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Mechanical behaviour of railway track

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Abstract

Stone pathways are very widely used in the railway sector because of their flexibility of the construction or maintenance point of view. To improve the effectiveness of this structure, it is necessary to control the mechanical behaviour of this complex structure whose traffic loads are transmitted to the platform (ballast and in adjacent layers) beams rail and the ties spaced regularly. In this study we propose a two-dimensional model simulating the structure path under environment Plaxis finite elements according to the boundaries conditions of the problem and idealizing the passage of the infinite to a finite beam which the extension of the rail consists of a rigid steel of (L) length based on spring of stiffness K whose response is similar to the infinite semielastic support continuous beam. This model is improved with consideration of the rigidity of the blocks in rotation. The analysis is carried out first in the elastic field, then we analyzed the structure with plastic deformation. Apparametric analysis is performed on the thickness of the layers, on the constant mechanical "E" and "υ", interaction of two blochets……...
The comparison of this model is made from tests carry out on site. The results are very satisfactory. Parametric analysis is performed on the different mechanical parameters on thickness of layers.

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Keywords: Beam rail; ballast; finite elements; plasticity; plaxis, reaction modulus.

1. Introduction :

A Sizing and rail structures maintenance procedures require methods of predictions of the mechanical behavior under the influence of loads simulating the action of trains. The main interest of these methods is to determine the settlement of structure induced by traffic loads. The simplest representation of a continuous linear foundation is the Winkler model[1], in this model rail is represented by an infinite beam of Euler – Bernoulli supported by a

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continuous linear elastic foundation. The physical shortcomings of the Winkler model enabled, several authors propose discrete models of the railway, in these models we include the model predict by (G.SAUVAGE)[2] , which may take into account the interaction between the ties. The established formula is based on Boussinesq theory for a multi-layer soil [3] and [4]. To identify the settlement of the ballast in the vertical plane, a trial of a third part, entitled "Micro ballast", proposed by Guerin[5]. The results of this test are used to establish the settlement of the ballast that connects an increment of settlement to the elastic deflection of the whole formed by the ballast and soil on which it rests. The parameters involved in the loading, the quality of the soil supporting the ballast and the thickness of the layer of ballast are discussed. V. Bodin [6] two laws of lateral compaction of the ballast: a valid after few cycles of loading and the other adapted to a large number of cycles. The sum of these two acts to describe the overall behaviour of the ballast under loading. These laws are in agreement with measurements made in the process. The main purpose of this paper is to present a digital model under environment Plaxis. A parametric analysis is performed in order to highlight the influence of some parameters on the deflection. The results of this model have been confronted to many others and they are satisfactory.

2. Description of the structure model of the rail road :

The track is considered a bilayer (Ballast, soil) structure, with blocks in concrete based on the layer of ballast.
blocks are regular spacing of 0. 6 m figure1.

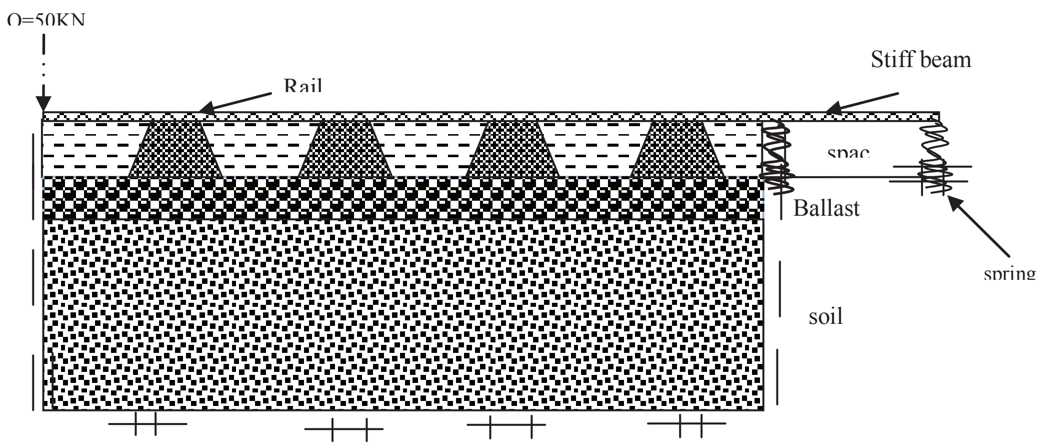

Figure.1: Structure modelling of the railway by Plaxis

The geometrical and mechanical characteristics of the different layers and the rail beam are presented in Table1.

Matérials	E(Mpa)	I (m^4)	μ	γ (KN /m^3)	Thickness (m)
rail	$2,10^5$	$30,55\ .10^{-6}$	-----	------	----
Blochet	4.10^4	--------	0.2	25	0.26
Space	10^{-4}	---------	0.2	0.1	0.26
Ballast	450	---------	0.3	18	0.3
Sol	30	----------	0.4	18	1.4

Table1 :Physical parameters of structure

The choice of the thicknesses of the layer's materials, as well as their mechanical characteristics have been taken from SAUVAGE data. The analysis will be performed on a portion of the structure rail way which should reflect the mechanical behaviour of the infinite beam. The analysis and the implementation of boundary conditions is therefore important to be able to simulate the actual mechanical behavior.

3. Boundaries conditions

Under the effect of vertical load Q representing the result of the load for the structure from the wipers. The rail on periodic support beam (blocks resting on ballast) is an axisymmetric problem.
We analyze the half of the structure involving that charge taken into consideration is Q/2 by issuing the following boundary conditions.

- Only the vertical displacement of the structure at the point of load application is authorized.
- Horizontal movement zero following the lateral limits of the model.
- The rotation is blocked at the level of the axis of symmetry.
- Based on discrete support outside a vacuum between the rail and ballast is idealized by a constant low mechanical characteristics.
- The rail is extended by the equivalent system (based on springs) whose behaviour resulting under the action of a vertical effort and a time will be similar to the semi-infinite beam. Thus it is necessary to assess the length L of the beam and the rigidities of the K springs.

4. Evaluation of the parameters L and K of the numerical model equivalent to an elastic semi-infinite beam on support.

The evaluation of the parameters the length 'L'of the beam and the rigidity of the 'K' support will be as folows:

:

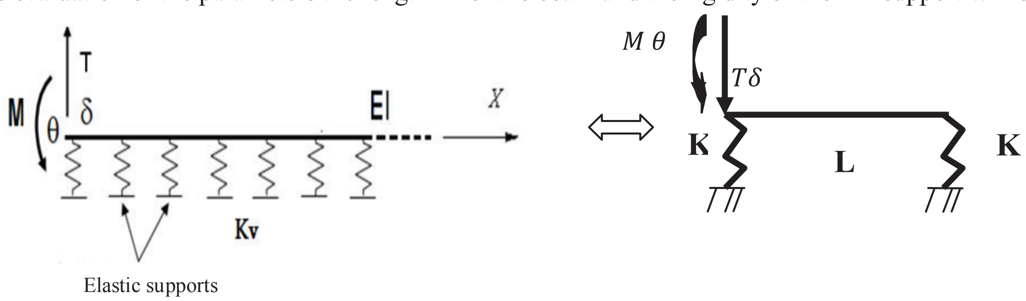

Figure 2 : System beam on springs equivalent to a semi-infinite beam on elastic supports

T: vertical external force
M: Outside moment
δ: vertical displacement associated with the application of T
θ: rotation associated with the application of M
The evaluation associated with the vertical force T vertical displacement δ and θ rotation associated with the time M can be described by equation (1) :

$$\begin{Bmatrix} \delta \\ \theta \end{Bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{Bmatrix} T \\ M \end{Bmatrix} \quad (1)$$

The coefficients a_{ij} of the flexibility matrix are function of α and EI, or α is the inverse length of the Winkler beam and EI the rigidity of the beam.

4.1 Analysis of semi-infinite beam sought with concentrated force :

The point of application of the load time is zero and the effort deciding in the section immediately right this point is equal to (-T)

$$\begin{cases} T = \frac{K_V}{2\alpha}\delta \rightarrow \delta = \frac{2\alpha}{K_V}T \\ \theta = \delta' = \frac{2\alpha^2 T}{K_V} \end{cases} \rightarrow \begin{cases} a_{11} = \frac{1}{2\alpha^3 EI} \\ a_{21} = \frac{1}{2\alpha^3 EI} \end{cases}$$ With (α length reverse beam of Winkler): $\alpha = \sqrt[4]{\frac{K_v}{4EI}}$

4.2 Analysis of the semi-infinite beam sought with moment

The point of application of the torque moment is equal to M, and the sum of the responses of elastic support is zero:

$\delta = \frac{2\alpha^2 M}{K_v} \rightarrow a_{12} = \frac{1}{2\alpha^2 EI}$ and $\theta = \delta' = \frac{4\alpha^3 M}{K_v} \rightarrow a_{22} = \frac{1}{\alpha EI}$ with $\alpha = \sqrt[4]{\frac{K_v}{4EI}}$

For the elastic semi infinite on support continuous beam we will have:

$$\begin{Bmatrix} \delta \\ \theta \end{Bmatrix} = \frac{l^2}{2EI}\begin{bmatrix} l & 1 \\ 1 & \frac{2}{l} \end{bmatrix}\begin{Bmatrix} T \\ M \end{Bmatrix} = \frac{l^2}{2EI}[A]\begin{Bmatrix} T \\ M \end{Bmatrix}$$

5. Analysis of finite beam (with elastic support)

We consider now the finite beam Figure.3 including at one of the ends a concentrated load T and a moment Mr. the beam is supported by two springs of rigidity K with a distance L. Therefore to find the value of the stiffness of the springs K and L the length of the beam. the analysis is performed in the linear domain[11], we governing efforts T and M..

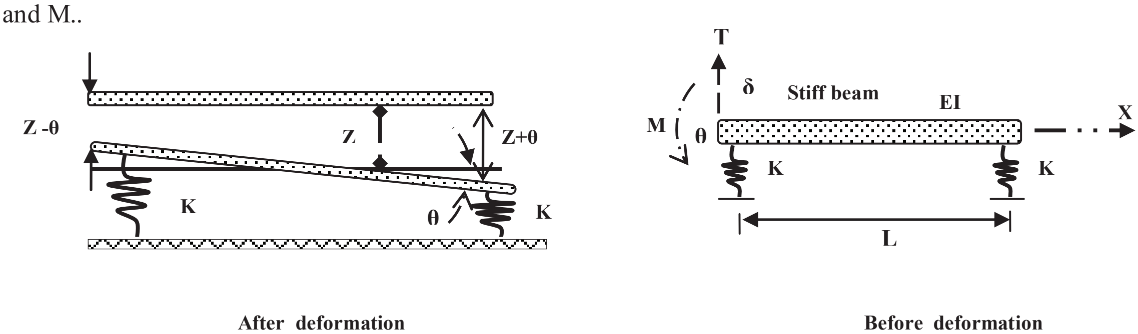

Figure 3 : Finite beam equivalente a semi infinite beam

5.1. Analysis of the beam on elastic support sought by a concentrated load.

Therefore after the determination of the matrix, it remains to determine the value of K and L, we proceed in the same way for determined flexibility matrix but for a beam on two spring with equivalent rigidity K and a finite length L.

$$\begin{Bmatrix} \delta \\ \theta \end{Bmatrix} = \frac{1}{K^* L}\begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}\begin{Bmatrix} T \\ M \end{Bmatrix} \quad (2)$$

Under the influence of the concentrated load balance analysis allows to:

$$\begin{cases} M = TL = K^*\delta L \\ M = K^* L^2 \theta \end{cases} \rightarrow \begin{cases} b_{11} = \frac{1}{K^*} \\ b_{21} = \frac{1}{K^* L} \end{cases}$$

5.2. Analysis of the beam on elastic support sought by moment:

It will be conducted similary under the effect of the moment we can deduce the following results for the beam on two elastic support and length L:

$$\begin{cases} \delta = \frac{M}{K^*L} \\ \theta = \frac{2M}{K^*L^2} \end{cases} \rightarrow \begin{cases} b_{12} = \frac{1}{K^*L} \\ b_{22} = \frac{2}{K^*L^2} \end{cases} \rightarrow \begin{Bmatrix} \delta \\ \theta \end{Bmatrix} = \frac{1}{K^*L} \begin{bmatrix} L & 1 \\ 1 & \frac{2}{L} \end{bmatrix} \begin{Bmatrix} T \\ M \end{Bmatrix} = \frac{1}{K^*L} [B] \begin{Bmatrix} T \\ M \end{Bmatrix} \quad (3)$$

Therefore for the system steel + springs give the same answer to that of the infinite semi on support beam elastic. it takes:

$$A = B \rightarrow \{a_{11} = b_{11}; a_{21} = b_{12}; a_{21} = b_{21}; a_{22} = b_{22} \rightarrow \begin{cases} L = l \\ K^* = \frac{2EI}{l^3} \end{cases} \quad (4)$$

The two systems, infinite semi beam and the beam with springs, K is stiffness and length L springs have the same answer. So to determine in advance the flexural stiffness of the rail equivalent it must specify the values of, EI, k_v.Several research has been conducted for the determination of the reaction k_{v1} module, and the authors propose relationships based on the experimental. Terzaghi [7] defines that the module of reaction is a function of the k_{v1} plate test module. Other authors ' Biot, Vlassov, Vesic, Meyerhof, Selvadurai [8] [9, [10] [11] propose relationship function of the geometry of the Foundation and of constant mechanical s: Young E module and the coefficient of fish µ.] We propose a numerical determination of reaction module k_v under environment plaxis.

6. Determination of the k_v. numérique path under environment Plaxis module :

When the module of the k_v track non-directly accessible to experience this is a simulation by Plaxis [13] to assess. its value by the application of a unit charge on a blochet resting on a layer of soil. We have been interested only in the vertical displacement of the structure at the point of application of the load, so we have chosen to block horizontal displacement at ends, and a total blocking (horizontal and vertical) at the lower to the ground level.

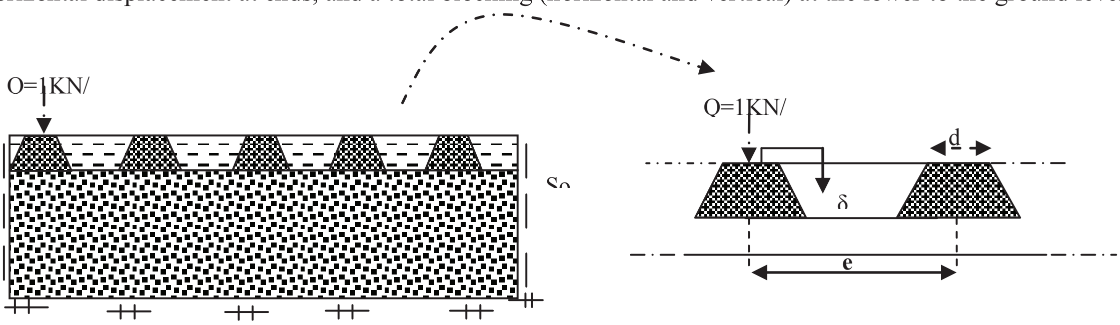

Figure 4: Evaluation of railway modulus

Therefore, after the simulation and after having determined the flexural stiffness of the beam using the Winkler solution [1] for a maximum displacement. This rigidity corresponds to a given stiffness which is a function of the geometry of the blochet. Thus the values of K and L are determined.

$\delta_v = 3.66.10^{-6}m \rightarrow K_v = 73.68Mpa$

The replacement of the values estimated in the equation (4),With : EI=6110KN. m^2 gives :

$K = 27.96 \times 10^3 KN/m$, $L = 0.758m$

7. Analysis and discussion of the numerique model

The structure channel rail added to the foundation (layers and platform) represented (Fig.5) is a multilayer set which the mechanical behavior is extremely complex .the modeling system, such as we describe it below, is intended to best represent the physical problem and to allow :

- The determination of the displacement and stress in various layers fields
- study of transmission in the adjacent blocks of the load applied to the right of a crossing.

- The study of the effect of taking or not support rotation stiffness

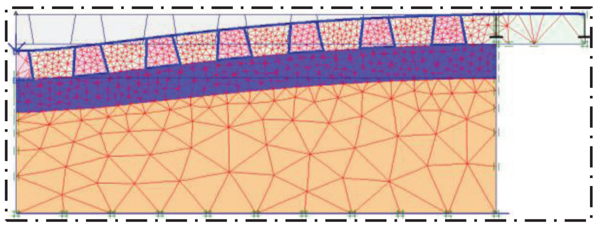

Figure 5: settlement of raiway (numerical model)

8. .Parametric study:

The parametric study will be conducted on the influence of Poisson's ratio, modulus of elasticity of the soil and that of the ballast on the deflection. An analysis was conducted on the influence of the thickness of the Sub layers on the response of the structure.

8.1. Poison's ratio µs :

The influence of Poisson's ratio is a achived figure.7.We observe mor the value of the Poisson's ration is important more defltion is mitigated.

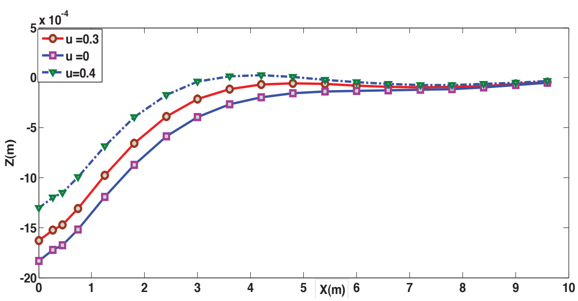

Figure 6 : Influence of Poisson ratio υ_s of soil on the displacement

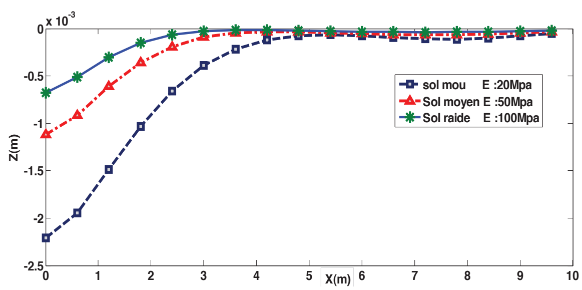

Figure . 8 : Influence of elasticity modulus of soil on the displacement

This influence tends a disappear six metres from the point of application of the solicitation (convergence of the three curves).

8.2. Young modulus Es:

To test the influence of the elasticity modulus of ground , we vary this modulus between (20Mpa and 100Mpa), by taking the stiffness roadbed ballast to 450Mpa, the stiffness vary accordingly to their stresses history either soft or stiff soils. (20Mpa (soft), 50Mpa (mean), 100Mpa (stiff).
The results are shown in the following curves Figure.8.We note that settlement decreased very significantly with the increase of Young's modulus, the area of sensitivity of the way to the this parameter is 4 m by report point of application of the load.

8.3. The elasticity modulus of the ballast (Young's modulus) Eb:

we assume in this analysis that the ballast after several cycles of solicitation has been deteriorated (100MPa, 250MPa), the behavior of this ballast compared to a ballast whose mechanical properties are seen to be standards of use. We noticed that the displacement increase with the used ballast.

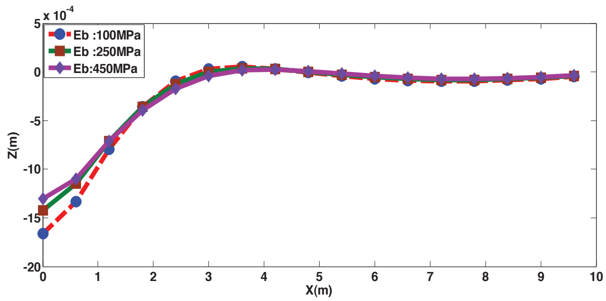

Figure .9: Effect of elasticity modulus of ballast on the behavior of the railway

8.4. Effect of thickness of sub layer (Elasto-plastic model):

the bidimensional model with the Elastoplastic behavior has been used. The influence of the thickness of sub-ballast (G.N.T) and subshell was shown. Increasing displacement with reduced thickness of the layer of sub-ballast which presents the importance of this layer. We observe, however, that beyond the third adjacent blochet negative stresses and the uprisings of the track.

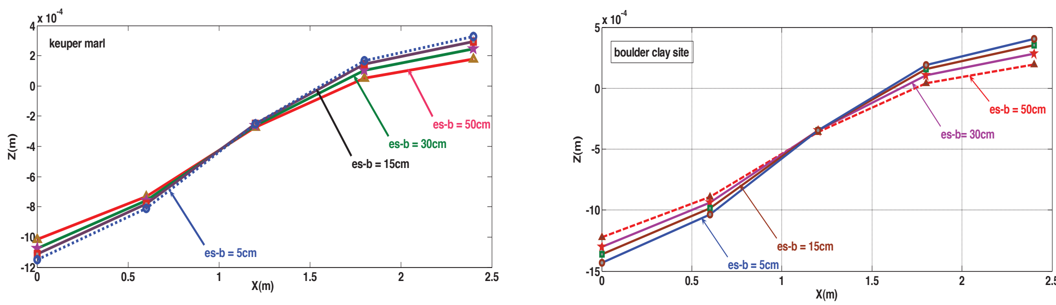

Figure. 10.11 : vertical displacements at the blocks at lower level (Elasto-plastic calculation)

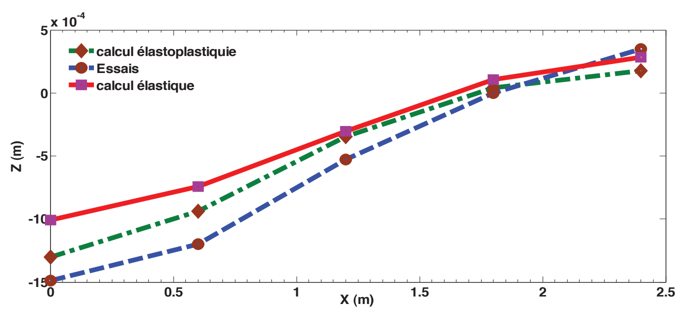

Figure .12 Comparison of displacements: Numerical model - test in situ

Figures (10,11) give the vertical displacements at the blocks at lower level, in the case of a clay soil (Boulder clay, Keuper marl) which allowed us to see the influence of the soil's quality on the behaviour of the track. The different curve represent the influence of the thickness of the layer of su-ballast on the behaviour of the track. We compared the model established in finite elements from tests in situ by Profillidis [12] figure 12. Elastic model results are quite distant, however the Elastoplastic model gives satisfactory results.

9.Conclusion:

We analyzed the mechanical behaviour pathways by a static loading. The two-dimensional analysis of the finite elements of the mechanical behaviour of the track and its Foundation using elastic laws behavior and Elastoplastic, allowed us to analyze some parameters affecting the deflection of the structure.

Poisson's ratio affects the deflection.

The quality of the ballast (after having been used) affect the deflection.

The thickness of the sub layer affect the deflection.

The quality of the platform affects the response of the structure.

The confrontation of the model tests on site are satisfactory.

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