteration of balance of Raphson Newton was employed in the analyzes of convergence of the numerical iterations.

Positive the Statique test On Section under Rail was carried out, to evaluate its execution under such a loading.

The results of numerical modeling obtained by software ANSYS show overall a reasonably good agreement with the experimental test results.

6. References

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