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3D STATIC-NUMERICAL ANALYSIS OF THE SPACING BETWEEN RAILWAY TRACK SLEEPERS.

MASTER THESIS

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ABSTRACT

TITLE: 3D STATIC-NUMERICAL ANALYSIS OF THE SPACING BETWEEN RAILWAY TRACK SLEEPERS.

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KEYWORDS: RAILWAYS, SLEEPERS SPACING, COST SAVINGS, FINITE ELEMENTS, TRACK DESIGN, TRACK PERFORMANCE.

Due to the size and scope of the project, the following TFM will focus, for time and content reasons, on the development of the 3D static modelling of the case studies proposed in the ODSTRACK project. The train load and track will be modelled by ANSYS. All its elements, and various case studies will be addressed. In particular, for the sleeper modulus, four different cases will be proposed that the investigation has obtained during its 2D analysis by DARTS program, the first of which is the one being adopted for 0.6 m. The other three values that will be assigned in the modelling are 0.7m, 0.8m, and finally 0.9m. These will serve as a base model and feedback for the following steps of the research, which include getting calibrated through laboratory tests in order to conduct a comparation between the theorical and experimental results that will be performed later in 2022. This final research project will be presented as a complementary work to the ODSTRACK Project that has conducted the same 3D analysis on focus on different elements that make up the fastenings system in railway tracks. In this case the rest of track superstructure elements have been analysed (rail, pads, sleepers and ballast).

RESUMEN

TÍTULO: ANÁLISIS ESTÁTICO-NUMÉRICO EN 3D DE LA SEPARACIÓN ENTRE TRAVIESAS DE VÍAS FÉRREAS.

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PALABRAS CLAVE: FERROCARRILES, SEPARACIÓN DE TRAVIESAS, AHORRO DE COSTES, ELEMENTOS FINITOS, DISEÑO DE VÍAS, RENDIMIENTO DE LAS VÍAS.

Debido al tamaño e importancia del proyecto, el siguiente TFM se centrará, por razones de tiempo y contenido, en el desarrollo de la modelización numérica en 3D de los casos prácticos propuestos en el proyecto ODSTRACK. Se modelará la carga del tren y la vía con el programa ANSYS, con todos sus elementos, y se abordarán varios casos de estudio. En particular, para el módulo de las traviesas, se propondrán cuatro casos diferentes que la investigación ha obtenido durante su análisis 2D mediante el programa DARTS, siendo el primero de ellos el que se está adoptando para 0,6 m. Los otros tres valores que se asignarán en la modelización son 0,7m, 0.8m y finalmente 0,9m. Estos servirán como modelo base y feedback para los siguientes pasos de la investigación, que incluyen la calibración mediante pruebas de laboratorio para realizar una comparación entre los resultados teóricos y experimentales que se realizará más adelante en 2022. Este proyecto fin de carrera se presentará como un trabajo complementario al Proyecto ODSTRACK que ha realizado el mismo análisis 3D centrado en los diferentes elementos que componen el sistema de sujeción en las vías férreas. En este caso se han analizado el resto de los elementos de la superestructura ferroviaria (carril, pads, traviesas, balasto)

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I. INTRODUCTION

The railway track system plays an important role in the transport network of any country and discussing its ways of construction and maintenance are quite fundamental. Before the emergence of high-speed rail (HSR), most attention has been given to the preservation of the track superstructure consisting of rails, fasteners, and sleeps, and looking for approaches that would help with saving up its costs during such operations, and unfortunately no attention has been given to the opportunity of reducing costs since the beginning of its construction by increasing the distance between sleepers since this subject has been a taboo since the origins of the railways.

The work carried out in this thesis is related to one of the main stages of the ODSTRACK project, Optimal Distance between Sleepers in conventional and high-speed Tracks, which is a scientific investigation that has been launched in 2018 by the research group of the University of Cantabria in collaboration with other researchers and professors from other universities (Project of reference: RTI2018-096809-J-I00, granted by MCIN/ AEI/10.13039/501100011033/ and FEDER "Una manera de hacer Europa") [1]. Until now, this research has been conducted to a great degree by the principal investigator Roberto Sañudo Ortega, from the Group of Railways Engineering (SUM+LAB) from University of Cantabria, that aims to reduce the costs of construction and maintenance of railway infrastructure.

In general, the optimization process of a railway project, both in the design of the work and in the management of the exercise, it is necessary to adequately analyse the relationships between the different types of variables that make up the complex "man-vehicle-infrastructure system", in order to be able to identify the most appropriate actions to maximize the comfort of passengers and the safety of travel. Therefore, to achieve a smooth rolling and guidance of vehicles in these conditions, it is vital to have support elements that react with minimal deformations (non-existent or small elastic deformations) to the stresses produced by the passing of the train. These support elements (rail pads and sleepers) must attenuate all train loads to reduce the stresses and strains that reach the platform.

The shape and dimensions of the rail network used today are the product of a long development through history, based mainly on trial-and-error approaches. Concerning the track gauge (distance between the inner sides of the head of the two rails of a railway measured at 14 mm below the rolling surface), in principle, each continent adopted its own value, for historical reasons, until an international track gauge equals to 1435 mm was codified in the UIC standard (Union Internationale des Chemins de Fer).

Like track gauge, sleepers have also been studied over time: their shape, dimensions and spacing between them have undergone changes. Today, the commonly accepted distance between sleepers in Europe is 0.6 m. Other continents, such as the United States, use different modules that vary considerably between countries and regions. It is important to note that a greater number of sleepers allows for smoother rolling and reduced ground deformations. The number of sleepers varies between 1000 sleepers per km and 2000 sleepers per km and depends on various factors such as train loads, speed, degree of traffic on the track and the radius of the curves.

Despite railway infrastructure evolution, with the introduction of new models and solutions to improve the track performance, the influence of the position of the sleepers on the track has never been sufficiently studied: there is almost no analysis of the track forces and deformations generated when using several spacings between the sleepers.

As the title indicates, the key point of the project is to **find an optimal distance between the sleepers and to propose a cost-effective solution that can be easily implemented.** This will reduce construction, maintenance and renovation costs and increase the quality of the equipment. The results can create a new vision for the design of ballasted railway superstructures.

The stage of research on which this thesis focuses on is the dynamic simulations on a 3D finite element model of the track, for various case studies. Among them, besides increasing the distance between consecutive sleepers, there are also solutions in which different geometries are adopted both for the sleepers themselves and for the other elements of the railway superstructure.

The 2D analysis was carried out using the Dynamic Analysis of Rail Track Structures (DARTS) software, where a track and vehicle model were first created, then boundary conditions and a dynamic load were defined. Before proceeding with the simulation, in a preliminary analysis, a size of 0.05 m was chosen for the mesh elements, capable of allowing an accurate representation of all the components of the track and achieving precise results with acceptable computational efforts.

Two case studies were then defined, in the first one the spacing between sleepers was varied without further modifications to the elements, while in the second case the spacing was set at one meter and the pad size was altered.

Through this first parametric analysis in 2D we have been able to estimate a sleeper spacing by putting an estimation to the track resistance parameters and their limit values.

From this assessment, for the first case study, the increase of sleeper's separation is limited to approximately **0.83 m** due to the pressure on the ballast. While for the second practical case we have registered no limitation for both a smaller and larger size of the pads.

Hence, the results of this first stage of the project lead to the conclusion that, on a current track, without any modifications, the separation can be increased by more than 20 cm, which would already allow a substantial cost saving. Moreover, if we consider a pad size of 10 cm or 30 cm the spacing can also reach 1 m which, as we will see in detail in the following chapters, would allow savings of up to 40% of the total construction costs.

The results obtained, with low computational costs and therefore in a short time, will serve as a basis for a more precise, but also less time-consuming, three-dimensional analysis. Without a doubt every numerical analysis will be supported by laboratory tests that will confirm or deny its previous outcomes. The first conclusions of 2D study have shown that the distance between sleepers can be increased without causing any damages which conclude that the construction costs of the railway infrastructure can be diminished.

This following thesis is as stated in the abstract earlier represents a complementary work to the same one developed by Francisco Alberto Alonso Rodriguez who has had part of the same investigation that it is being led and supervised by Roberto Sañudo Ortega. His previous work was based on the study of deformation and stress in the elements of fastenings system however in here, the studied elements are rails, sleepers, pads, and ballast. Thus, and due to this reason, it can be found similarities when it comes to the methodology of work and description of the program, also it should be mentioned that modelling has been done using the same finite element software "ANSYS" but not the same version, with the research project "ODSTRACK" and the thesis of bachelor's degree of Francisco that had been presented in September [2]. The previous work in [2] used a previous version of ANSYS software (ANSYS R 19.2), here a recent version of ANSYS (ANSYS 2021 R2) has been used to make the simulations and the analysis.

II. OBJECTIVES

The main objective of the project is based on an increase in the distance between sleepers in such a way that these rail support elements can be optimized while always maintaining the safety and functionality of the track.

The corresponding study of this new configuration of rail infrastructure elements makes it necessary to design and develop a model simulating the future real scenario (track and train) so that the whole can be analysed, and its behaviour can be seen. It will be also necessary to set up an initial track model so that its medium and long-term performance can be evaluated. For this purpose, numerical model will be created and then experimentally calibrated on a real scale through laboratory tests.

The results extracted and interpreted from the model will allow the development of a new guideline for the placement of the sleepers, contributing to the reduction of the costs associated with them both in the construction process and in the maintenance and renewal phase. In the same way, it will also be studied how to incorporate it to the existing tracks in the renewal and maintenance periods, studying the possible alternatives and opting for the one that does not involve an increase in operating costs.

The importance of the study lays mainly in focusing on the sleepers and pads since they represent a major cost in the superstructure as a whole, both in terms of route construction and renovation. Therefore, the motive for such a study is twofold:

- First, is **Technical**: the railway track is a complex structure. Therefore, given the importance of this element in the transmission of forces from the railway to the ground. It is one of the main elements that receives and attenuates the load coming from the trains. As reader will see latter, its tasks are crucial in the operation of the railway system, as well as the transmission of loads, the inclination of the rails and the guarantee of the track gauge.

- Second is **Economical** one: given the large number of sleepers in the rail network, during construction and maintenance, it can be said that the cost associated with the number of sleepers is inversely proportional to the distance or spacing between them, i.e., the greater the spacing, the lower the costs.

Thus, the analysis of these elements must be thorough, and in fact, prior to an economic estimate, first and foremost we need to establish a balance between the following elements:

- Their price and that of connection or isolation devices they require.
- Its durability, the service life of the operation depends on the material from which they are formed and the conditions in which they work.
- The cost of recovery, associated with reuse in secondary stations or temporary tracks during construction of a main track.
- Maintenance costs during its useful life and the costs necessary to extend it.

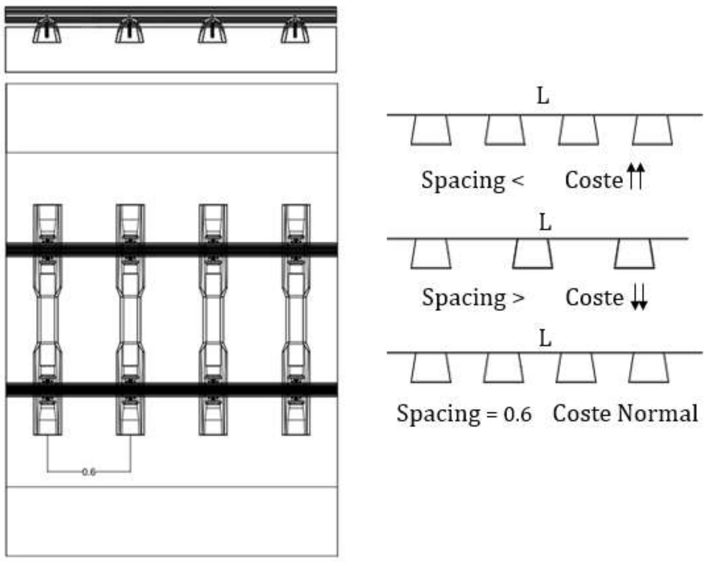


Figure 1. Model that represents the influence of different positions of sleepers on the track

In order to understand the savings that can lead to an increase in the separation of sleepers on a track, and thus the motivation for the study, an economic justification is proposed before starting the project.

The technical justification will be presented later once the relevant calculations and laboratory tests have been carried out.

The number of sleepers per unit length of track is easily obtained by dividing the total length of the section by the spacing distance used.

$$N_{\text{Sleepers}} = \frac{\text{Total length of the track}}{\text{Spacing distance used}}$$

The most common distance between sleepers is 60 cm. So, considering 1 km of track and a 0.6 m spacing, we obtain:

$$\mathrm{N}_{\mathrm{Sleepers}} = \frac{1000}{0.6} = 1666.66 \cong 1667 \; sleepers/Km$$

This is assuming a simple section, without any structures or delicate points. In the case that we are not in these conditions, for example, the section includes armament devices, tunnels, stations or singular structures, the number of sleepers can change, normally increases.

So, in the case of a simple section, the cost per unit of length can be obtained as the cost of each sleeper multiplied by the total number of sleepers per km. Suppose each sleeper costs Cs and the total cost per unit length is CTL.

$$CTL = \mathrm{N}_{\mathrm{Sleepers/Length}} * \mathrm{Cs}$$

Considering, for example, a cost of 100 euros which is an average cost, the cost associated with 1 km of track with a separation of 0.6 m will be:

$$CTL = 1667 * 100 \text{ €} = 166.700 \text{ €}$$

If we consider now a slightly larger step such as 0.7m and repeat the same calculation, we obtain:

$$CTL = \frac{1000}{0.7} * 100 \text{ €} \cong 142.900 \text{ €}$$

Consequently, for just one kilometre of track, we have a saving of 23.800 €, which in 10 km of track corresponds to 238.000 €. A substantial savings considering that we have only increased the distance by 10 cm and only for 10 km. The following graph shows the relationship between the different modules and the savings.

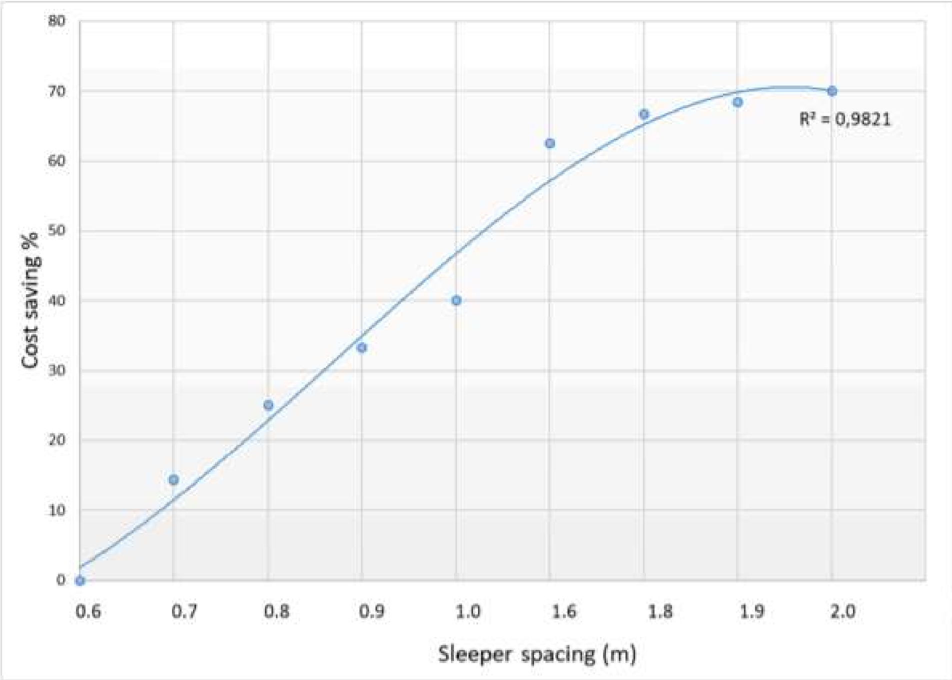


Figure 2. Costs saving depending on the sleeper's separation [3]

The initial justification tells us that, from an economic point of view, the increase in the module decreases the initial construction costs. However, we still know nothing about how this increase affects future maintenance and upkeep costs and whether or not, these offset the costs initially saved in the construction phase. We also do not know whether it is possible and economically feasible to modify the sleeper geometry to allow for this expanded spacing and to make it cost-effective.

III. STATE OF THE ART

Relatively, many of the characteristics of the elements that make up the railway track superstructure has been determined throughout history through approximate experiments. The evolution of high-speed trains in recent years has allowed, in addition to the introduction of new and more resistant elements in the track structure, the development of many products to improve the operating conditions and the life of the already used materials. On some occasions, however, the methodologies have been chosen only because they work initially, without any real basic scientific development.

However, given the economic importance of sleepers, which has been discussed above, it is important to know why, or at least the original rationale for the separation distance that is currently adopted. In the past, a 75 cm spacing was used, and today most of the network adopts a 60 cm spacing, both for conventional and high-speed lines.

The following table shows a compilation of the most relevant characteristic values used in different parts of the world together with the most usual material of manufacture [3].

Table 1. Most representative sleeper spacings globally [3].

Country	Sleeper spacing commonly used	Material
Austria	650, 700, 710, 810, 850	Wood, Steel, Concrete
Australia	495, 533, 592, 610, 622, 666, 672, 762, 763, 661, 720, 787	Wood, Steel, Concrete
France	580, 625, 660, 666, 700, 800	Wood, Steel, Concrete
Germany	580, 600, 620, 625, 630, 650, 660, 666, 670, 680, 700, 760, 780, 850	Wood, Steel, Concrete
Greece	600, 700, 826	Wood, Steel
Ireland	610, 760, 826	Wood, Steel
Italy	600, 630, 640, 692, 700, 720, 725, 730, 750, 752, 770, 800, 833, 850, 860, 910	Wood, Concrete
Spain	500, 600, 630, 650, 660, 666, 700, 750, 770, 800	Wood, Concrete
Denmark	650, 700, 750	Wood
Sweden	500, 650, 710, 750, 770, 800, 830, 865	Wood, Concrete
Switzerland	500, 650, 710, 750, 770, 800, 830, 865	Wood, Steel, Concrete

United Kingdom	550, 600, 620, 630, 640, 650, 660, 666, 670, 680, 700, 706, 715, 720, 750, 800, 820, 900, 1000	Wood, Steel, Concrete
Canada	460, 495, 508, 510, 520, 534, 540, 542, 555, 559, 762	Wood
Mexico	495, 500, 508, 533, 546, 559, 560, 572, 610, 624, 690	Wood, Concrete
Bolivia	500, 600, 666, 800	Wood
Guyana	660, 831	Wood
Uruguay	666, 769	Wood, Steel, Concrete
Venezuela	500, 690, 800, 862	Wood, Concrete
Ethiopia	625, 692, 800, 818	Steel
Malagasy	666, 800	Wood, Steel
Malawi	826	Wood, Steel, Concrete
Morocco	580, 858	Wood, Steel, Concrete
Mozambique	666, 685, 769	Wood, Steel
South Africa	700, 800, 813	Wood, Steel, Concrete
Sudan	770	Wood
India	670, 680, 840	Wood, Steel, Concrete
Indonesia	680, 800	Wood, Steel
Japan	380, 500, 555, 575, 580, 595, 620, 625, 650, 660, 671, 690, 700, 710, 750, 770	Wood, Concrete
Nepal	860, 925	Wood
Syria	795, 868	Metal

Nowadays, there are studies on the influence that a given spacing, and the stiffness of the supported plates placed on the sleepers have on the longitudinal defects of the rails. [4] Longitudinal irregular wear of the undulatory type remains one of the most poorly understood phenomena that can deteriorate wheel and rail profiles in the railway industry.

This wear manifests itself in the form of extensive undulations on the profile surfaces in the direction of travel (Fig. 3). It thus constitutes sources of excitation of uncomfortable vibrations (noise) and sources of fatigue.

The study of this phenomenon began at the end of the 19th century. For a century, there have been numerous studies on this problem. However, not all the existing work can fully explain the mechanisms of formation and development of this type of wear.

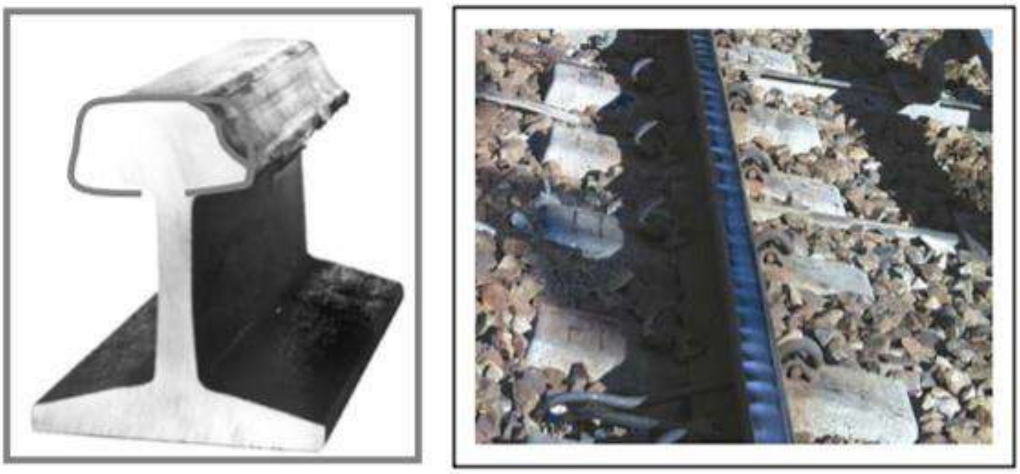


Figure 3. Worn rail and Corrugated rail wear

Wave wear is defined as the appearance of bumps and dips on the rail surface in the longitudinal direction. To study this type of defect, we can model the worn rail surface by a wave (sinusoidal) surface. The undulatory wear is then characterized by two parameters: the wavelength and the amplitude.

Since 1971, Carson, Johnson, and Gray [5] have found that undulatory rail wear is caused by a combination of two mechanisms: a wavelength fixing mechanism and a damage mechanism.

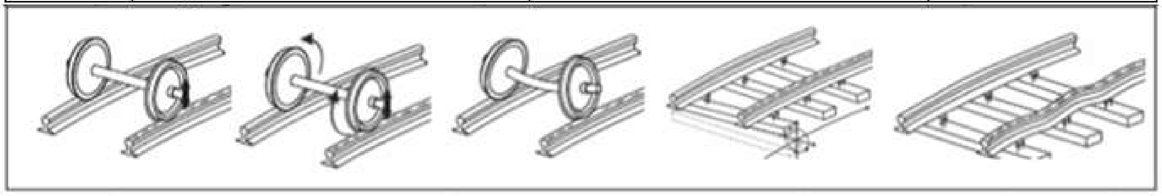
- **Wavelength fixing mechanism:** There is always an initial roughness on the surface of a rail (new or worn). For a mathematical model of undulatory wear, an initial roughness is assumed in the form of a spectrum with wavelengths in the 5-100 mm band for the "short-pitch corrugation" type. This roughness is the input of the track-vehicle dynamics which creates fluctuations in contact forces, sliding and contact area size. These fluctuations are greater at certain frequencies. For a given train speed, this means that wear is greater at certain wavelengths. This is the wavelength fixing mechanism. After millions of passes of the train, a wave shape of the rail surface will be formed. The wavelength fixation mechanisms are often the resonances of the coupled track-vehicle system (P2 Mode), or the resonance of the pinned-pinned mode of the rail with the discrete supports.

- **Damage mechanism:** Different damage mechanisms are assumed to be the cause of undulatory wear, such as: wear, plastic deformation or rolling fatigue. In most of the existing models for the short-pitch corrugation type, wear is considered as the damage mechanism.

Another classification (Table 2) of the types of undulatory rail wear can be found in the report of the “Transit Cooperative Research Program”. This classification is in fact that of Grassie and Kalousek [6] with minor modifications.

Table 2. Classification of undulatory wear of the « Transit Cooperative Research Program TCRP » [7].

Type	Damage mechanism	Wavelength fixing mechanism	Wavelenght
1	Plastic flow, fatigue	P2 Resonance	200-1500 mm
2	Longitudinal wear	Axle torsion	50-200 mm
3	Lateral wear	Bending modes	40-60 mm
4	Lateral wear	Sleeper Resonance	40-60 mm
5	Longitudinal wear	Pinned-Pinned Resonance	25-80 mm



The current method of dealing with corrugated rail wear is to grind or replace the rails which is a very costly operation. Different techniques can be found that are used to address the causes of diverse types of rail wear. Collette (2007) [8] has listed these main techniques in the table below (Table 3).

Results reveal that sleeper distance of 1000 mm yields higher corrugation growth rate, with steeper exponential relationship between average wear depth and number of wheelset passages, than 500 mm sleeper distance. Rail corrugation dominant wavelengths for 1000 mm and 500 mm sleeper distances also increase with corrugation growth. As such, **sleeper distance of 500 mm** is recommended to reduce rail corrugation growth, thereby lowering maintenance costs, and improving reliability, maintainability, availability, and safety of rail transportation.

Table 3. ***Treatment of undulatory rail wear [8]***

Preventive measures	Type 1	Type 2	Type 3	Type 4	Type 5
1. Direct fixing of the flexible rails	++	-	-	-	+
2. Flexible under-rail pad	+	+	-	+	+
3. Greasing of the rail head	-	++	-	++	-
4. Friction control (rail)	+	+	+	+	+
5. Hardened steel rail	++	++	+	+	+
6. Rail guide removal	-	-	+	-	-
7. Rail profil optimization	-	+	+	+	-
8. Increase the curve radius of the track	-	+	+	+	-
9. Reduce acceleration and braking	+	+	-	-	-
10. Modification of sleepers spacing	-	-	-	-	+
11. Greasing of the wheel flange	-	+	-	+	-
12. Friction control (wheel)	+	+	+	+	++
13. Axle torsion absorber	-	+	-	-	-
14. Steering	+	+	-	+	-
15. Flexible/Soft wheels	+	+	+	+	+
16.flexible drive assembly	-	+	-	-	-
17. Preventive rail grinding	++	-	-	++	-
18. Absorber on sleeper	-	-	-	-	-
++ used with success; + positive results but not yet tested; - no recommendation					

As well, other studies can be found on the influence of sleeper size on sleeper behaviour [9], including more specific studies of the influence of separation in singular points such as transition zones [10].

Preliminary analyses on this subject [11] are carried out from a technical point of view, examining different separations, and studying the variations of certain variables (such as vertical displacements on sleepers, stresses under the sleepers, bending moments in the rails) for all considered speeds. However, neither the railway movements nor the accelerations produced, for example, in the sleepers themselves are mentioned. Further analysis is therefore required.

From a safety point of view, more sleepers are needed to give the track more stability. This lower limit can be given by a minimum distance necessary to obtain a correct batting of track. It is necessary to consider that with a distance between the sleepers of 0.6 m (measured between their axes) and their base width of 0.3 m, the spacing of the sleepers corresponds to the width of one of them, so it is possible to place the sleepers without leaving any spaces and then eliminate the intermediate. Thus, a spacing of 0.6 m leaves only 0.3 m between the inner faces of two adjacent sleepers.

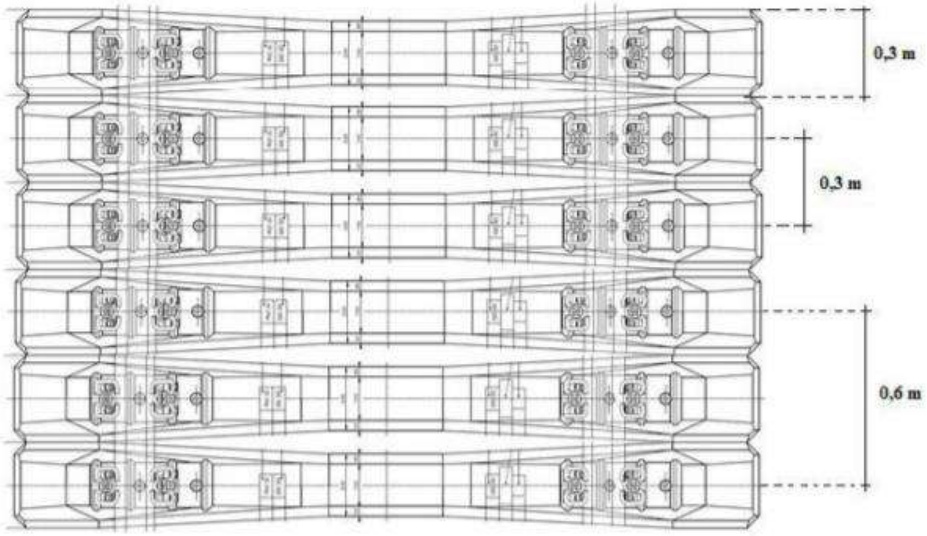


Figure 4. No separation between sleepers [3]

From the previous figure it can be seen a possible explanation of the measure used today, based simply on a practical rule of implementation to get the job done. Another intuitive way to explain this distance is to think of the distance travelled by a worker with a single comfortable step, that is, a comfortable separation for a track operator to move from sleeper to sleeper without touching the ballast. These are only supposition for a commonly distance used nowadays in sleepers' separation in a track.

However, the distance between sleepers depends on several factors: the resistance of the rails, the type of sleeper, the depth of the ballast thickness, the axle loads, the bearing capacity of the subbase and the volume and speed of traffic that the track carries.

Authors such as Chandra Satish [12] describe indirectly sleeper density as the number of spacing of sleepers in the track. The sleeper density is designated in two forms:

- Firstly, as the number of sleepers per rail of standard length
- Or secondly, as the number of sleepers per kilometre.

The sleeper density as the number of sleepers per rail of standard length is defined as (M+K) where M is the length of the rail in meters and (K) is a constant varying from 2 to 9 depending on the importance of the line.

From the number of sleepers as defined above, sleeper density can also be denoted as the number of sleepers per kilometre.

Depending upon the sleeper density, the number of sleepers in a length of rail is decided and their spacing is kept as uniform as possible, except at and near the joint (since the joint represents the weakest link).

The sleepers on either side of the joint are spaced as closely as possible, considering the space needed between two sleepers for packing and making the joint behave as a suspended joint and not as a supported joint.

The next two sleepers, called shoulder sleepers, are so spaced as to maintain a uniform spacing of intermediate sleepers (see Figure 5).

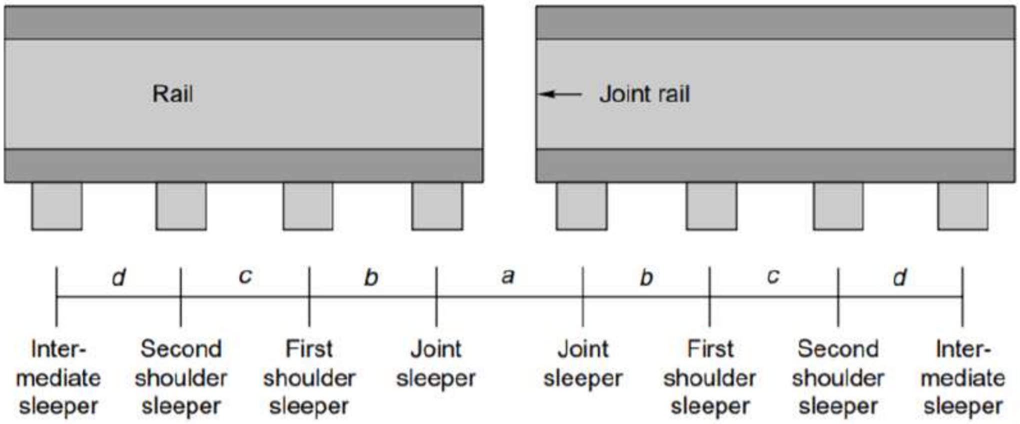


Figure 5. Spacing of sleepers on a fish-plated track [12]

The spacing (a) and (b) are standardized for a particular gauge and type of sleepers. The spacing (c) is then so adjusted to remain between 'b' and 'd' as to achieve the spacing (d) in whole centimetres.

The same author proposes a table (Table 4) in which a modulus is defined according to the material of the sleepers and their position relative to the rail joints for two track widths. The distance decreases when there is joints.

Table 4. Spacing of sleepers on a fish-plated track [12]

Spacing of sleepers	*Broad gauge centre-to-centre spacing (mm)*		*Meter gauge centre-to-centre spacing (mm)*	
	Wooden	*Metal*	*Wooden*	*Metal*
Between joint sleepers (*a*)	300	380	250	330
Between joint sleepers and the first shoulder sleeper (*b*)	610	610	580	580
Between first shoulder sleeper and second shoulder sleeper (*c*) for sleeper density $M + 4$	700 (640)*	720 (630)	700 (620)	710 (600)
Between intermediate sleepers (*d*) for sleeper density $M + 4$	840 (680)	830 (680)	820 (720)	810 (640)

* Values within parentheses are those for sleeper density $M + 7$.

The following points should be kept in mind while deciding about the railway sleeper density:

- The spacing of railway sleepers in a track depends on factors such as (1) Lateral thrust of locomotives, (2) Axle load coming, (3) type and strength of the sleepers.
- The stiffness of a track is increased by increasing weight of rail or by increasing the railway sleeper density and the adoption of either one or other methods depend on comparative cost of rails.
- The sleeper density cannot be increased indefinitely as a certain minimum distance is required between the two adjacent sleepers for packing ballast.
- In case of staggered joints on cure an extra sleeper is to be put up as sleepers are to be provided on either side of joint.
- All sleepers need not be placed at equal distance apart. Sleepers at rail joints are placed nearer and some two or three railway sleepers near the joint sleepers are spaced closer than the sleepers in the remaining length of rail.

Table 5. Spacing of sleepers for welded track [12]

No. of sleepers per km	*Exact centre-to-centre spacing required as per calculation (mm)*	*Centre-to-centre spacing to be provided in the field (mm)*	
		LWR track	*SWR track*
1660	602.4	600	–
1540	649.3	650	660
1310	763.3	–	780

For long welded rails (LWR) a uniform spacing of 65 cm and 60 cm are adopted for sleeper density of 1540 per km and 1660 per km respectively. For short-welded rails (SWR), sleeper spacing are arrived at based on the above principles, taking into consideration the increase or decrease of the length of short-welded rails paved depended upon the System of welding (in this case, when it comes to a SWR, it can have a separation of up to 0.78 m).

D.J. Thompson and T.X. Wu have regarded in their research that some parameters of railway track such as the sleeper spacing, and the ballast stiffness are not constant along the track since they are irregular in reality [13]. Through the results obtained although it is limited, de France discovered that the sleeper spacing on a newly laid section of track had a standard deviation of 39 mm compared with a mean of 628 mm while the ballast stiffness had more significant variation that were measured in limited frequency region of 50–1500Hz with the individual sleepers uncoupled from the rail and found to have a standard deviation of around 25% of the mean value. Other results as shown in from two sites in Sweden, display an analogous tendency, however it was noted that the values of standard deviations were smaller. These results are summarized in Table 6.

Table 6. Mean and standard deviation of sleeper spacing and ballast stiffness (for whole sleeper) [14]

	Sleepers spacing, mm		**Ballast stiffness, MN/m**	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**
Southampton	628	39 (6%)	300	75 (25%)
Gasakulla	625	17 (3%)	255	16 (6%)
Grundbro	650	20 (3%)	186	22 (12%)

Due to the influence of the ballast, the rail pad stiffness might fluctuate from one pad to another depending on many factors, however nothing has been confirmed by any concrete study since the variations are likely to be much smaller.

To determine the effects on the rail vibration of random variations in these parameters, it has been conducted several numerical calculations (with consideration of the computing time that must be as minimal as possible) using a simple Timoshenko beam model, with a condition of only considering the vertical vibration of the rail. Sleepers spacing and ballast stiffness values were selected based on a uniform distribution.

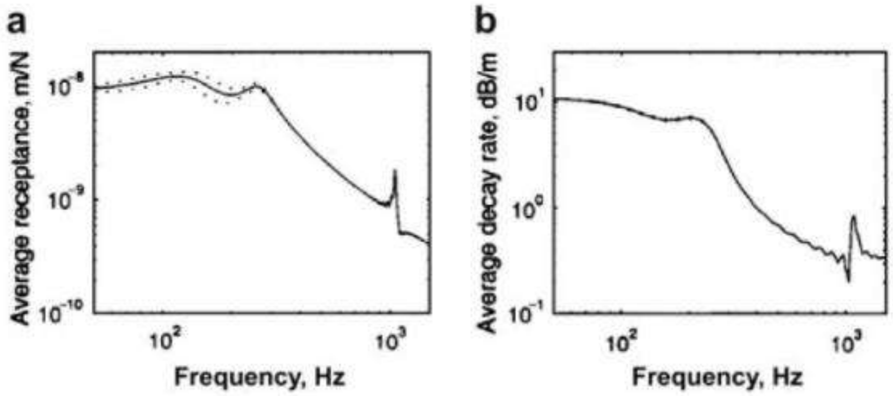


Figure 6. Results for random ballast stiffness with random factor r distributed in [0 2], sleepers pacing d = 0.6 m, excitation acting at mid-span. (a) Amplitude of point receptance, (b) wave propagation decay rate [13].

The results obtained (Figure 6) from an important variation in these parameters, indicated a 40% of the standard deviations and 20% of the mean whereas the values obtained in the previous table (table 6) are substantially smaller. The conclusion that they got, was that random ballast stiffness has only an effect on the response of track at low frequencies, below about 300 Hz whereas the effect on track decay rate has been proven that it is negligible since he is based on many sleepers.

In the contrary, the response effect of random sleepers spacing can be noticed over the whole frequency range 50-1500 Hz studied. However, it is worth mentioning that in this case the decay rate gets affected mainly at higher frequencies.

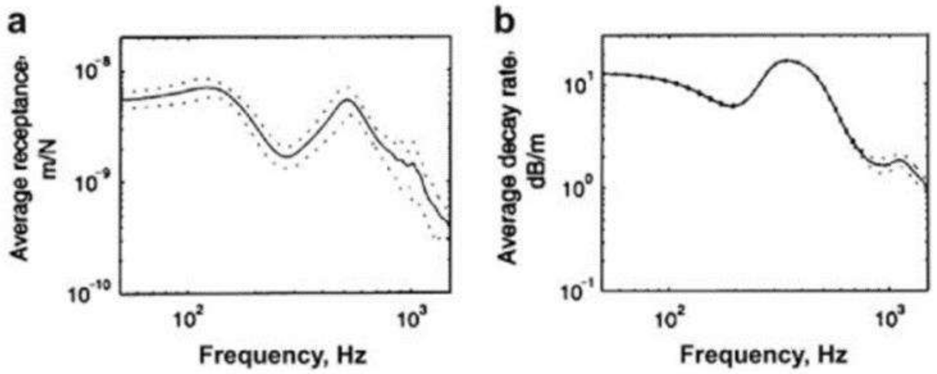


Figure 7. Results for random sleeper spacing distributed in [0.3 m, 0.9 m] and ballast stiffness with random factor r distributed in [0 2], for stiffer pad Kp = 344 MN/m with excitation acting at midspan [13]

The previous figure represents the results obtained while studying both the variation of sleepers spacing and ballast stiffness, with one more condition of using a pad five time stiffer than usual. It has been revealed how greater its effect on the track receptance compared to the case of softer pad in particularly around the pinned-pinned area, though it generates a minimal effect when it comes to its decay rate.

Moreover, when it comes to the railway rolling noise, such variation in both parameters leads to a minor effect and has almost no increase or decrease in the noise generated by the track.

According to some studies that have considered increasing the size of sleepers as one of the potential solutions to get a stiffer, heavier, and stable track however its construction and preservation's costs get to be too expensive in the long term due to accelerated wear.

In Nazmul's case [15], his paper focuses more on the relationship between the sleepers spacing, the ballast thickness and distribution stress angle. Discussing the distribution of vehicle (refers to the wheel in particular) loads from the rail to the sleepers, since track structure is made of series of elements that works coherently as one body, each of which has its principal role to accomplish that relies on spreading the axle loads, permitting the next element to productively carry on the mission of support.

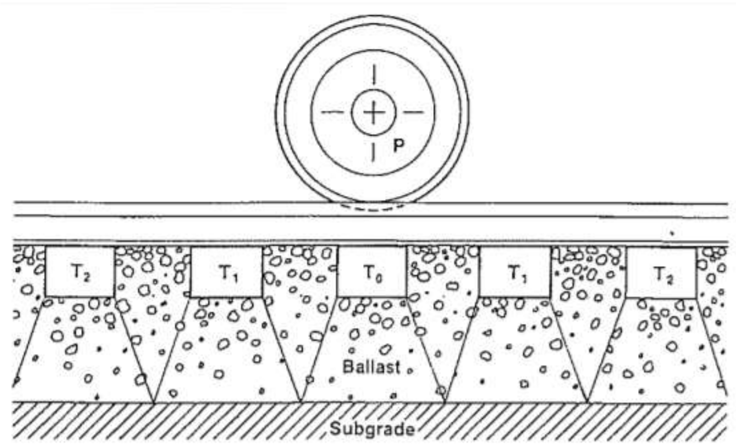


Figure 8. Distribution of vertical loads from the rail to the subgrade [16]

Theoretically, the figure 8 presents the loads distribution that it gets transferred from the rails to the sleepers, then from the sleepers through the ballast to reach the subgrade level, expressing through showing that the load applied by one wheel is distributed over several cross sleepers, so the ballast layer starts spreading the loads over a wide area in order to reduce the actual pressure that attains the subgrade.

As one of the key functions of the track structure, allowing the distribution of the large wheel forces all the way through the ballast and sub-ballast, with a reduction of its corresponding pressures to a compatible level that will not surpass the one of the subgrades.

Direct Fixation Fastener (DFF) spacing has been analysed through the relationship between axle load distribution and load dispersion on the subgrade by the ballast, Hasan has conveyed sleeper spacing in terms of characteristic length of the track and defined three types of sleepers' spacing: Desirable, maximum allowable and absolute maximum. He has considered different percentage of load distribution on sleepers, since his study was based on using Benkel beam theory by Esveld, respecting AREMA guidelines in the matter.

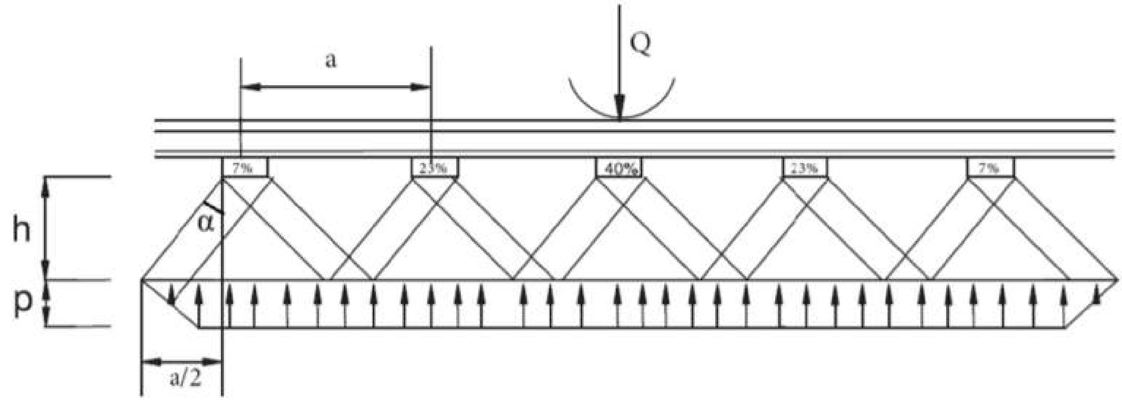


Figure 9. Schematic representation for calculation of optimum ballast bed thickness [3]

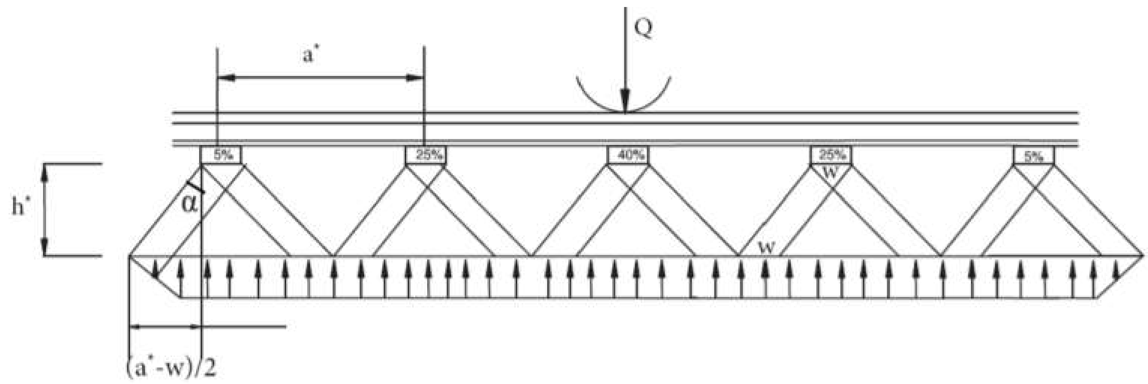


Figure 10. Alternate schematic representation for calculation ballast bed thickness [3]

The variables that are presented in the figures 9 and 10, are summoned in the following equation:

$$h = \frac{a}{2 * \tan\alpha} \quad ; \quad h * = \frac{(a *) - w}{2 * \tan\alpha}$$

Where a is the conventional sleeper spacing in case there is an overlap in the contact pressure between ballast and sub-ballast of adjacent sleepers, a* is as the sleepers' maximum spacing in case of inexistence of overlap in the pressure area and α is the angle of stress distribution. However, the values of these parameters depend on the type of the sleeper whether it is wooden or concrete or another type from the mentioned, track modulus u and lastly on the axle load applied on each sleeper. He got to prove that to attain the desirable load distribution over each sleeper, the distance between sleepers ought to be less than the characteristic length.

In yet another study, Zou, and Wen [17] were interested in how sleeper spacing related to track vibrations. In particular, how during the design face of railway tracks, optimal sleeper spacing can be incorporated and reduce the track's overall vibration. In the study, the authors applied a coupling model made with vehicle tracks of varying working conditions. Using this model, they were able to measure how sleeper distance affect 'vertical vibrations' coming from the rail track. In particular, how does the load capacity and speed of the vehicle system affect the vertical vibration.

The study concluded that under low speeds, whatever the sleeper spacings, the vertical vibrations remain within the same frequency. On the other hand, at higher speeds, there are significant vertical vibrations depending on the sleeper spacings which lead them to recommend the optimum distance between 0.54m to 0.67m.

Surendra Bisht [18] presents an approach that rail track designers can use to come up with designs of heavy haul railways that keeps the track integrity while minimizing construction costs. This approach takes account of numerous track structure components and how they can be optimally utilized while still maintaining track performance. The rail structure analysed included lateral track stability, contact stresses, bending stresses, sleeper ballast contact pressures.

From the comparison between different types of sleepers (timber, steel, and concrete), the optimum sleeper spacing is steel sleepers spaced at 700mm which is able to reach a 11% reduction of costs. Moreover, this type of sleeper, with a ballast depth of 280mm, proved to be easier to maintain, can handle 40-ton axle load and is ideal for ensuring the lateral stability of the rail track with little susceptibility to buckling.

The interaction between vehicle and track is the main reason of creating the vibration resonances and phenomena of wave propagation in the passing bands. As solution to enhance these effects, it has proposed a solution that relies on the utilization of different types of sleepers spacing yet the results has indicate that there is a slight improvement just in case of high speeds and that option of considering non-constant distance between sleepers can provide improvements in track dynamic studies however it wouldn't be considered as an economical solution since it proved to be costly compared to the conventional distance we already apply [19].

It is necessary to study the long-term performance of these new track configuration. Recent studies, offer approaches of the evolution for a track with different sleeper distance scenarios. For example, Sañudo et al. (2021) [3] estimate years of track renewal operations (for all track superstructure elements) in relation to sleepers 'distance. For example, rails under 300-1000 million of tonnages are replaced between

10-15 years for a conventional distance between sleepers of 0.6 m. If this distance increases for example to 1.0 m this replacement needs to be done in 5 years.

From this literature review it can be seen that despite the evolution of railway infrastructure, there are fewer studies that analyse the position of sleepers on the track, the recent studies can be found in [3]. Sleepers spacing is different from one country to another and in some cases is higher than 0.6 m, so this means that it can be increased. It is important to pay close attention to these special cases where this is used and why it is not generalized. Although there are some studies about it, there is almost no analysis of the forces and deformations of the track that ware generated when various spacings are used between sleepers, which makes this topic is worth a profound investigation in order to explain the possibility to increase this distance and save money in this type of infrastructure.

IV. THESIS METHODOLOGY

The main objective of the ODSTRACK research project is to study and analyse the behaviour of all track superstructure elements for different distances between supporting elements (sleepers), on conventional ballast tracks. More specifically and in addition to the main study, this Master thesis will focus on the divergence of track sleepers. The methodology presented below aims to determine the performance and effectiveness of the track structure under different sleeper distances.

The objective is to determine whether the results obtained are applicable to existing and newly constructed railways. The methodology proposed for this theoretical and practical study is explained below. After studying existing cases or similar experiments in the bibliography and compiling their findings, the next step is to design a finite element section of the track (already done in the first part of the ODSTRACK project) and then to develop a three-dimensional model for further study of the element-by-element superstructure for the track.

In order to study variables such as vertical stresses, vertical displacement, they must be well defined before implementing the numerical model, in this case plans and dimensions of the elements of the study will be done in AutoCAD file then transferred to ANSYS21 R2 following the same steps in ODSTRACK Project and previous Fastener's analysis [1,2].

The study of the stresses and strains (vertical displacement) of all the elements that make up the track superstructure will be carried out, paying particular attention to the performance of the superstructure as a whole. The study will be carried out at different distances between the sleepers laid on the ballast.

Following this scheme, the aim is to get the prospect of increasing spacing between sleepers and see the influence of such option on the different elements that make up the track structure. A static study will be carried out on a numerical model that can be later contrasted with the results obtained in laboratory tests.

The final objective of the project is to check if it is possible to increase the sleeper spacing on conventional ballasted tracks and its consequences in the economic field both in new construction and renovation and maintenance of existing tracks. In the same way, a short- and long-term study can guarantee a similar or possibly lower maintenance cost compared to the current railway superstructure maintenance plan. A detailed guide to the new design methods will be developed.

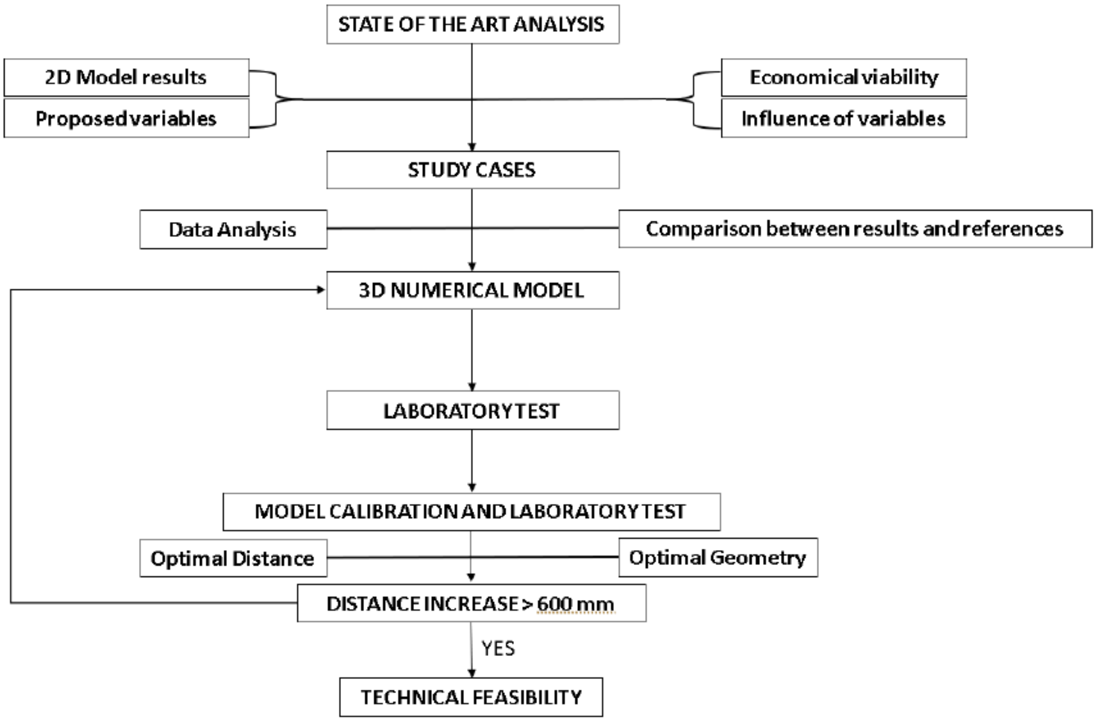


Figure 11. Followed methodology of the project ODSTRACK [1]

The principal points on which ***ODSTRACK Project*** is based and the steps that have been taken, are as follows (taken from [1]):

1) ***FIRST STEP:*** Analysis of its proper literature which refers to the previous studies conducted about the same theme.
Initially, a bibliographic search of previous studies was conducted that would go beyond the national and international scope, in which the most important variables were studied in order to have a global idea about how the difference in spacing affects the track.

   The University of Cantabria has previous thesis work [20], three publications in prestigious scientific journals [21, 10, 3] and an international conference [13] (developed by the research group SUM+LAB), which gives the research group extensive experience on the subject of railway tracks infrastructure.

2) ***SECOND STEP:*** Design and numerical modelling of the track. Behaviour and analysis of the model in different case studies. Obtaining optimal solutions.
Furthermore, an analysis of the track elements was performed through dynamic finite element modelling. Several case studies were presented according to the speed of the trains, the varied materials of the superstructure

and the different dimensions of the sleepers. For each of them, several variables were calculated, such as:

- The distance between the axes of the sleepers (d), a key factor in the study.
- Vertical displacements under the sleeper.
- Forces under the sleepers (on the ballast).
- The bending moment in the central section of the rail (Msc).
- Stresses in the central section of the rail (shear stress).

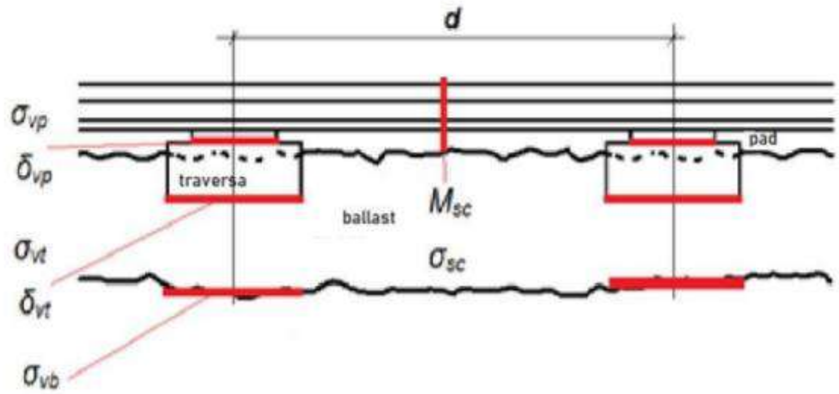


Figure 12. Variables to consider when studying distance between sleepers [*1*]

Too high values of these variables can cause structural problems, damaging the railway track by reducing its quality. In particular, they can occur:

- Vertical displacements can produce significant leaps or bounces during the travel between the wheel and the rail, which can be detrimental and even hazardous.
- Vertical stresses on the supports, they can cause their rupture if they get to be very important.
- High vertical accelerations which can have negative effects on passengers, as well as on the comfort and stability of the travel. For example, according to the guidelines, a passenger can be accelerated up to 1 m/s^2.
- Structural degradation such as breakage and fatigue of sleepers, rails, ballast, etc.
- Wear and tear of track structure and its rolling material caused by the alteration of the vertical deformability of the railway track.
- Loss of track geometry such as levelling and alignment.

All this aggravates maintenance problems and creates difficulties in operating conditions, traffic restrictions and speed limits, even derailing rolling stock.
In addition to the loss of passenger comfort, which in the long run means increased maintenance costs.
Initially, the 2D analysis was done using the DARTS program, both static and dynamic, but a more thorough 3D analysis is certainly needed with a more powerful program and with more accurate simulations.
For this additional simulation, ANSYS software will be used, which allows for element-by-element behaviour analysis.

3) ***THIRD STEP:*** Proposal of several cases of study to reach the optimal solution.
By performing different case studies (for different sleepers' spacing), the optimal separation can be achieved. Initially, the increased spacing will be applied without further modification of the existing elements.
Later, cases will be added with improvements in materials and dimensions of the elements, such as using lighter rails, increasing the surface area of the sleepers, using different construction materials for the sleepers. The speed of the trains will also be changed to evaluate the influence of the separation at different travel speeds.

4) ***FOURTH STEP:*** Laboratory tests of the theoretical model and the cases studied.
The finite element modelling and simulations are needed to create a numerical model of the track and study its behaviour when the sleeper spacing changes. Laboratory tests are also needed to calibrate the previous numerical models and create a more accurate model of the railway superstructure.
These laboratory tests will be performed with static load tests and dynamic load cycles. Fatigue analysis will also be performed in the same manner to study the medium- and long-term effects (fatigue). The same variables previously defined, studied and analysed in computer simulation, will be measured again. The behaviour of the superstructure will be monitored.
Also, the deterioration and integrity will be evaluated during and after the application of the loads. To conclude this step, a vibration analysis is planned to see how the mass behaves towards increasing separation. In a first step, a theoretical model will be built which will be calibrated by laboratory tests.

5) ***FIFTH STEP:*** Comparison of computational models and laboratory test results.
At this stage, the results obtained from the numerical models will be compared with those from the laboratory tests trying to calibrate the previous numerical models.
The final model will be found which will be used for the most thorough and accurate analysis. Here, the behaviour of the railway track elements will be analysed again.
Ultimately, the long-term effects will also be analysed to get a general idea of how increased spacing and contact area between the sleeper and ballast may affect maintenance. This would have characterized the behaviour of a section of street where sleepers were separated.

6) ***SIXTH STEP:*** Analysis of track elements, its maintenance, and its technical feasibility.
Many elements compose a railway superstructure, and it is necessary to see how they behave along the track, as well as to study their evolution in time. It is also necessary to see if it is possible to replace the old sleepers by new ones or simply to separate the existing ones at a certain distance during maintenance and renovation operations.
Certainly, the work on the track affects its subsequent performance, so it is important to see how the renovation work affects the new configuration of the elements.
In the end, the feasibility of innovative solutions must be studied (without increasing costs).

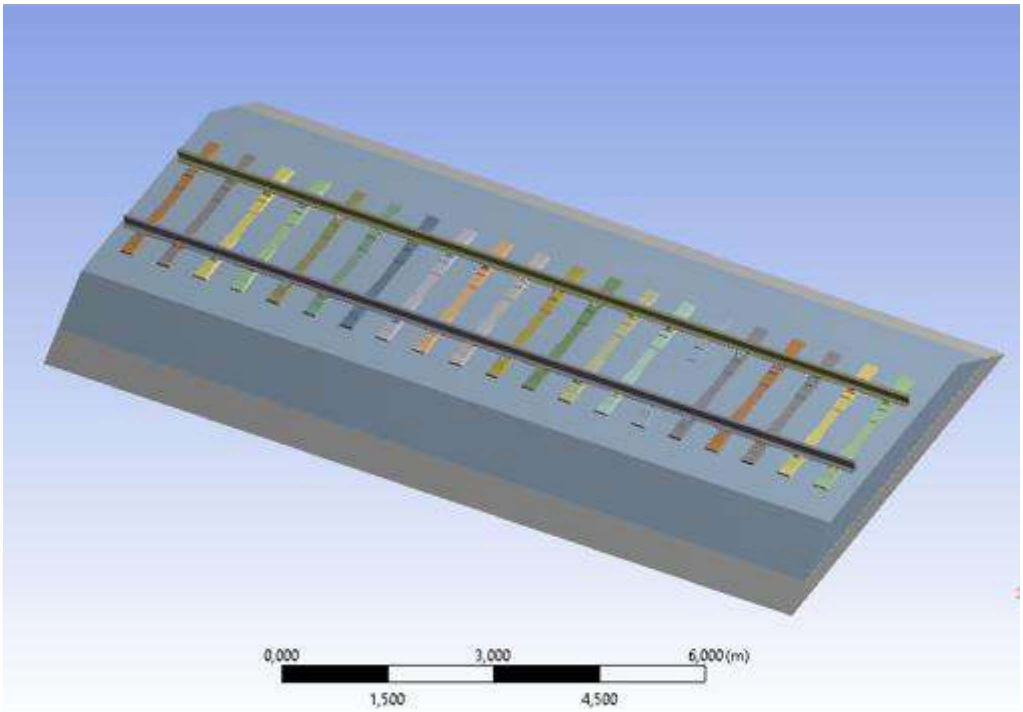


Figure 13. 3D Track Model in ANSYS

To summarize the methodology, the scheme in Figure 11 presents the steps and processes of the **overall *ODSTRACK*** project. This methodology tries to assemble all existing information from various sources (articles, books, websites, etc....). Once this collection is done, a 3D model is created, and two case studies will be set to perform a numerical simulation.

The **two main cases** that the thesis will concentrate on would be as follow:

- Study of various sleepers spacing (0.6m, 0.7m, 0.8m and 0.9m) while applying the loads on rails between sleepers.
- Study of various sleepers spacing (0.6m, 0.7m, 0.8m and 0.9m) while applying the loads on rails over sleepers.

Then a full-scale laboratory test will serve to calibrate the above numerical models. The laboratory tests will avoid testing on a real railway, which would be costly and more difficult.

After creating several case studies, it will be possible to verify the different solutions proposed to increase the distance between sleepers. To finalize the project, a technical feasibility study is necessary to take all the results of the project to a study on a real ballasted track. Based on the results obtained, guidelines will be drafted to be considered to carry out the increase of the distance between sleepers.

Once the methodology of the main ODSTRACK project has been defined, we will define the structure and where this master's thesis is located in the general project. Currently, in the general project, the previous studies of data collection and the calculations of a two-dimensional numerical model have already been carried out.

The current objective of this Master thesis is the creation of a three-dimensional numerical model using the finite element program ANSYS 21 R2. This work will focus on analysing the behaviour of the elements that make up the superstructure of the railway by applying loads on different spacings between sleepers using the aforementioned software.

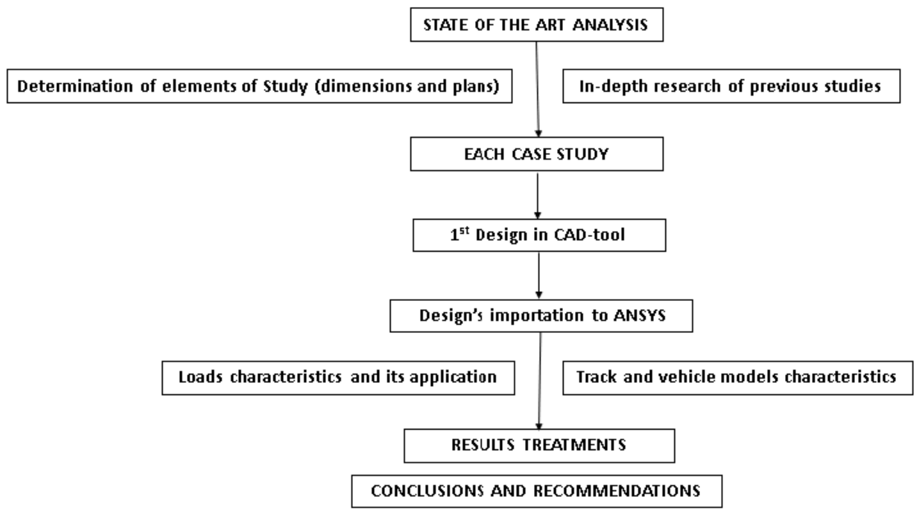


Figure 14. Summary of the methodology followed in the ***corresponding thesis***

The main points to be followed in this master's thesis in order to carry out the study are listed below:

- **Analysis of the state of the art** by obtaining existing information related to the subject of the project. Conducting an in-depth search of all possible previous studies on the increase in spacing between sleepers is mandatory.
- Obtaining plans and dimensions of the elements of study from the state of the art. Once the geometry of the elements that make up the track structure has been obtained, its **design** will be proceeded in a **CAD-type tool**.
- Realization of the **three-dimensional numerical model** using the finite element software chosen from the geometry created in the previous point.

- After design of the track and vehicle models, an analysis of its **deformation behaviour** with variation in the spacing between sleepers while supporting the same loads in each case study.
- Estimation of **prediction models** of the **behaviour of superstructure elements** with the separation between sleepers.
- **Summarizing the conclusions obtained** from the numerical models. Recommendations for further research about the influence of rail spacing on rail joints and rail welds.

The main research project "ODSTRACK" [1] study all elements from track superstructure, the investigation showed in [2] tried to find what happen in the rail track fastenings. This current TFM is a continuation of [2] and it complements [1,2]. This thesis will help to understand and to analyse the rest of the track superstructure elements within the ODSTRACK project framework.

V. 3D MODEL

This section shows the program used for numerical modelling and the track and load models used during the simulations. The model and the program have been already used in previous work [1, 2]. Here a new version of the ANSYS software has been used for the analysis.

5.1. ANSYS PROGRAM

In the global project, the elements of study are the rail, sleepers, ballast, pads, and fastening elements. The sleepers will be the main object of study for this master's thesis.

There are numerous programs for problem solving by the finite element method [1, 2]. However, the software chosen for the in-depth analysis of the elements forming the track will be the ANSYS program in its version 21 R2. It is a software for the finite element simulation of various types of problems. The most common in the engineering area are the analysis and structural calculation of elements or structures, heat transfer problems, fluids, electromagnetic potentials, etc [22].

This program has several parts during the calculation, simulation and analysis. The pre-processing (generation of the models), obtaining solutions and post-processing (graphics, parametric model). For the case study, the program will allow us to model both the track superstructure and infrastructure, to apply a series of loads and to analyse the elements that compound the track superstructure, rail, fasteners, ballast, and sleepers in isolation.

Analytical solutions are all those mathematical expressions from which it is possible to obtain determined unknown. This expression is valid for the whole element under study, which includes any section of it and all the points that compose it. As a consequence, this type of expression requires solving differential equations which are too complex if all the variables that influence the real problem are considered, and it is not possible to solve them.

The finite element method is a numerical method used to solve highly complex problems in the engineering field (geometrical difficulty, difficulty in defining and calculating stresses, and characteristics of the materials forming the model). In general, for these problems it is impossible to find an analytical solution directly from mathematical expressions [23].

If, on the other hand, the finite element method is used, the problem is solved by posing a series of simultaneous algebraic equations instead of having to solve a large number of complex differential equations. To solve the problem, it must be discretized first.

With this procedure, approximate values of the unknowns are obtained for a given number of points within the element under study, which depend directly on the number of elements that make up the discretization of the part.

Discretization consists of the division of the element under study, previously modelled, into a system formed by sub-parts of the same in such a way that all these parts are equivalent to the element as a whole being. Each of these small bodies (finite elements) are interconnected by means of common points or nodes forming surfaces and behaving as closed elements that form independent control volumes which are in turn affected by the boundary conditions affecting the body under study as a whole.

5.2. TRACK MODEL

The track geometry has been made with a CAD tool. Once it is done, the 3D section will be exported to the three-dimensional calculation program previously chosen (ANSYS).

The track geometry corresponds to a high-speed single-track section, whose geometric structure is shown in the following figure.

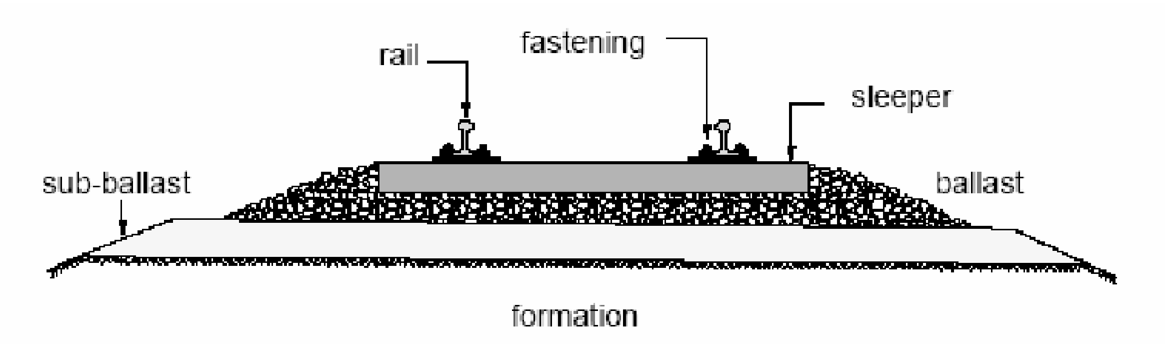


Figure 15. Components of the ballasted track.

The simplified track section to be used consists of UIC 60 rail, prestressed concrete monobloc sleepers, which rest on a ballast bed, a sub-ballast layer and a form layer on the natural terrain represented as a boundary condition. Longitudinal drainage works on both sides of the track will not be considered in the calculation.

The ballast layer will have a thickness of 500 mm so that the sleeper is semi-buried in it (20 cm + 30 cm under sleeper) and the sub-ballast layer will have a thickness of 300 mm. Both ballast and sub-ballast materials have different characteristics, which will be described later.

Modelling begins with the process of creating the track section using a CAD tool. The track model finally used will consist of the following parts:

- **Sub-ballast layer**: it will be placed just below the ballast layer, following the same considerations used in the ballast bench.
- **Ballast layer**: it is considered as a continuous solid for the simplification of the same.
- **Prestressed concrete monobloc sleepers**: When modelling, the sleeper will be considered as a solid of a single material, but with the proper sleepers and characteristics of a real prestressed sleeper.

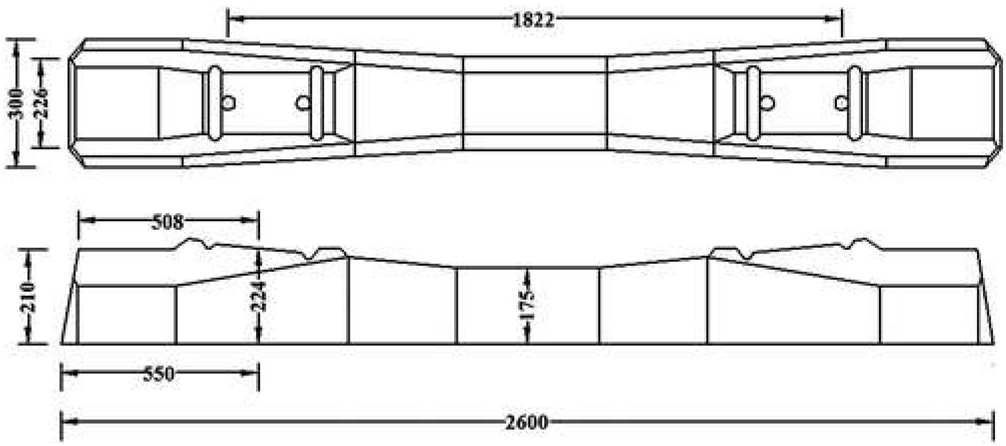


Figure 16. ***Example of a prestressed monobloc sleeper used in the model.***

- **Rails:** for the study we are going to work with UIC60 rails. The profile of this type of rail is shown in the following figure.

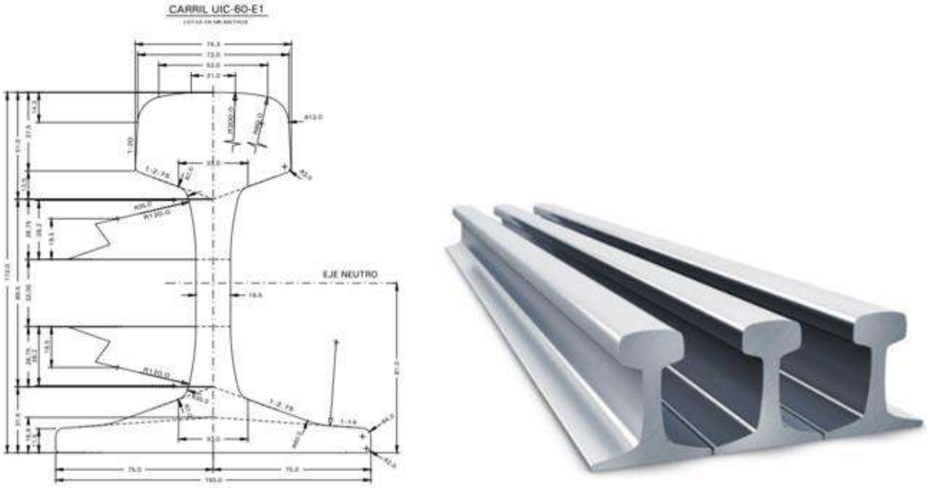


Figure 17. Detail and sectional view of UIC 60 rail [24]

- **Pads and fasteners:** These elements are placed between the sleepers and the rails as cushioning elements. The fastening used is of the Vossloh SKL type.

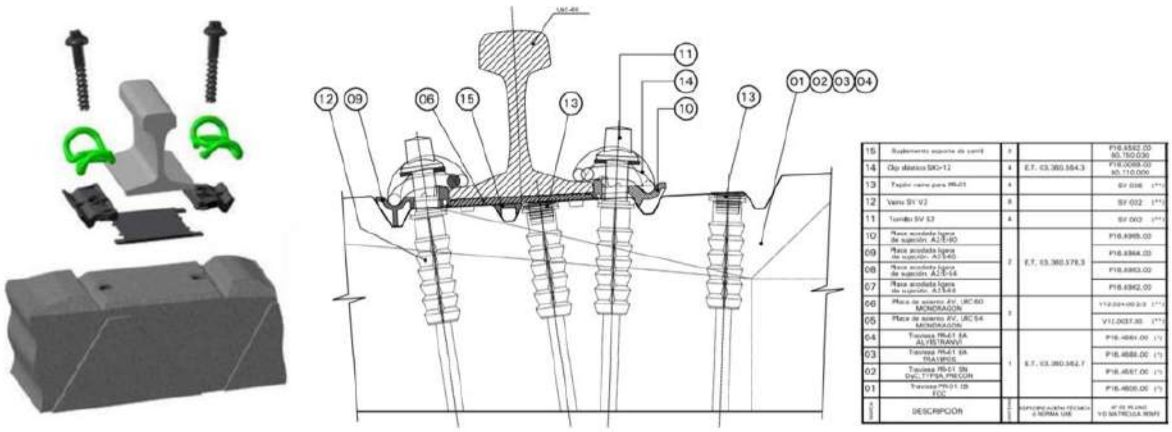


Figure 18. Detail of fasteners used, type Vossloh SKL [24]

The modelling begins with the process of creating the track section using a CAD tool in which the components mentioned above will be created.

To perform the first tests of the track modelling in the ANSYS 21 R2. program, a simplification of the track geometry has been used to achieve greater speed in the calculations and in the efficiency of the program itself.

The first tests for the correct calibration and adjustment of the program will be carried out with a track model composed of a sub-ballast layer, a ballast layer, four monobloc sleepers, eight pads, and two rails together with the corresponding fastening elements, the latter not included in the first calculation tests.

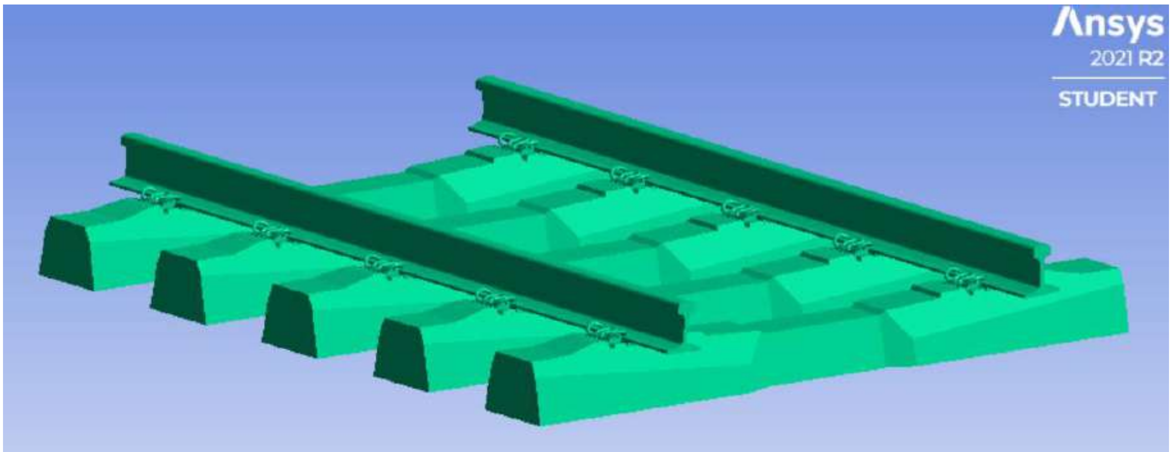


Figure 19. short track model of five sleepers.

It should be considered that the sleepers are placed mostly buried in the ballast bed, hence it will be necessary that in the model created they are embedded in the first layer of ballast, considering them as separate elements.

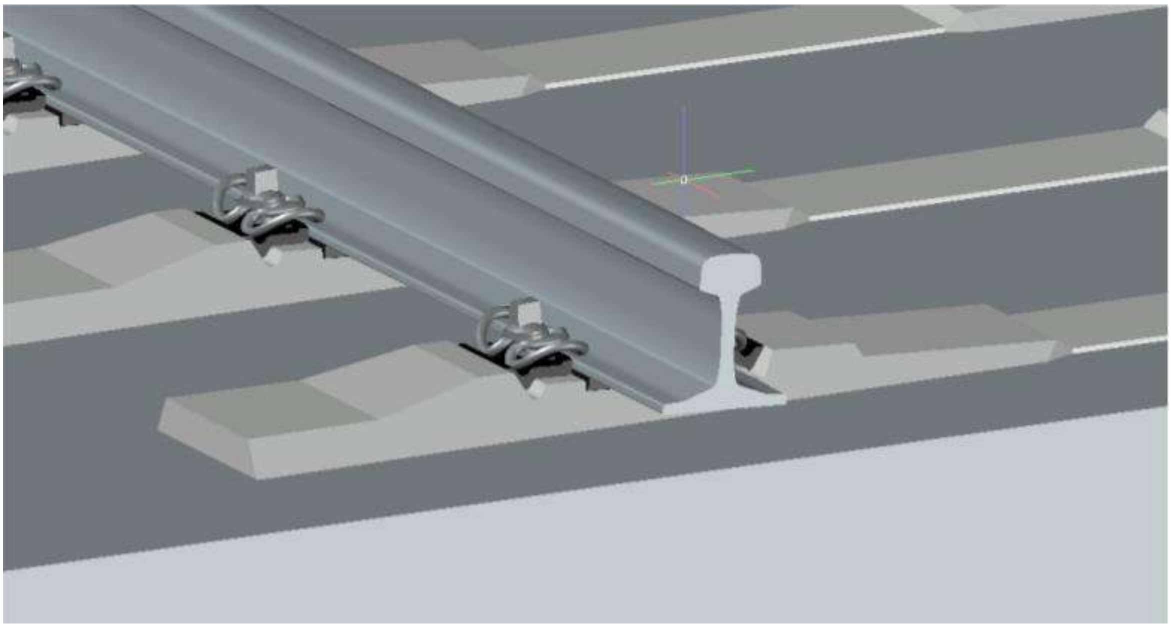


Figure 20. Details of sleepers being embedded in the ballast layer.

Before the beginning of the use of the ANSYS program. First, the materials of which each of the elements to be used are composed will be introduced with the corresponding proper sleepers and characteristics for their correct behaviour and characterization in the program. The elements that will compose the model are listed in the following table [25].

Table 7. Material properties used in ANSYS 21 R2 [2].

MATERIALS	PARAMETERS		
	Young's modulus (Mpa)	Poisson's ratio	Density (Kg/m³)
Rail	206000	0.3	7800
Pad	100	0.49	850
Clip	180000	0.3	7800
Codo-Pad	5200	0.34	1360
Concrete-Sleeper	62.4	0.2	2500
Ballast	170	0.3	1800
Sub-ballast	500	0.25	1600
Sheath/Vaina	2600	0.39	1140

No other layers below the sub-ballast have been included since the type cases analysed have given depreciable deformations and stresses in layers below the sub-ballast.

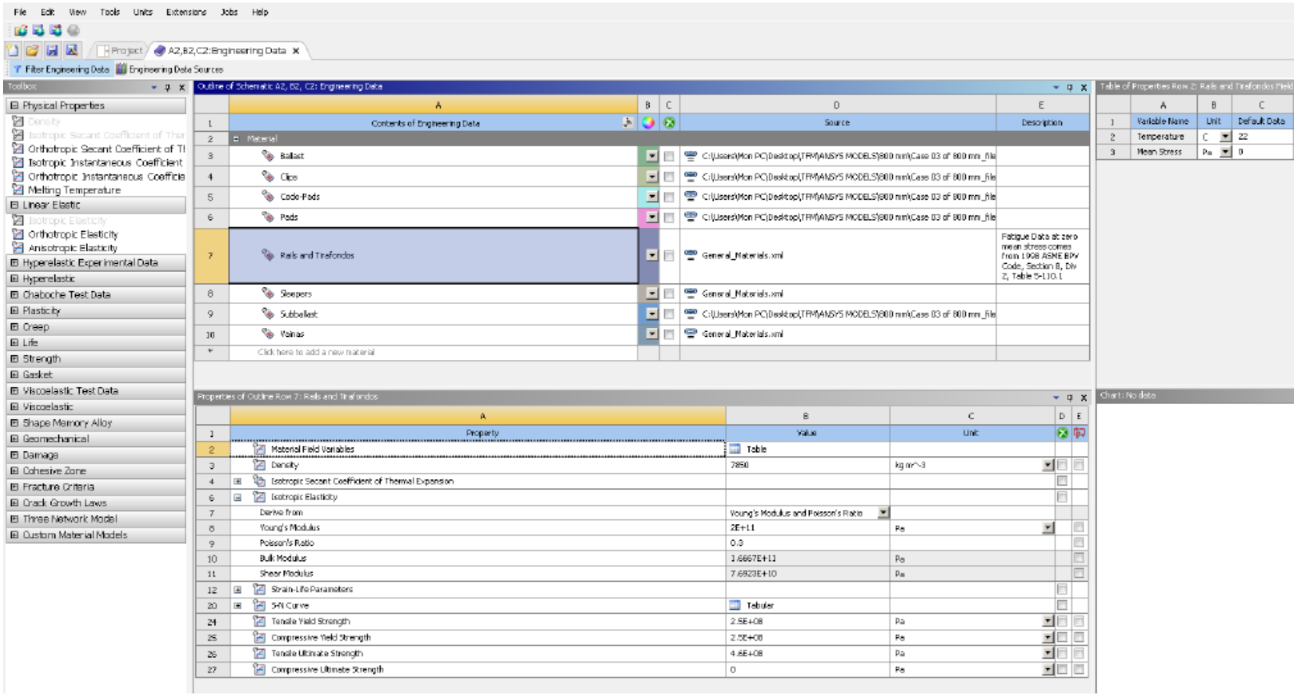


Figure 21. Materials defined in the ANSYS Workbench framework.

Once the materials have been defined, we proceed to import the geometry from the CAD-file to the ANSYS modelling space, SpaceClaim. As can be seen in Figures 22 and 23, each element of the model is represented by a different colour. In this program, this colour difference implies a correct modelling and that the components are going to behave as separate elements and not as a single solid element. Screenshots of the complete model and each of its component elements are shown below.

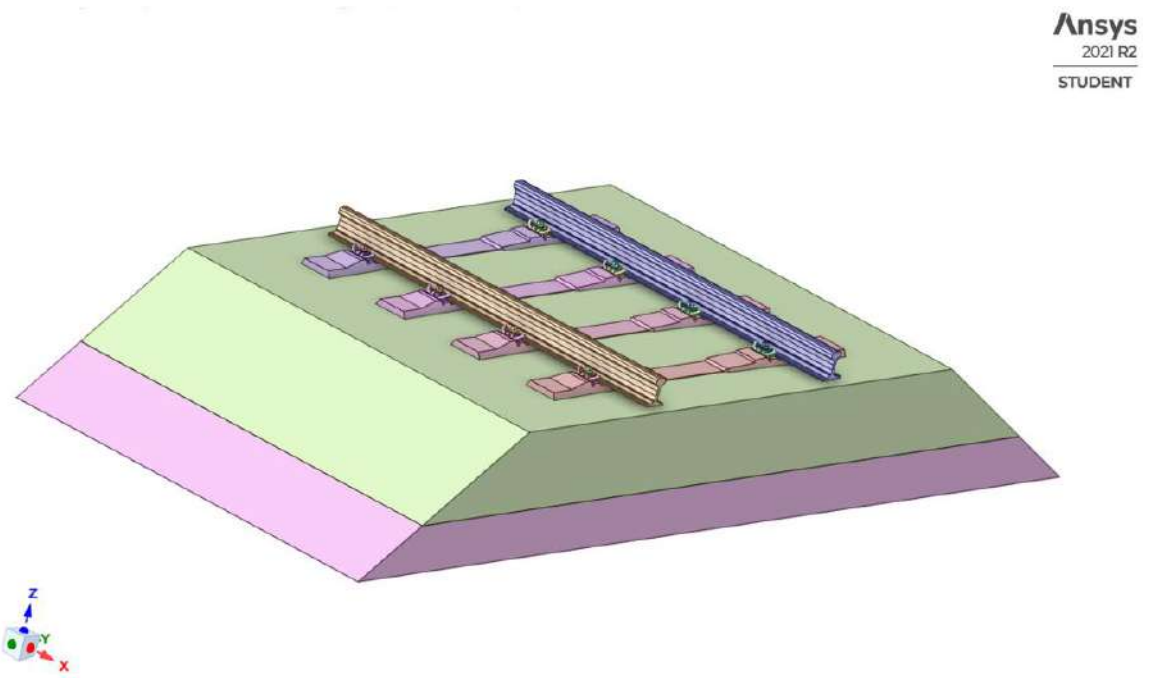


Figure 22. View of the section of track model used presented in ANSYS.

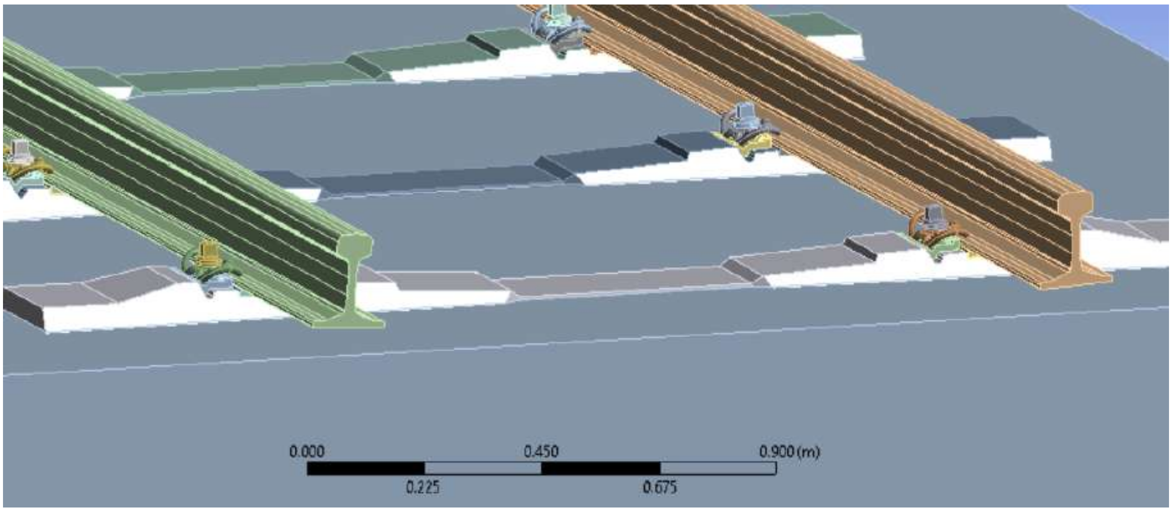


Figure 23. View up-close to the superstructure elements in ANSYS 21 R2.

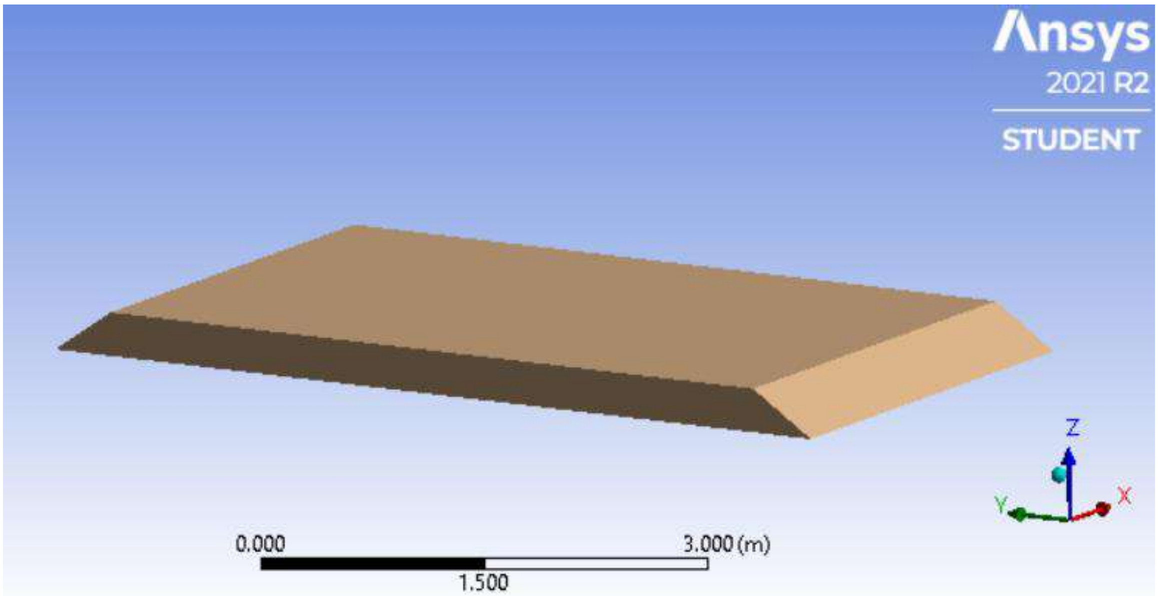


Figure 24. ***Representation of sub-***ballast in the ANSYS***21 R2***

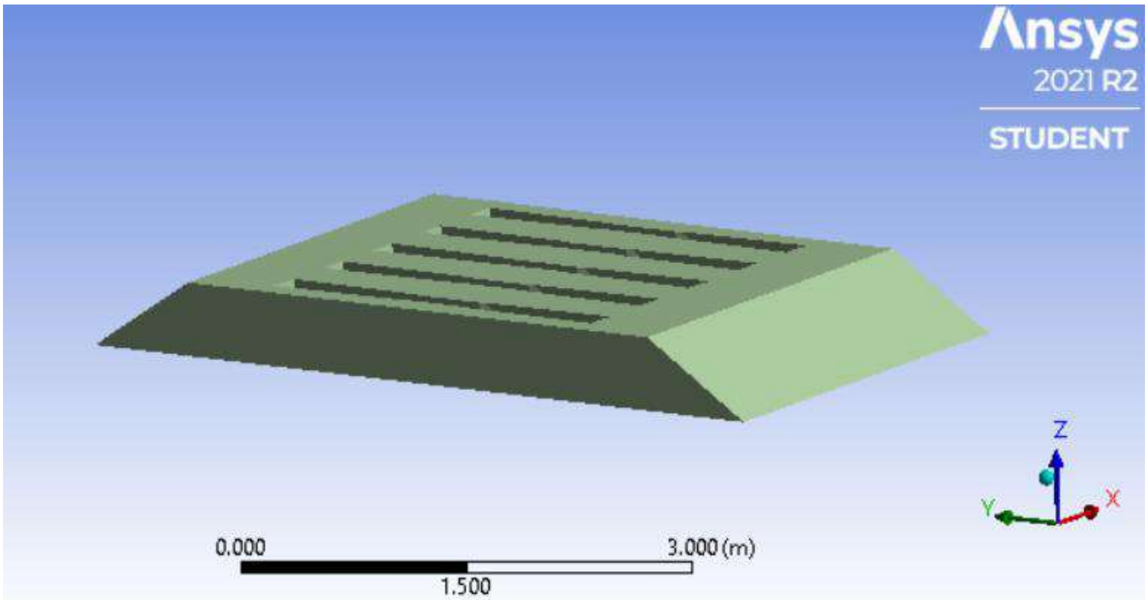


Figure 25. Representation of ballast layer in ANSYS21 R2

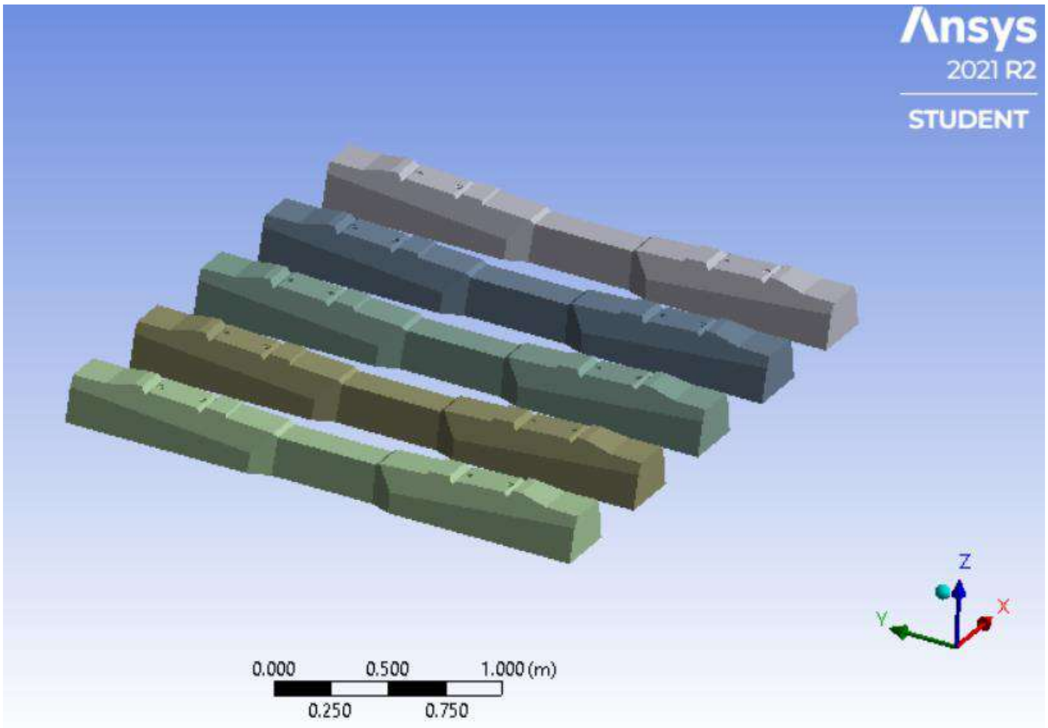


Figure 26. ***Representation of c***oncrete ***s***leepers in the ANSYS***21 R2***

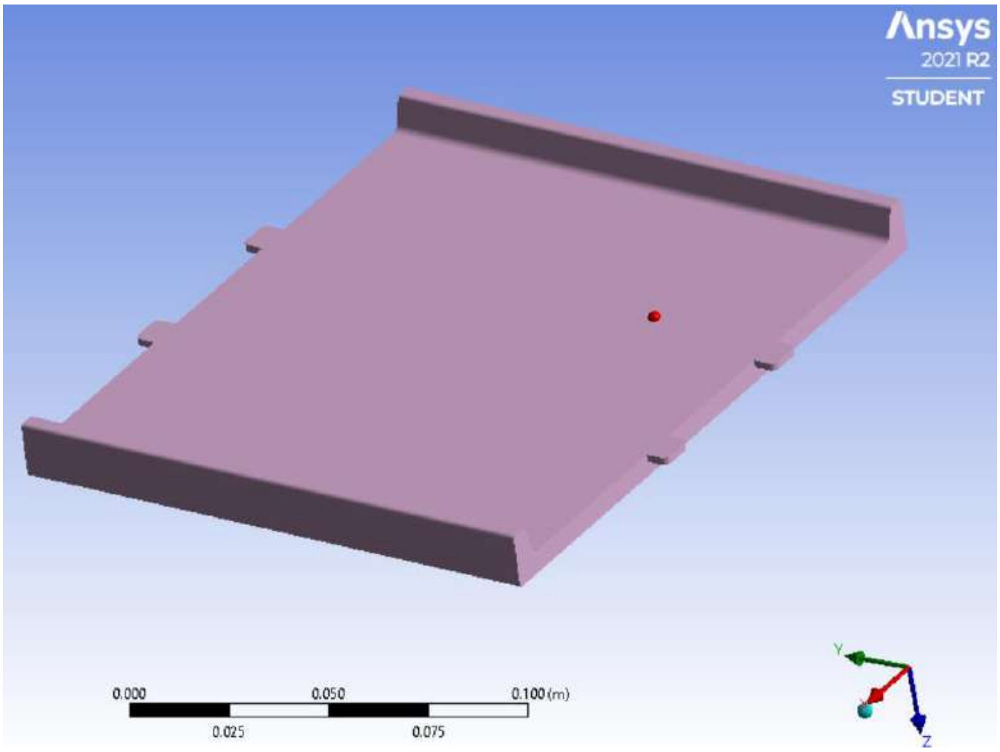


Figure 27. ***Representation of p***ad in ANSYS***21 R2***

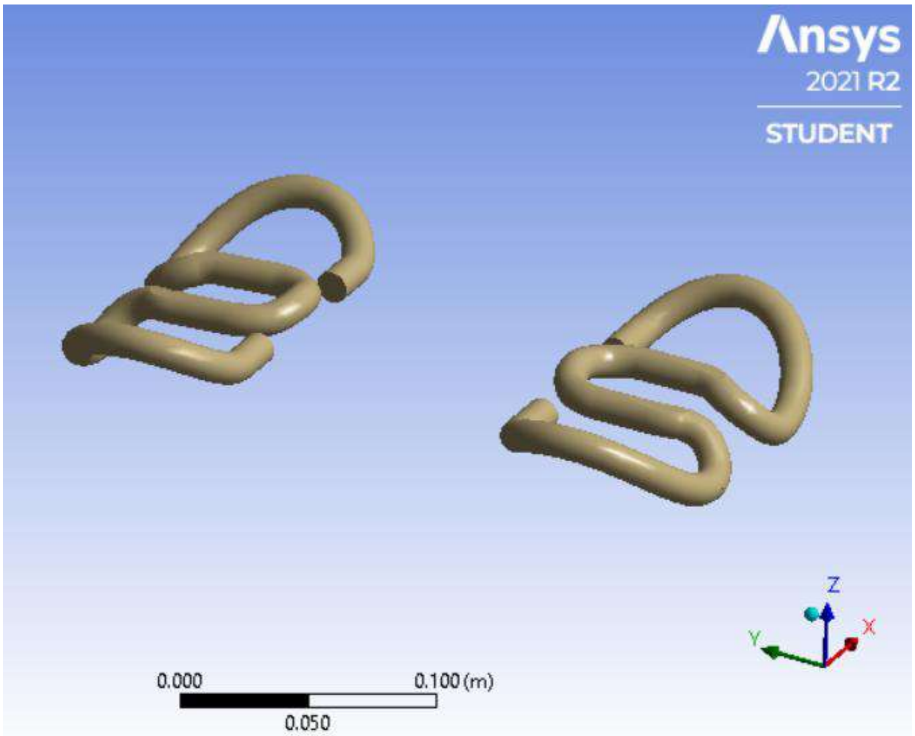


Figure 28. ***Representation of clips*** in ANSYS***21 R2***

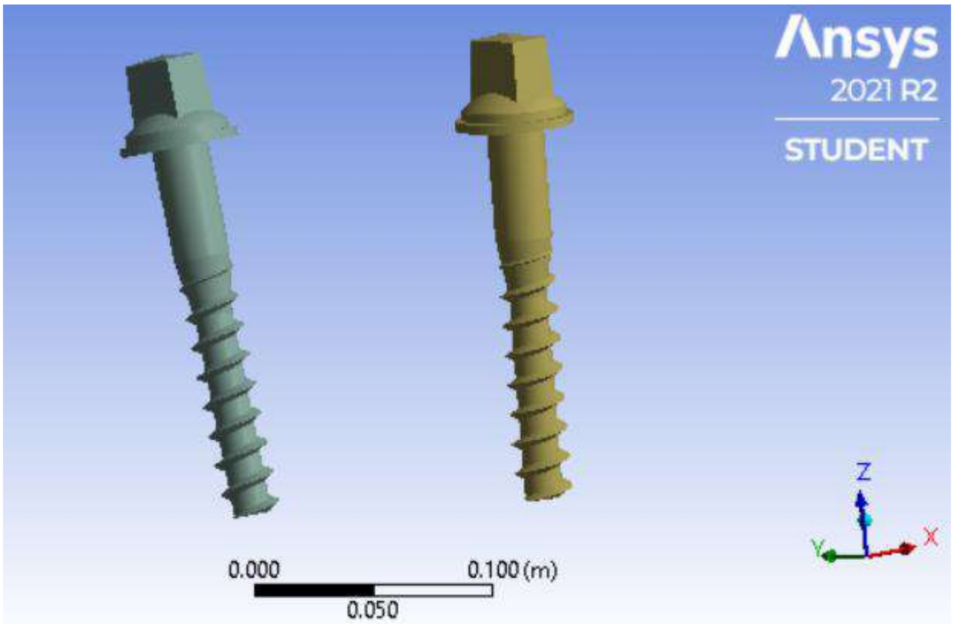


Figure 29. ***Representation of bolts*** in ANSYS***21 R2***

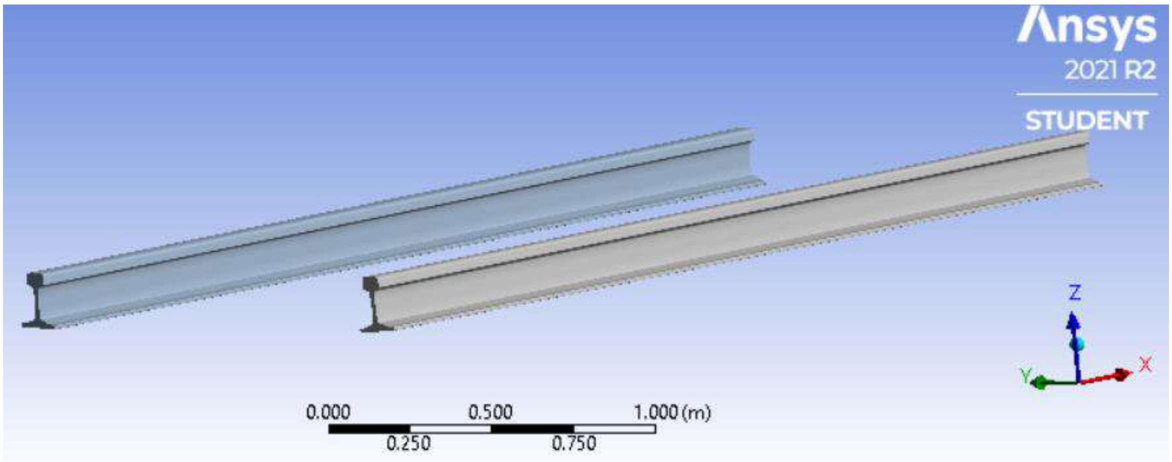


Figure 30. Representation of rails in ANSYS21 R2

For easier handling of the different elements, groupings will be created with the different parts that make up the track model. In the program these groupings are known as "Named selection" and are necessary to apply loads, give proper sleepers to the elements and more functions that will be exposed throughout the project.

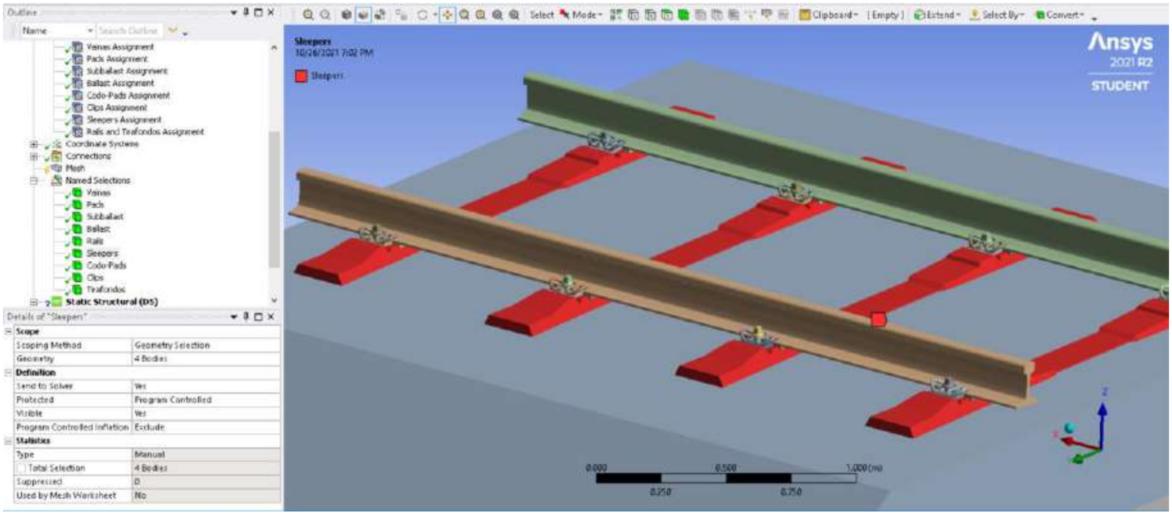


Figure 31. Example of creating a "Named Selection" Objects.

The next step will be the definition of the meshing of the model. It will consist of the division of the solids in small, interrelated parts where the different material resistance equations are applied to create the calculation matrix. It is possible to define points of interest where more detail is required by creating a denser mesh (see figure 33, table 8). In this case, the areas where a higher density mesh will be assigned will be the elements that form the rails and the fasteners since the latter will be the main element that would need to support the applied loads of the study of this work. To carry out this process we will use the groupings created in the previous point and the "Sizing" option when creating the new mesh. It is at this moment when we will define the spacing of the grid of each "Named Selection".

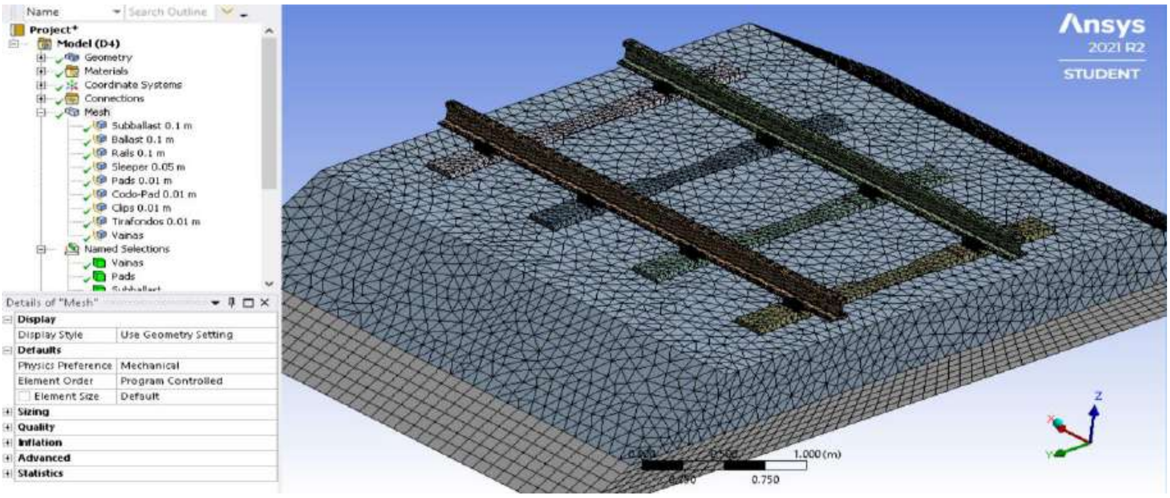


Figure 32. Track meshing in ANSYS 2021 R2 Mechanical modelling

Table 8. Mesh size per element used during simulations [2]

ELEMENTS	MESH SIZE
Ballast	0.1 m
Sub-ballast	0.1 m
Sleepers	0.05 m
Pads	0.01 m
Codos-Pad	0.01 m
Clips	0.01 m
Bolt/Tirafondo	0.01 m
Rails	0.1 m

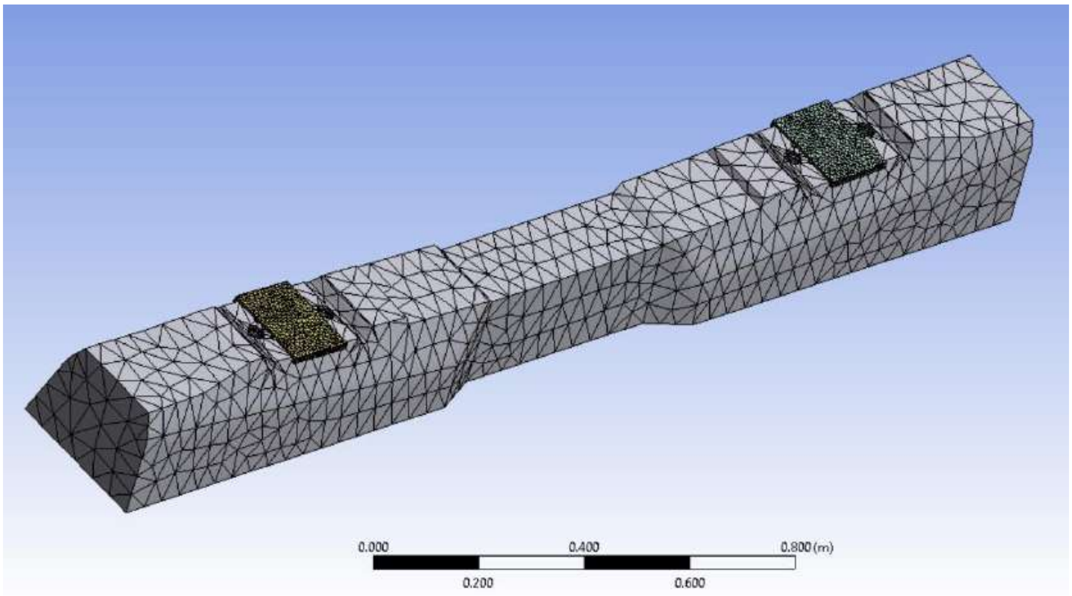


Figure 33. Detail of the mesh in the element's sleeper and its corresponding pads

As was done with the assignment of the mesh corresponding to each grouping, each "Named Selection" will be assigned the characteristics of the materials that form it, which have been defined in the first steps of the modelling in the ANSYS 21 R2. program by creating "Material assignments".

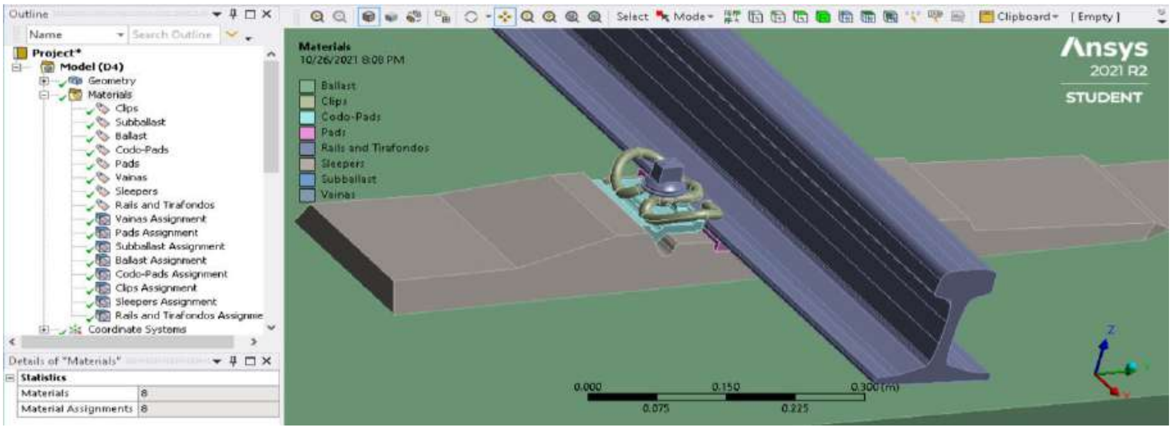


Figure 34. Example of material assignment in ANSYS

The contacts between the different elements that make up the model are made automatically by the program itself. There are several types of contacts that the program allows us to create: "bonded", "no separation", "frictional", "frictionless" and "rough"[26].

Table 9. Contact types and behaviours in Structural Analysis [2, 26]

TYPES OF CONTACT	
Bonded	In this contact, defined geometries act like one body. Bodies cannot move (no slide and no separate) and rotate between each other.
No Separation	Once the contact is detected, then the target and contact surface are sleepers up for the rest of the analysis. Slide is possible, but the nodes in contact are bonded to the target surface in normal direction.
Frictionless	The contact pair can slide on the target surface in the tangential direction and also can translate in the normal direction.
Rough	Friction coefficient tends to be infinite on body. Contact pair cannot move in the tangential direction because nodes in contact are glued on the target surface in tangential direction.

In this case a "Bounded" type contact will be assumed. The elements will behave as if they were a single element with the different characteristics of the materials of each part. The only movement allowed is rotation. A perfect contact and maximum friction between the different elements are assumed in order to use this type of contact.

To continue with the numerical model, it is necessary to define boundary conditions that define the space where the model is being tested. Due to the defined contact between elements, there is no risk of layers sliding over each other. A "Fixed Support" will be placed on the bottom face of the sub-ballast geometry, which will simulate the contact between sub-ballast and the subgrade, this condition will reduce the degrees of freedom of movement of the layer so that the base will act as a fixed element. The other fundamental condition to be introduced is the acceleration of gravity acting on all elements of the model, which is added as "Standard Earth Gravity" and having a negative vertical component of 9.8066 m/s^2.

Since no loop movement and no rail surface imperfections have been considered, the track is symmetrical, and the loads are symmetrical as well and therefore no buckling or excessive deformation in the transverse direction is expected.

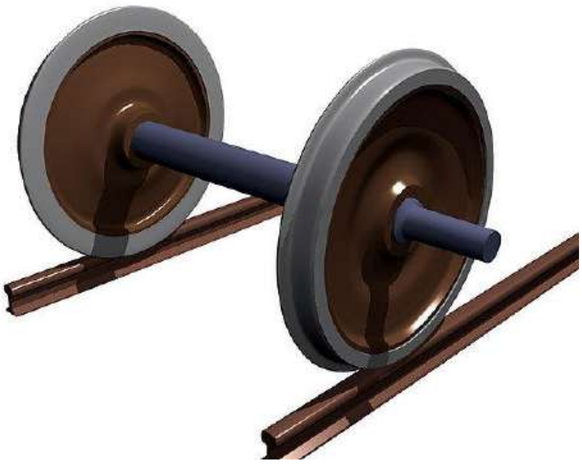


Figure 35. Wheel-rail contact example

To finish with the conditions and stresses acting on the model, the loads corresponding to a freight train will be added, remaining on the safety side for conventional and high speed (lighter) trains. This means 22 tons per axle, which will be modelled as two vertical downward loads of 11 tons each acting in the central area of the model on the rails, in the central span between sleepers in the 4-sleeper model. For load placement, the "Named Selection" element will be used again to define the points of application. They will be placed slightly offset from the rail head towards the longitudinal axis of the track to simulate the real wheel-rail contact. The main reasons that led us to adjust the wheel-rail load to a nodal force are the program's calculation time and the capacity of RAM memory of the computer. Therefore, the most suitable solution in such a case was to minimize the rail track elements to a certain number.

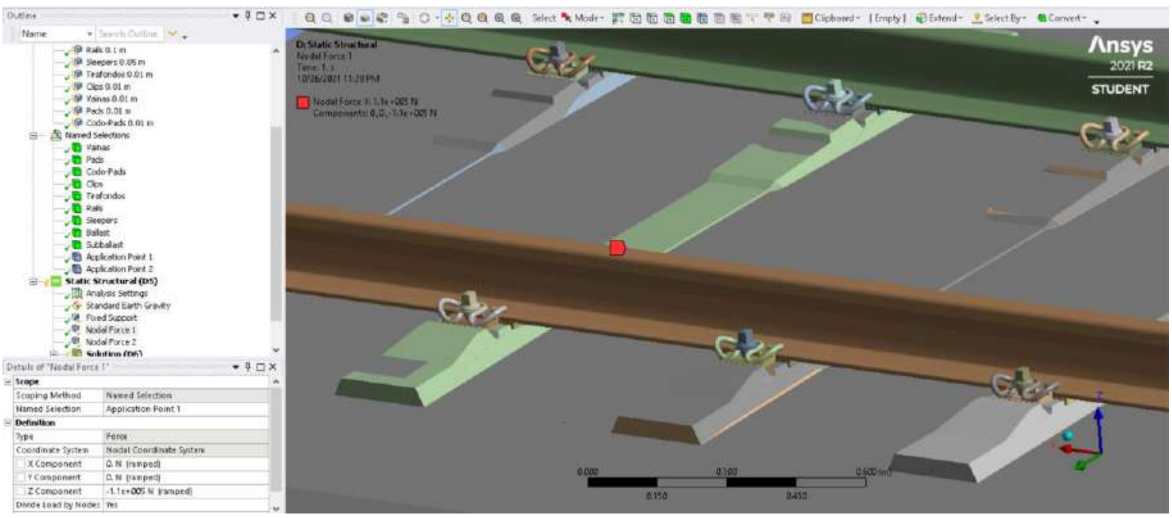


Figure 36. Boundary conditions and point of load application

The final step is to define the parameters to be measured in the model. In this case, as an initial test for the calibration of the model, it has been decided to take measurements of the deformations that are generated in the track. The program automatically adjusts the scale of the deformations so that they are visible and gives them a range of colours to be able to know at a glance where they are greater (red greater deformation and dark blue less deformation).

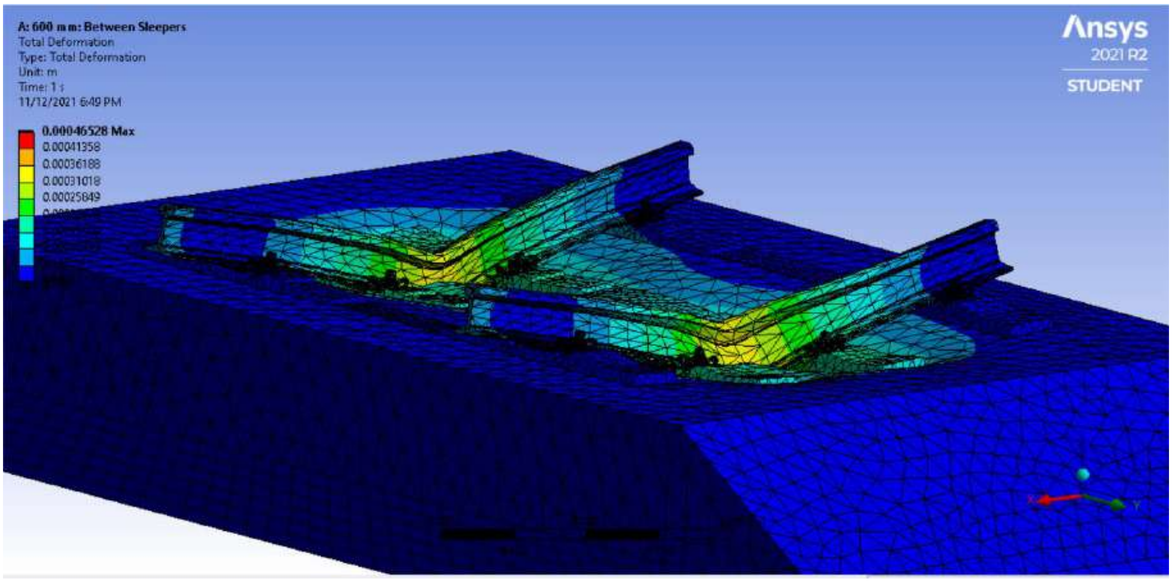


Figure 37. 3D track model presenting deformations due to loads applied in case 600mm

Once the correct operation of the initial model generated has been tested, the modelling of the different remaining case studies will be carried out. It has been considered to study how the loads of an axle act on the restraints as a function of the spacing between supports of 600 mm, 700 mm, 800 mm, and 900 mm. The loads will act on the centre span of the rail (four-sleeper model). The corresponding calculations and analyses will then be carried out to verify their functionality and structural integrity.

5.3. TRACK STATIC LOADS

Instead of a complete axle train (for high time consuming and big computer memory), authors decide to use vertical loads to simulate wheel loads. A static analysis was performed for two different load positions. This loads' scheme and the placement were used in [2]. Following the same scheme, there are two types of positions:

- ***Position between supports (between sleepers)***: the loads corresponding to one of the axles of the train centred between two of the sleepers of the modelled section are placed.

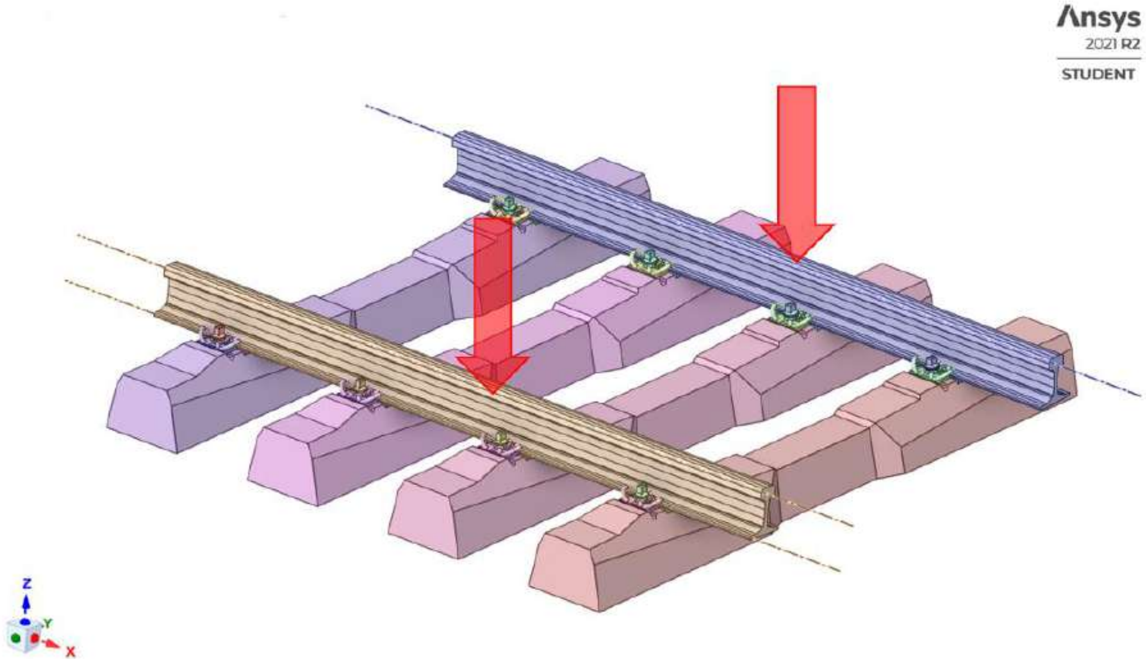


Figure 38. Loads applied between supports in SpaceClaim ANSYS 2021 R2

- ***Position on support (on sleeper)***: the loads corresponding to one of the axles centred on one of the sleepers of the modelled section are placed.

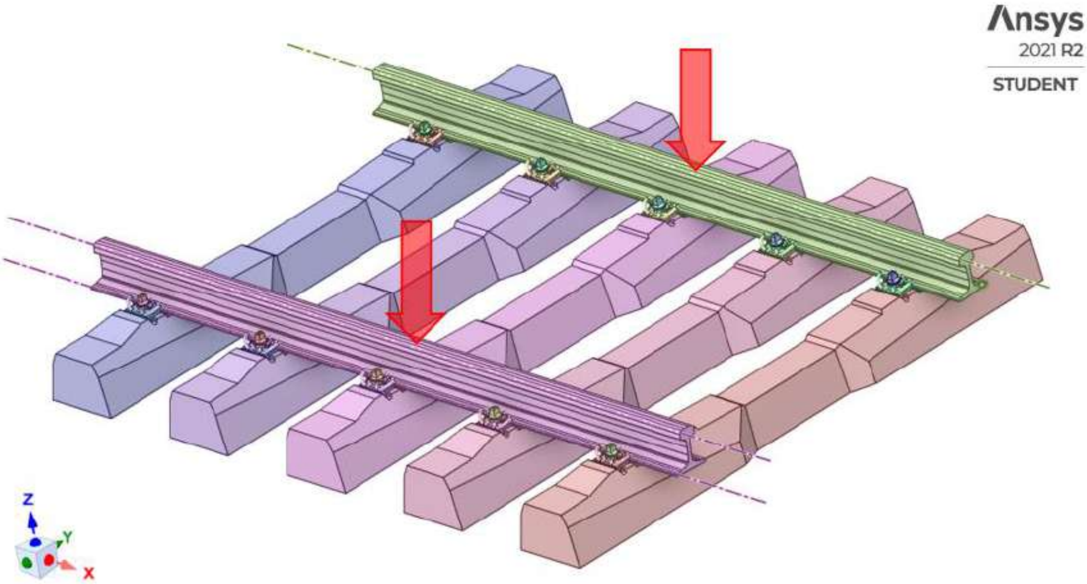


Figure 39. Loads applied on the support in the case of 5 sleepers presented in SpaceClaim

The spacing to be studied is defined by the preliminary two-dimensional calculations. This spacing will go from 600 mm, the current placement, increasing the spacing in each model by 0.1 m until reaching a distance of 900 mm, which according to the two-dimensional calculations would be the most unfavourable.

VI. RESULTS AND DISCUSSION

After the 3D model and the simulation by means of finite elements, the parameters obtained will be maximum total deformations in rails, sleepers, pads, and ballast and maximum Von Misses stresses in the same elements. We specially analysed those two parameters in particular since the objective is to determine if metals (ductile materials) will yield when subjected to a complex loading condition by comparing it to the material's yield stress which establishes the Von Mises yield Criterion.

The data are obtained from the reports generated by the ANSYS 21 R2. program. These reports will be added to this study as a data annex (see annexes). They contain all the information necessary for the generation of the model in three dimensions, geometry, materials, contacts, contour elements, etc.

6.1. ANALYSIS OF RESULTS

In the analysed model, the results of deformations and stresses in the superstructure of the track (rails, sleepers, pads, and ballast) have been acquired. A maximum analysis will be carried out to determine whether the structural safety thresholds of each component are exceeded and then an analysis of each parameter as a function of distance will be carried out to see if it is possible to determine a behavioural model based on the spacing between sleepers.

6.2. SUPERSTRUCTURE ELEMENTS MOST AFFECTED BY DISTANCE VARIATION

The following table show the data obtained from the model in one of the cases (table 10), filtered for quick interpretation later, as we only focused on the maximum deformation (table 11) and maximum stress values (table 12) experienced by the elements of the structure under study, the rails, the sleepers, the pads, and the ballast. Therefore, and to make a comparison the most important analysed variables were vertical displacements (deformation in ANSYS) and stress in all track elements (Equivalent stress in ANSYS).

Table 10. Deformation experienced by elements of rail track in the 1st case study obtained by ANSYS.

Elements	Distance	Minimum	Maximum	Average	Units
Rail	600	0.00421	0.48959	0.14568	mm
	700	0.00157	0.53994	0.15010	mm
	800	0.00052	0.59838	0.15483	mm
	900	0.00172	0.66550	0.16462	mm
Sleeper	600	0.10707	0.24018	0.17486	mm
	700	0.10812	0.24685	0.17833	mm
	800	0.10883	0.25199	0.18059	mm
	900	0.11008	0.25882	0.18412	mm
Ballast	600	0.00183	0.23167	0.04861	mm
	700	0.00182	0.23729	0.04454	mm
	800	0.00174	0.24064	0.04124	mm
	900	0.00076	0.24698	0.03808	mm
Pad	600	0.17248	0.27327	0.20810	mm
	700	0.17819	0.28682	0.21009	mm
	800	0.17884	0.28927	0.21335	mm
	900	0.18156	0.30559	0.22064	mm

Table 11. Summary of maximum values of deformation experienced by elements of track.

Maximum Deformation (mm)	Distance 600 mm		Distance 700 mm		Distance 800 mm		Distance 900 mm	
	Load between sleepers	Load on sleeper	Load between sleepers	Load on sleeper	Load between sleepers	Load on sleeper	Load between sleepers	Load on sleeper
Rails	0.46528	0.41386	0.53994	0.48912	0.59838	0.47521	0.6655	0.50738
Sleepers	0.22443	0.26954	0.24685	0.28495	0.25199	0.30175	0.25882	0.31792
Pads	0.28192	0.26958	0.28682	0.31927	0.28927	0.33720	0.30559	0.35944
Ballast	0.22179	0.26407	0.23729	0.27772	0.24064	0.29415	0.24698	0.30917

Table 12. Summary of maximum values of stress experienced by elements of track.

Maximum Equivalent Stress (MPa)	Distance 600 mm		Distance 700 mm		Distance 800 mm		Distance 900 mm	
	Load between sleepers	Load on sleeper	Load between sleepers	Load on sleeper	Load between sleepers	Load on sleeper	Load between sleepers	Load on sleeper
Rails	138.6200	80.9190	115.8500	124.9000	0.1348	122.0100	87.5880	93.1900
Sleepers	20.8760	18.9700	14.2080	18.2120	15.6490	15.6120	0.1442	12.1930
Pads	2.8138	1.5608	2.9959	1.9694	3.1162	2.5462	3.3631	2.8415
Ballast	0.1106	0.1441	0.1312	0.1590	0.1348	0.1676	0.1442	0.1781

According to the acquired results in the tables above, we observe that all elements are below the limits values suggested in the table 13 for both stresses and displacements as can be seen by comparing them.

Table 13. Limits values of stresses and displacements that the track elements can support.

TRACK ELEMENT	VARIABLE	LIMITS (Units)	REFERENCE
Rail	Displacements	Conventional track 1.0 (mm)	Maynar (2008) [27]
		High Speed track 0.75 (mm)	
	Stress	Compressive UIC 60 ,72 (MPa)	Martínez (1992) [28]
		Axial UIC 60, 92(MPa)	
		52 kg/ml Rail, 180(MPa)	Singh (2016) [29]
		60 kg/ml Rail, 225(MPa)	
		60 kg/ml Rail (break), 880(MPa)	Lichtberger (2011) [30]
	Bending stress	130(MPa)	Eisenman & Leykauf (1993) [31]
		UIC 60 (corrosion-CWR) 200(MPa)	Doyle (1980) [26]
		UIC 60 (New-CWR) 282(MPa)	
		UIC 60 (corrosion-Jointed) 210(MPa)	
		UIC 60 (New-jointed) 320(MPa)	
		fatigue (jointed) 78000 (kN/m^2)	Doyle (1980) [26]
		fatigue (CWR) 176(MPa)	
Sleeper	Displacements	5.0 (mm)	Bisht (2015) [18]
	Stress	6.5(MPa)	Doyle (1980) [26]
		compressive resistance 45(MPa)	Doyle (1980) [26]
		Softwood sleepers 1000-1500 (MPa)	Esveld (2001) [32]
	Contact pressure betwe	Hardwood sleepers 1500-2500 (MPa)	
		Concrete supports <= 4000 (MPa)	
	Bending stress	tensile stress 5.5	Doyle (1980) [26]
Ballast	stress	0.3(MPa)	Lichtberger (2011) [30]
		0.5 (MPa)	Esveld (2001) [32]

The maximum stresses obtained in the rails are below the maximum stress supported by those elements according to the values proposed by Singh (2016), also in the case of sleepers, the maximum values that have been obtained are conform with the projected limits values that are proposed by Esveld (2001) in the table 13. Moreover, when it comes to ballast, we notice that all the cases (600-700-800-900mm)

As we discussed previously, fastening elements also has an important role since they are made up of many elements that could affect the performance of the track, yet in this study, we will focus on pads besides the main elements as rails, sleepers, and ballast. According to the data obtained and the 3D simulations, the maximum values of both stress and deformation have been obtained with their position in the model. Thus, the maximum deformation and stress points in those elements for span loading case will be represented as follows:

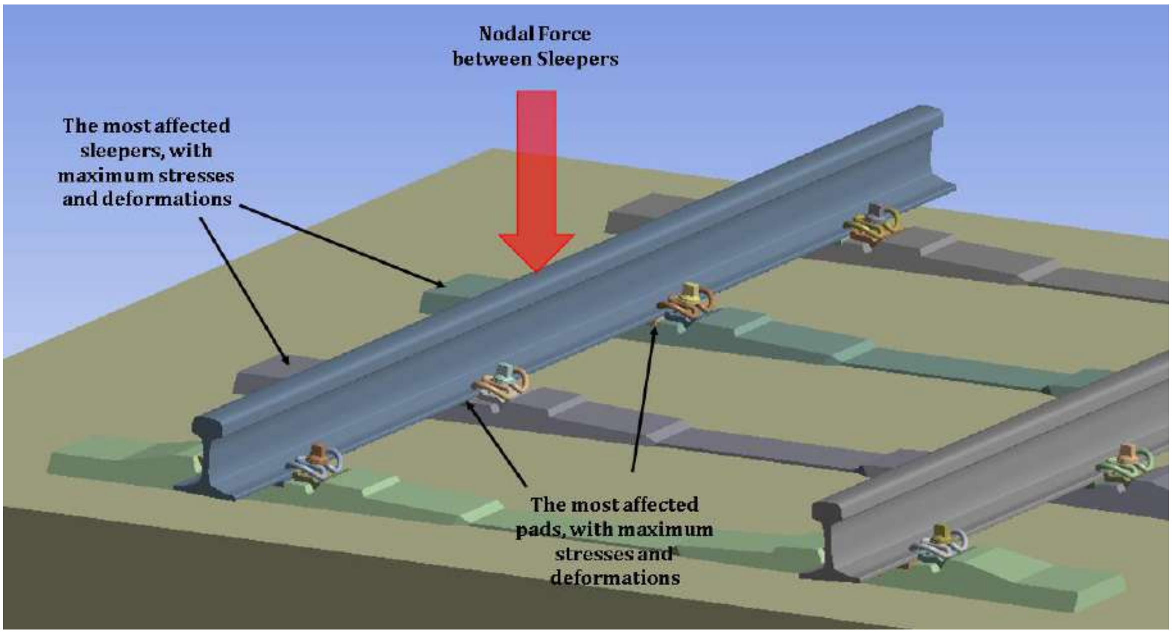


Figure 40. The most affected elements in the case of applied loads between sleepers (900 mm spacing)

In the first case study (of four-sleepers model), the most affected element of the rail track, are those of the central sleepers and on the inside of the track on both rails, as can be seen in figure 41. The symmetry of the model justifies these maximum effects on both sides of the load application point. It seems reasonable that it is the inner elements that are most affected since the axle load acts displaced on the middle of rail head.

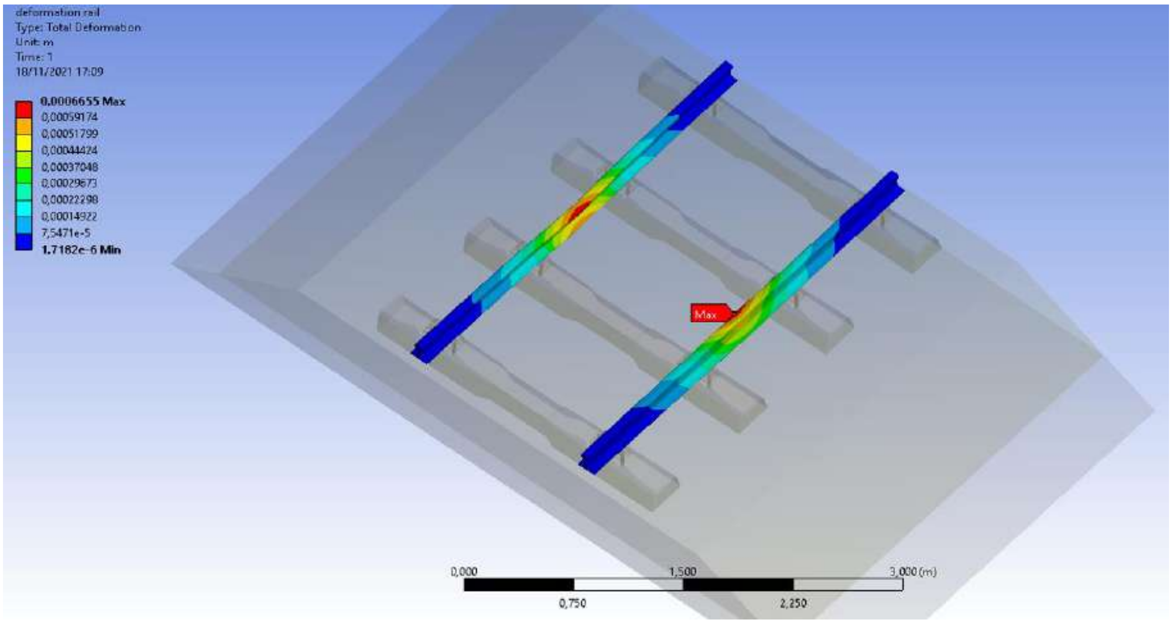


Figure 41. Distribution of deformation in the case of rails (m).

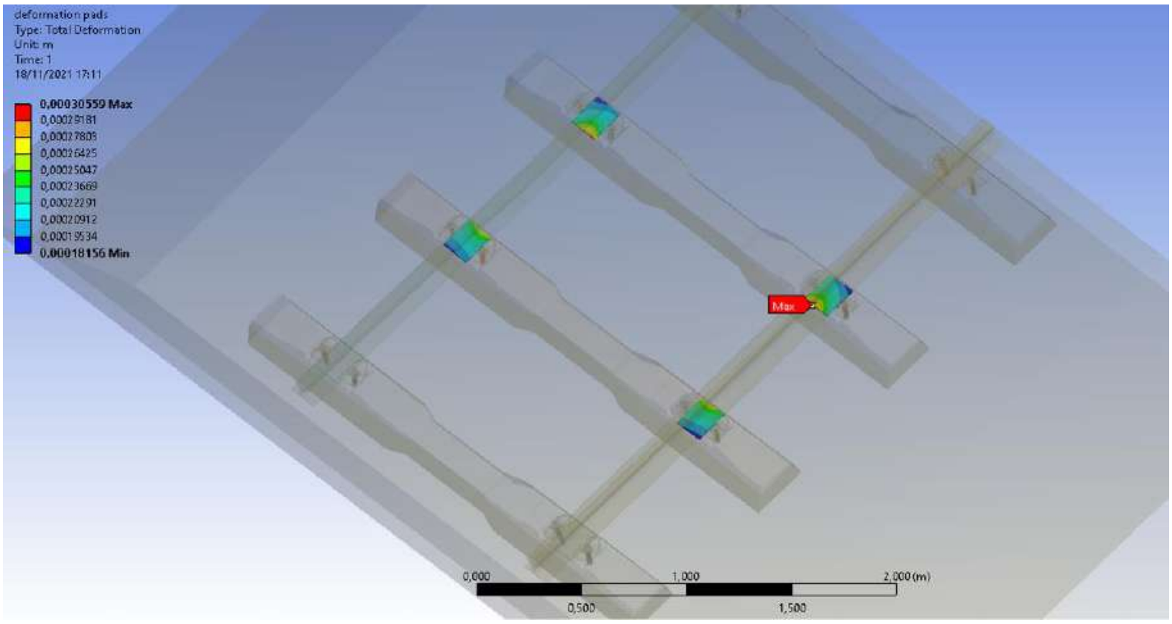


Figure 42. Distribution of deformation in the central pads (m).

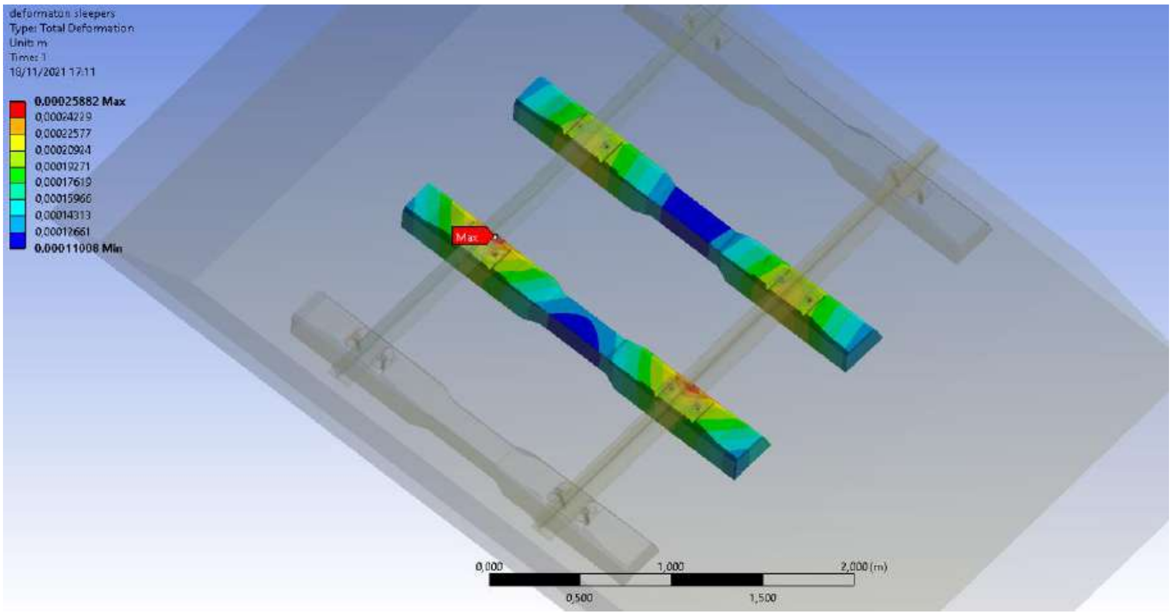


Figure 43. Distribution of deformation at the central sleepers (m).

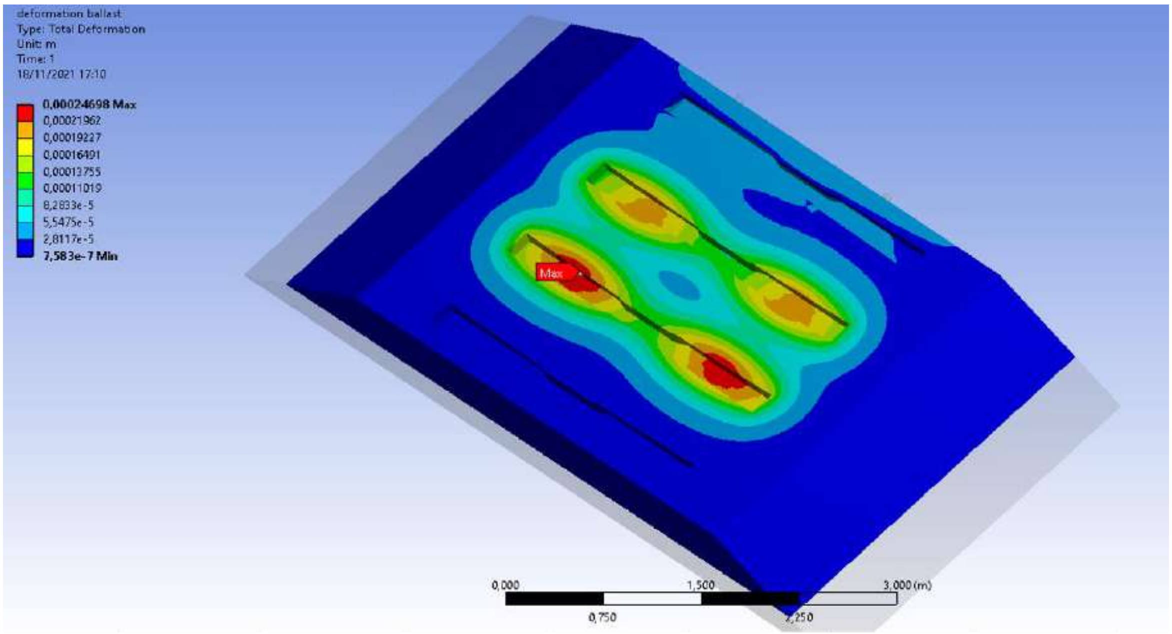


Figure 44. Distribution of deformation in the ballast (m).

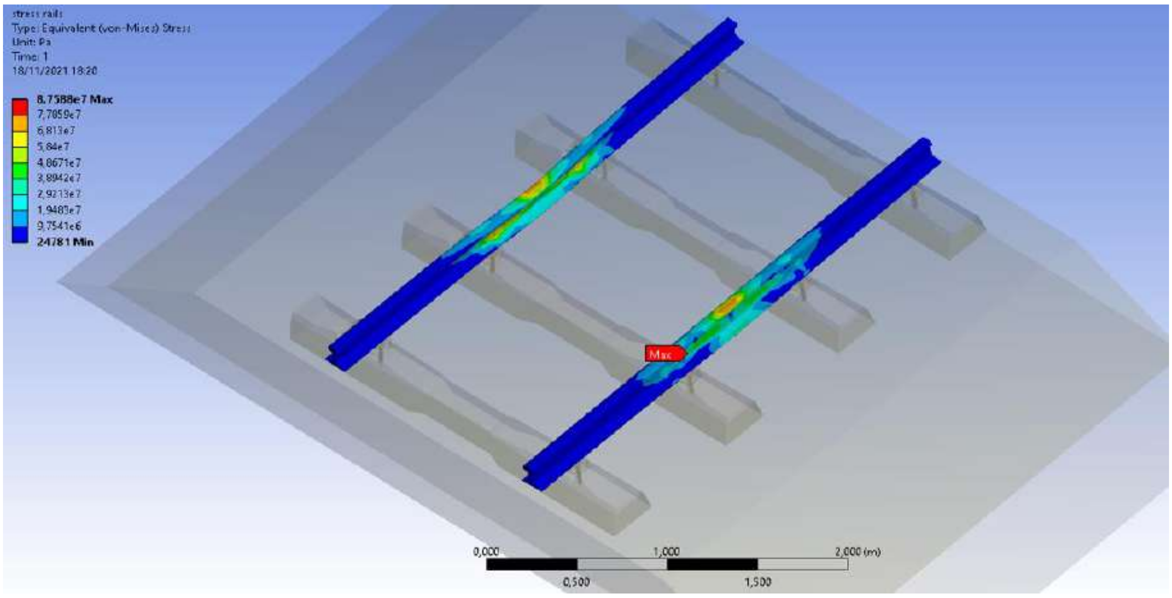


Figure 45. Distribution of Von Mises stress values on the rails (Pa)

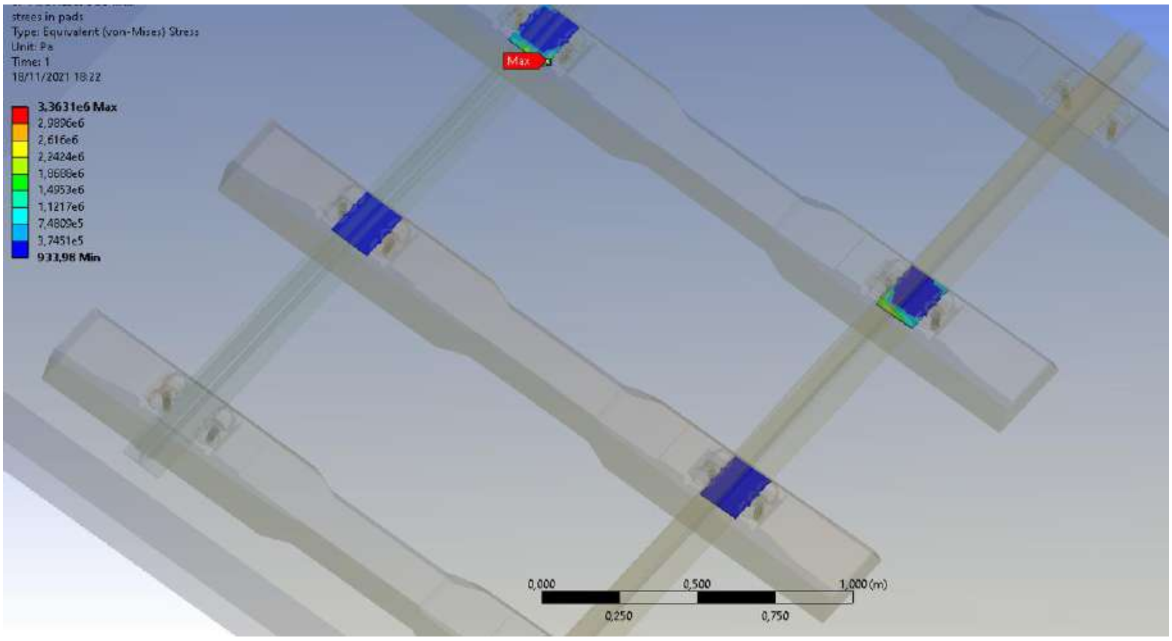


Figure 46. Distribution of Von Mises stress values between the central pads (Pa).

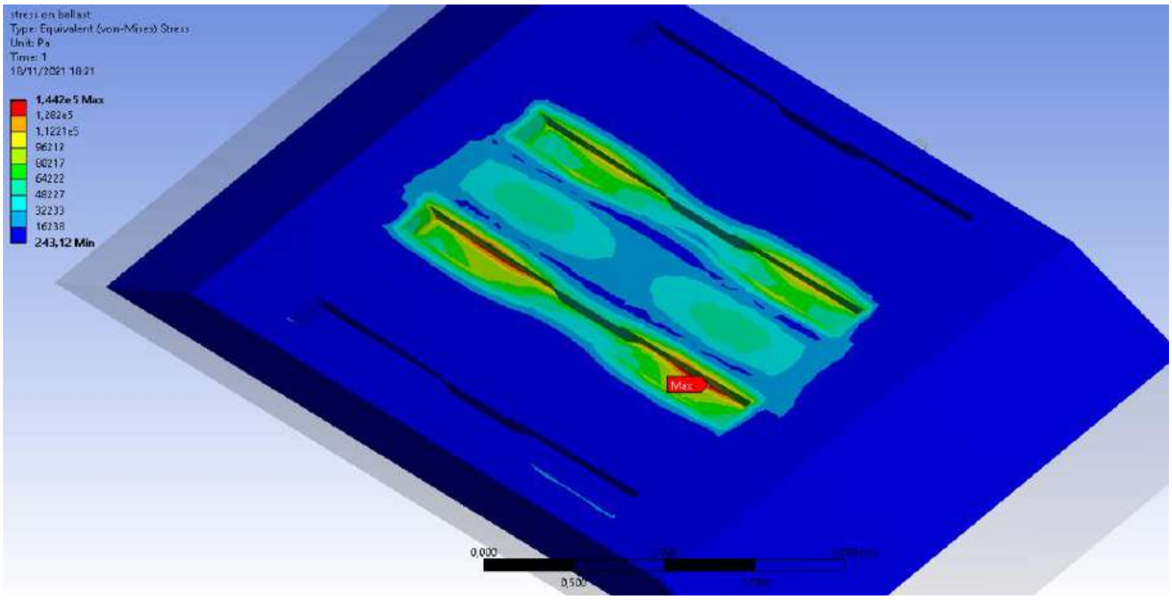


Figure 47. Distribution of Von Mises stress values on the ballast (Pa).

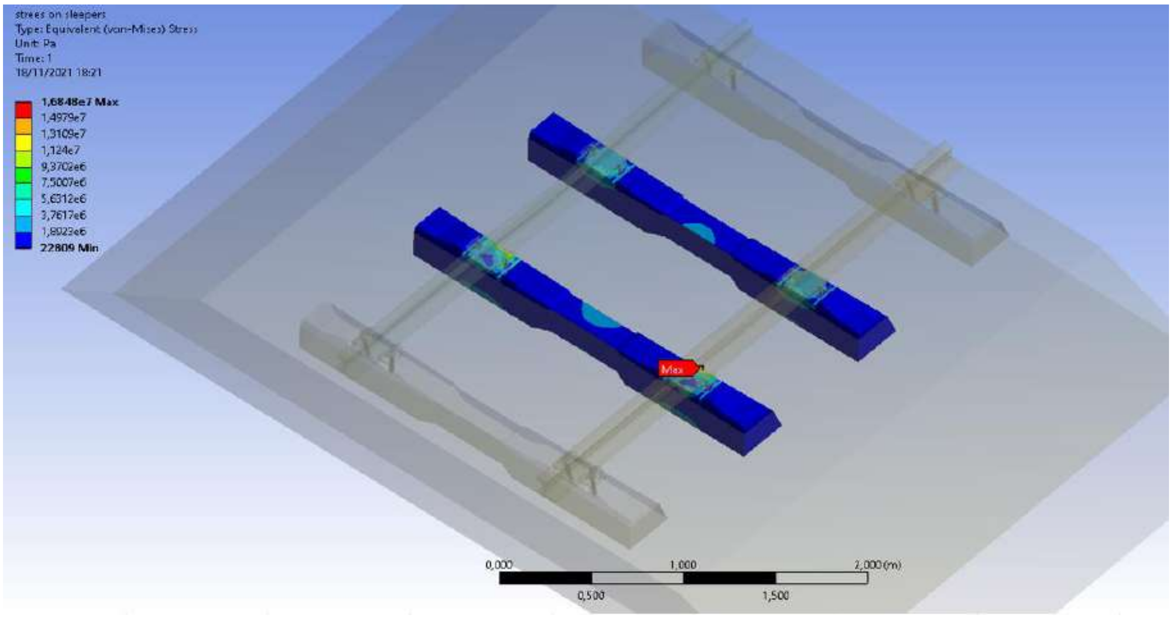


Figure 48. Distribution of Von Mises stress between the central sleepers (Pa).

These figures correspond to the rail, sleeper, pad, and ballast which record the maximum values of deformation (measured in meters) and stress (measured in pascals). They can be easily interpreted thanks to the range of colours, in shades of blue the zones with minimum values of deformation and stress and in red the most stressed and deformed areas. Thus, the maximum deformation and stress points in those elements in case of loads applied on support will be represented as follows:

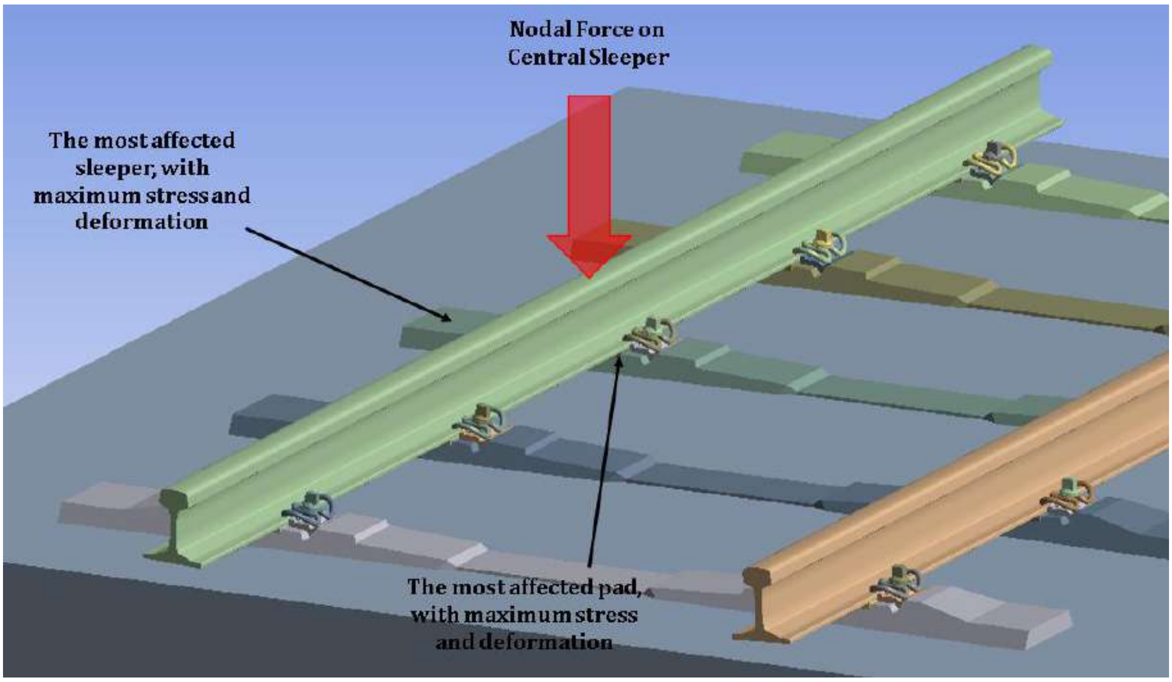


Figure 49. The most affected elements in the case of applying loads on the central sleeper (900 mm spacing)

In the second case study (of five-sleepers model), the most affected elements of the rail track, are mostly the central sleeper and those that situated below that sleeper, as can be seen in figure 50. The symmetry of the model justifies this distribution of the deformational effects on both sides of the load application point. It seems reasonable that it is the inner elements that are most affected since the axle load displaced on the central sleeper.

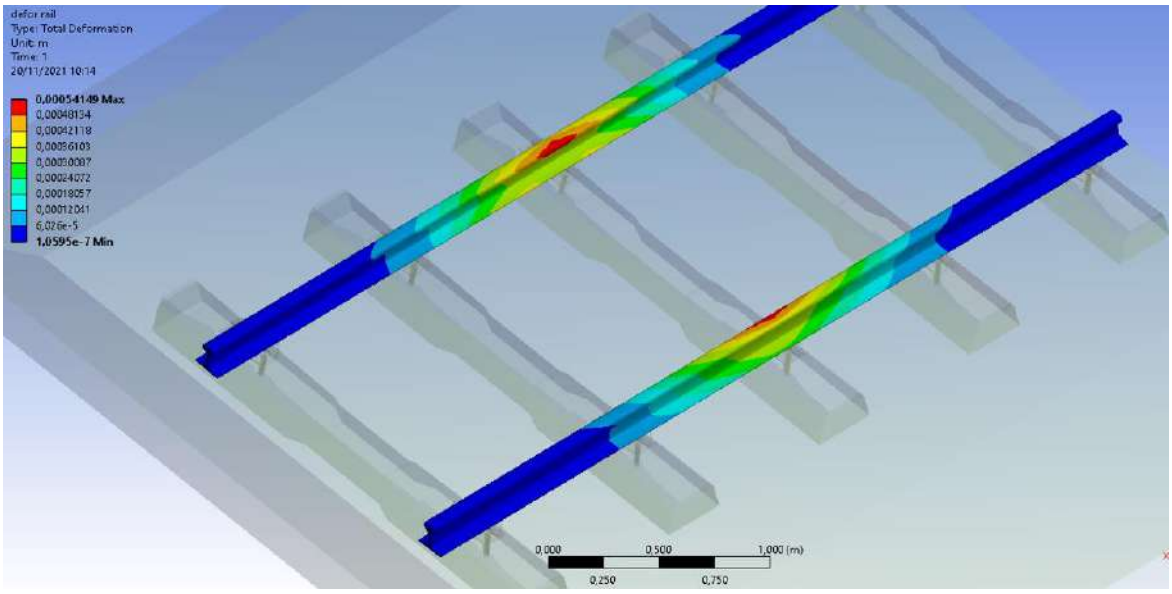


Figure 50. Distribution of deformation in the second case study of 5 sleepers (m).

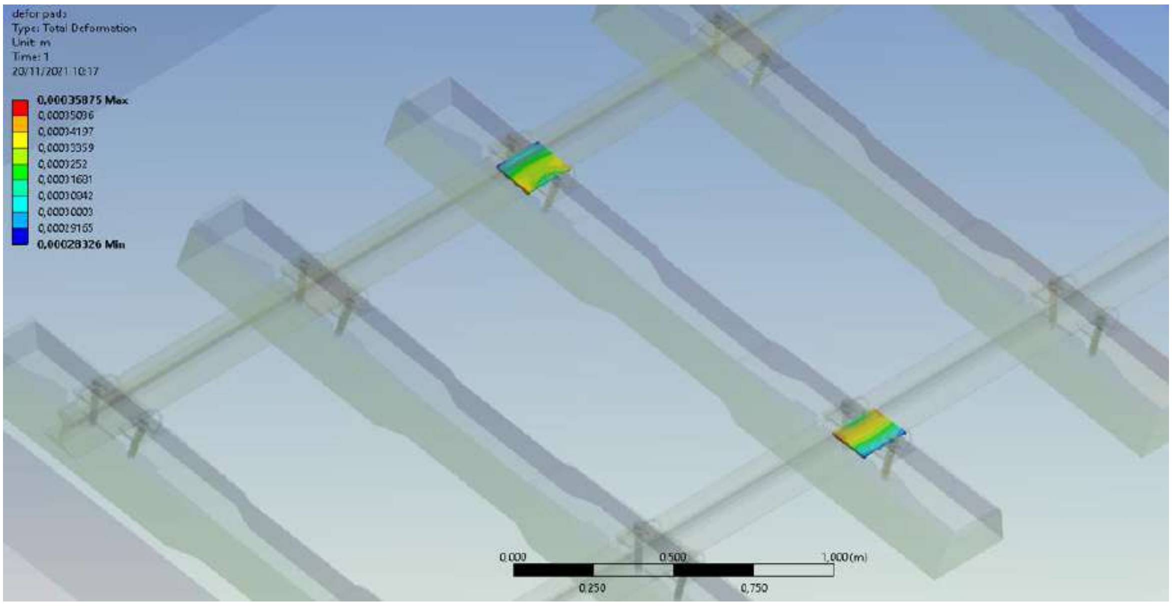


Figure 51. Distribution of deformation at the central pads (m).

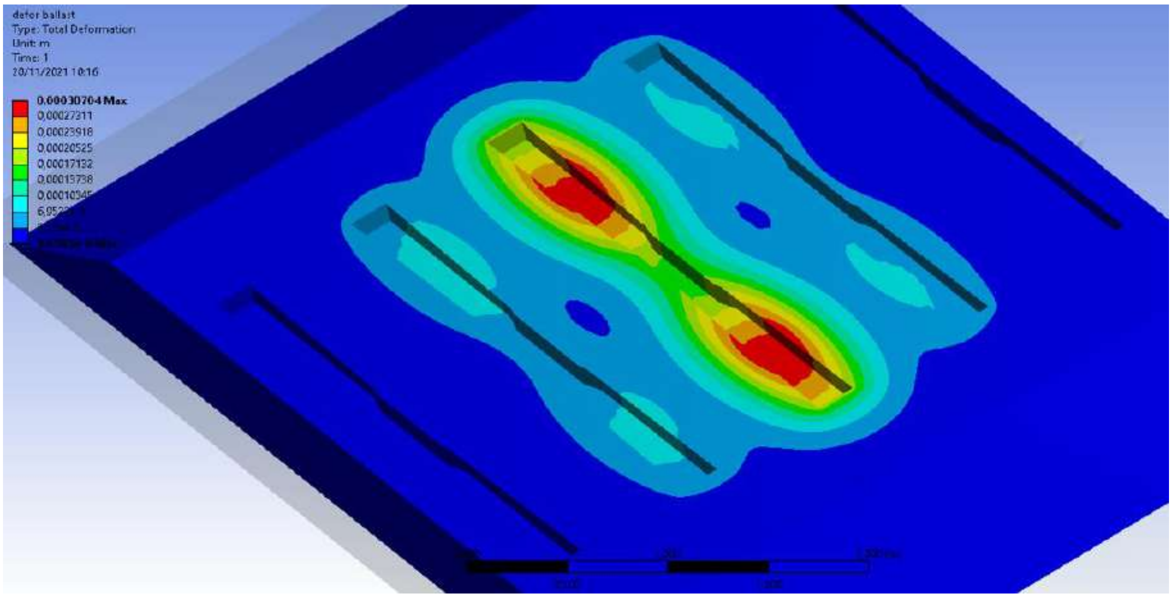


Figure 52. Distribution of deformation values on the layer of the ballast (m).

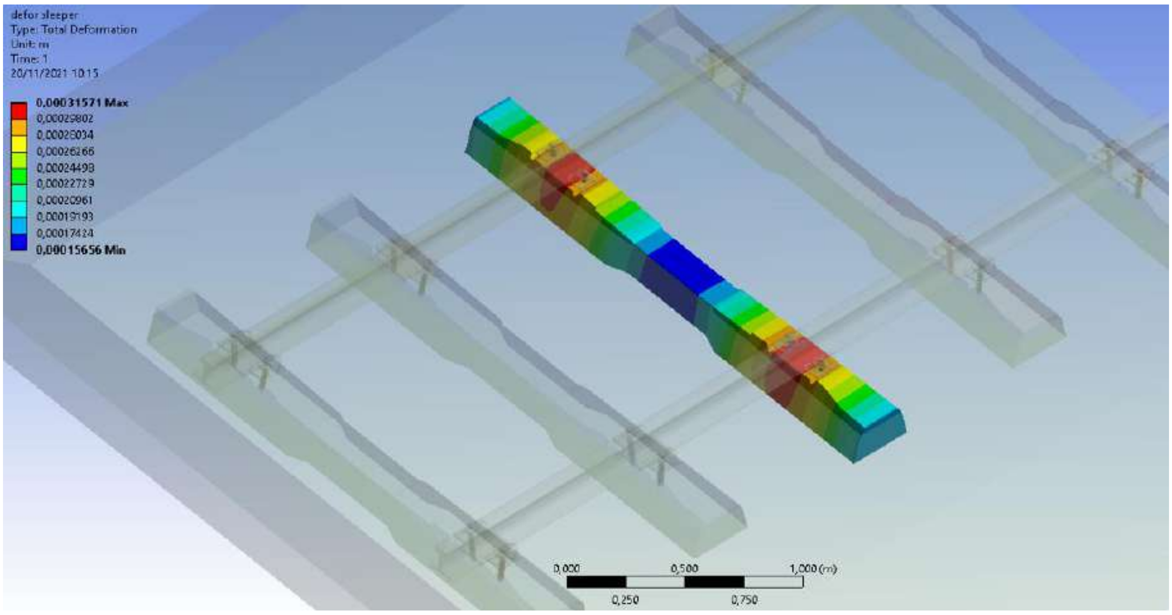


Figure 53. Distribution of deformation at the central sleeper (m).

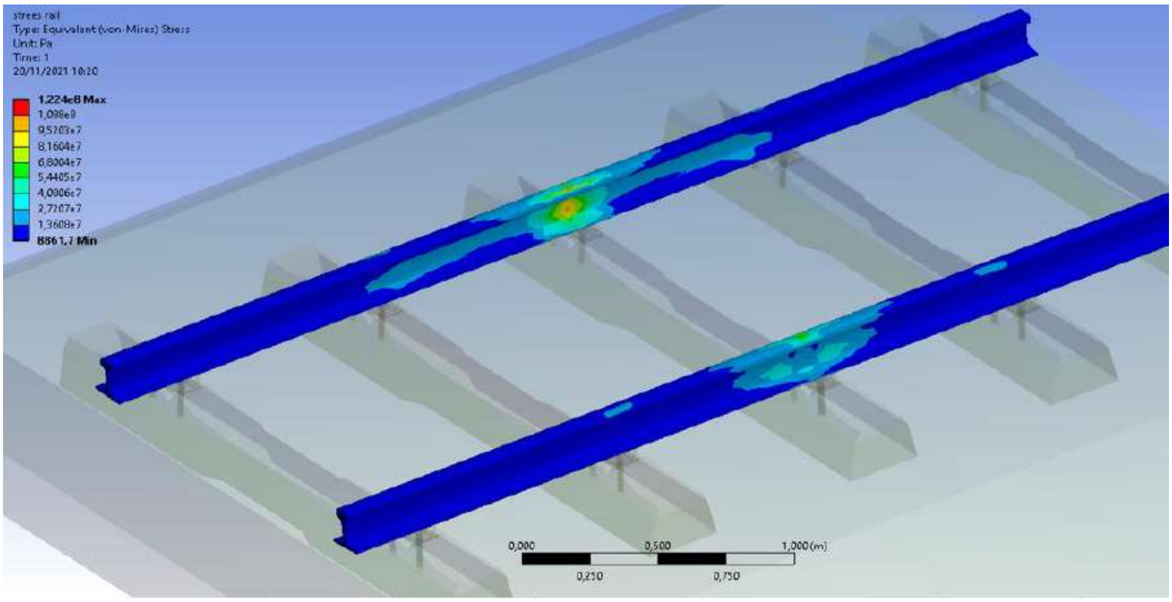


Figure 54. Von Mises stress at the rail (Pa)

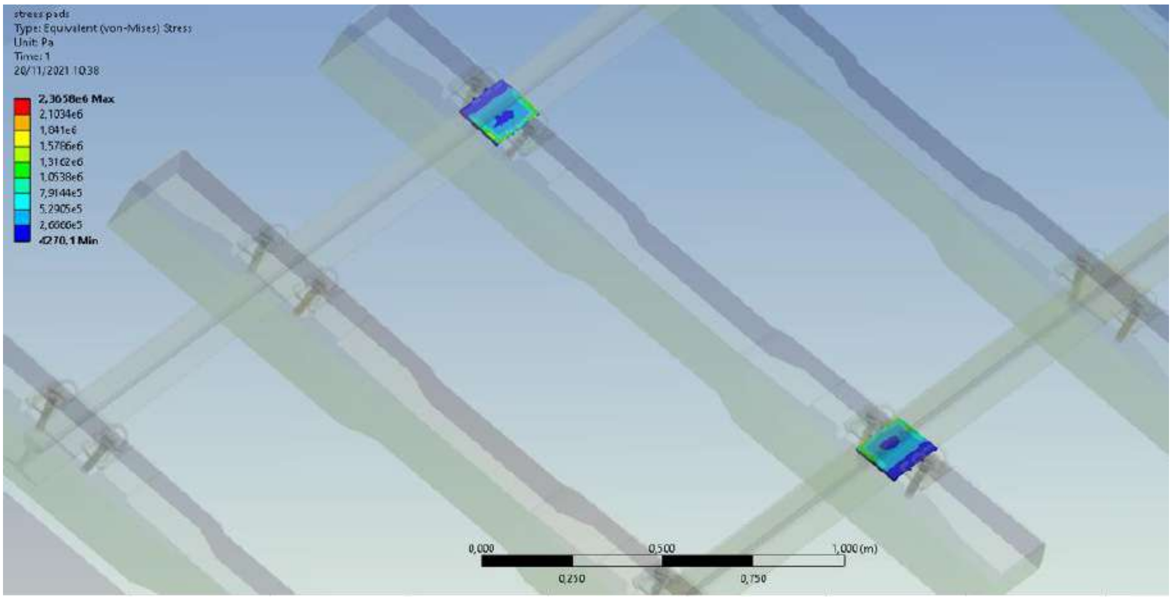


Figure 55. Von Mises stress at the central pad (Pa).

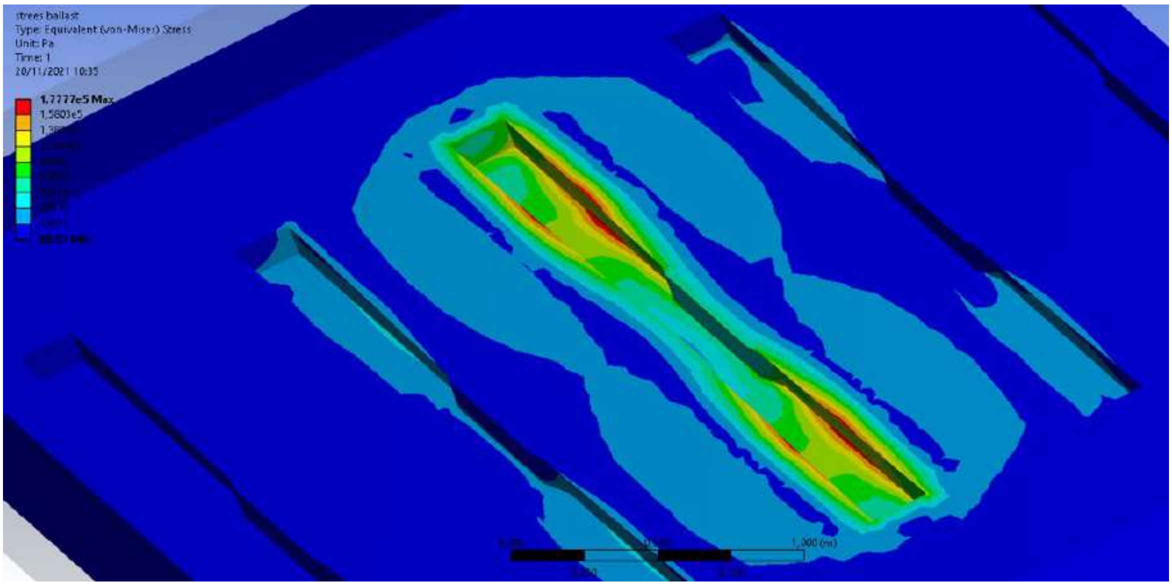


Figure 56. Von Mises stress in the ballast (Pa).

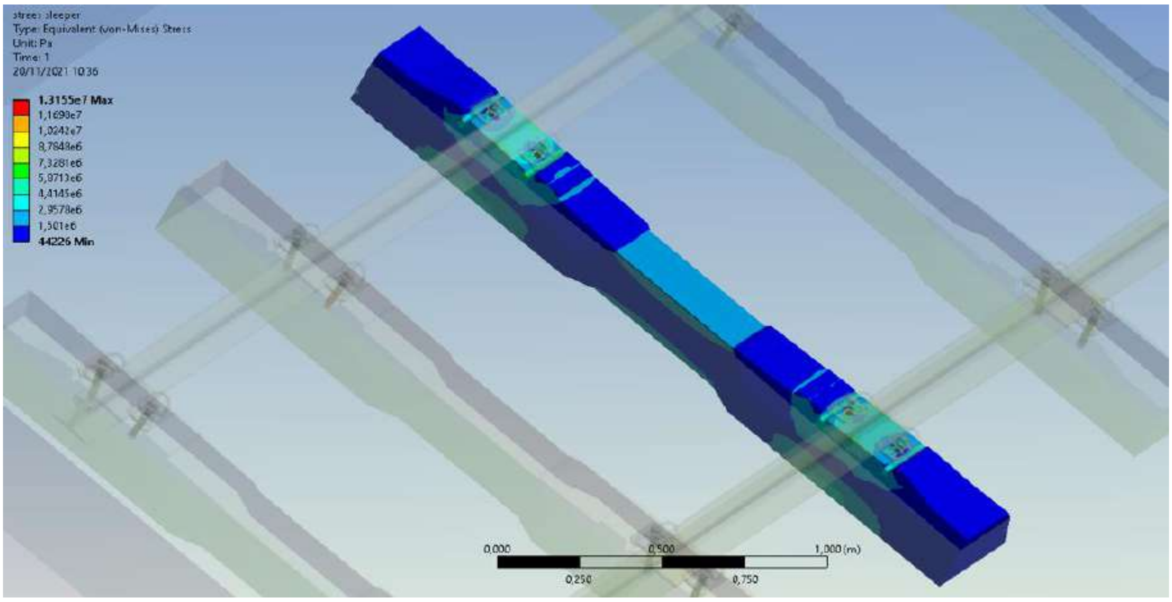


Figure 57. Von Mises stress at the central sleeper (Pa).

6.3. ANALYSING MAXIMUM VALUES

This section will focus on analysing maximum values obtained from numerical simulation with the maximum allowed values, according to table 13. Next subsections will analyse the maximum values obtained from 3D simulations (Vertical displacements and equivalent stress) with maximum values taken from bibliography (see table 13).

6.3.1. Deformation in track superstructure elements

The results obtained with the numerical simulations in both case studies compared to the permissible values suggested in the table 13 for each element in the deformation analysis, are as follows:

Figure 58. Maximum deformation in rails compared to the admissible values.

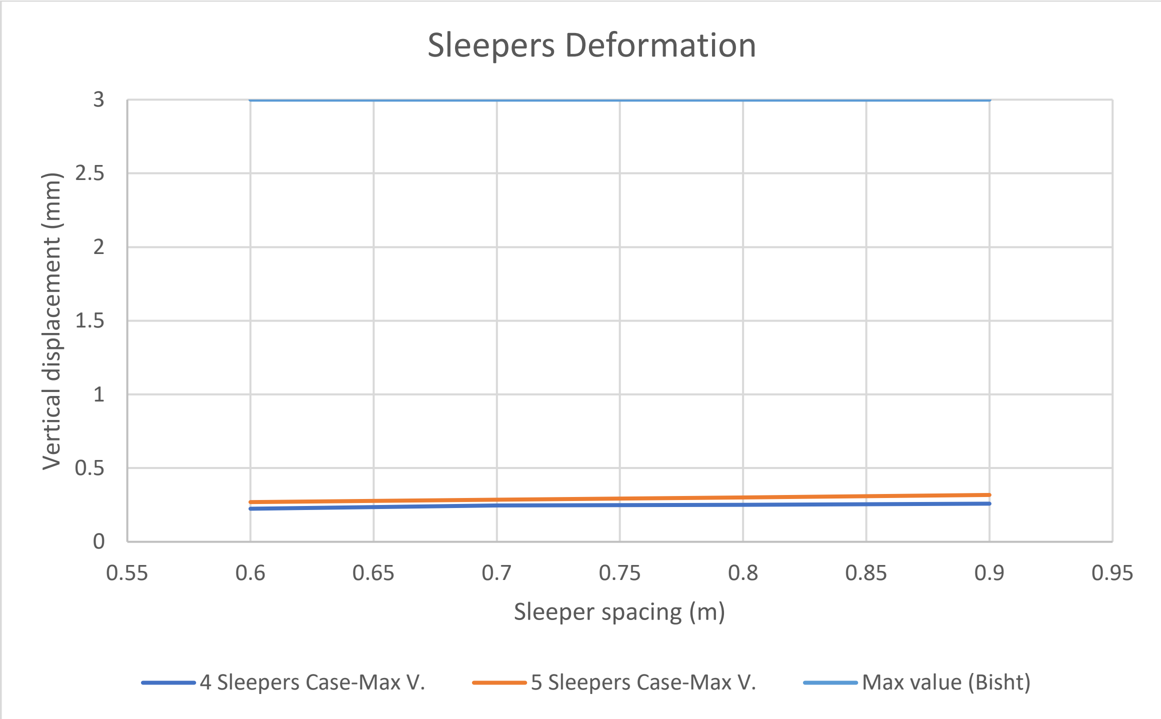


Figure 59. Maximum deformation in sleepers compared to the admissible values.

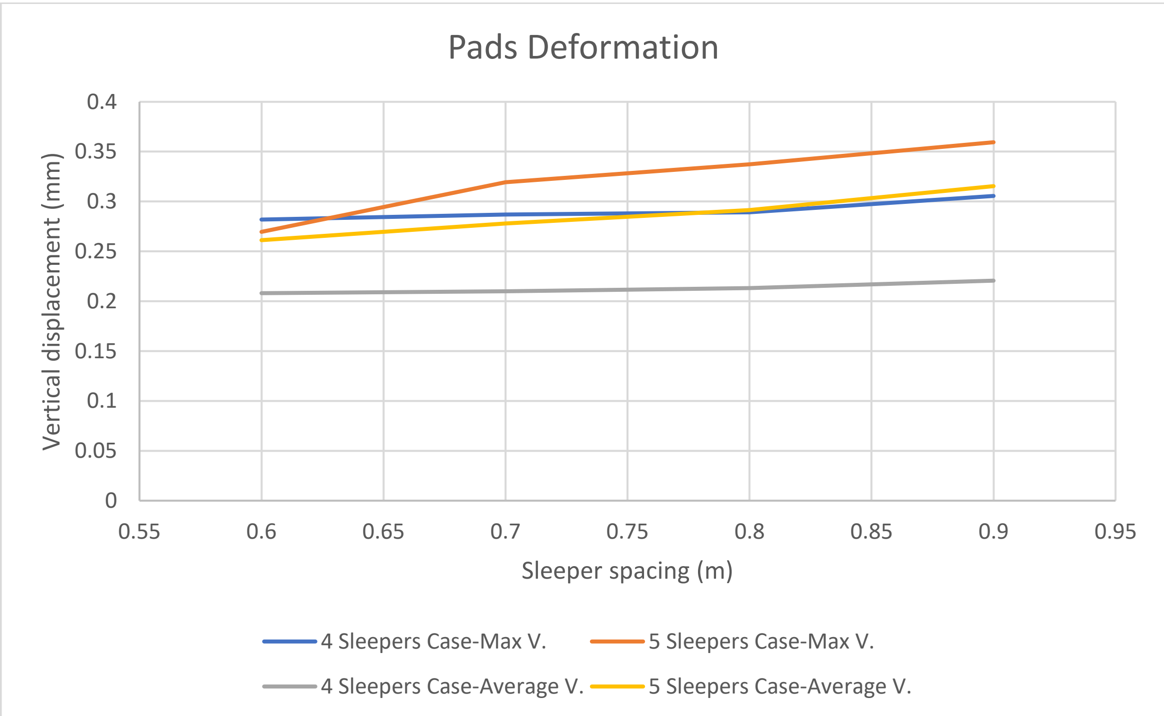


Figure 60. Maximum deformation in pads compared to the admissible values.

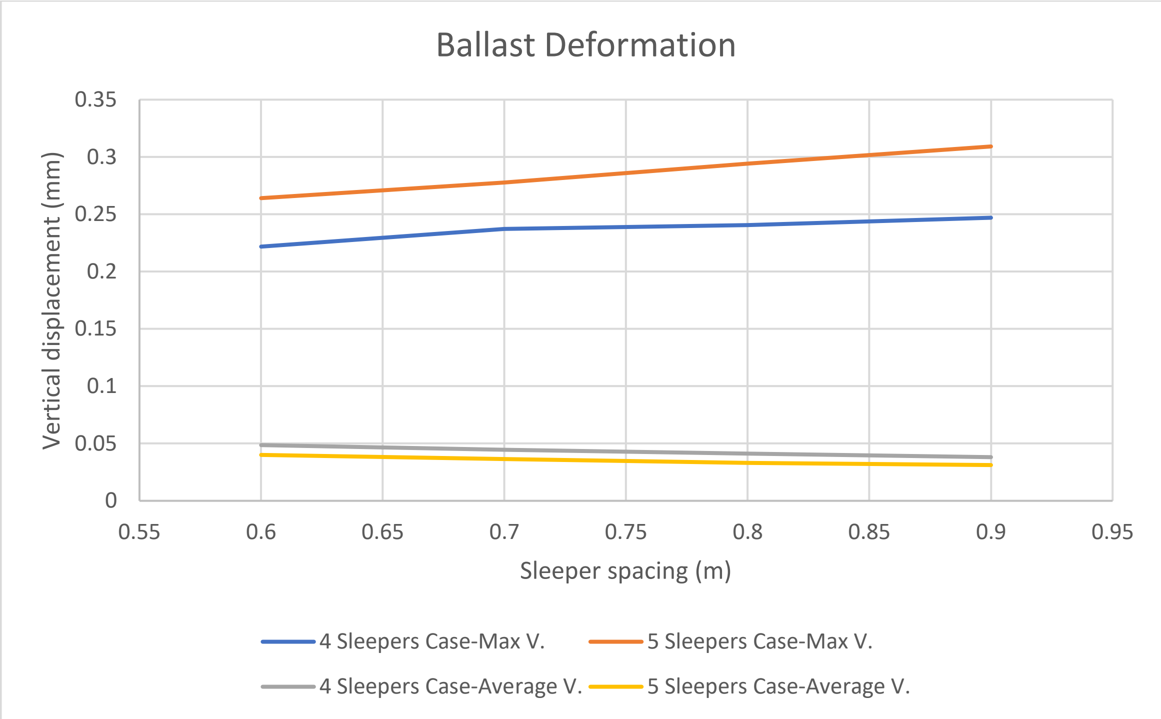


Figure 61. Maximum deformation in ballast compared to the admissible values.

6.3.2. Stress in track superstructure elements

The results obtained with the numerical simulations in both case studies compared to the permitted values recommended in the table 13 for each element in the deformation analysis, are as follows:

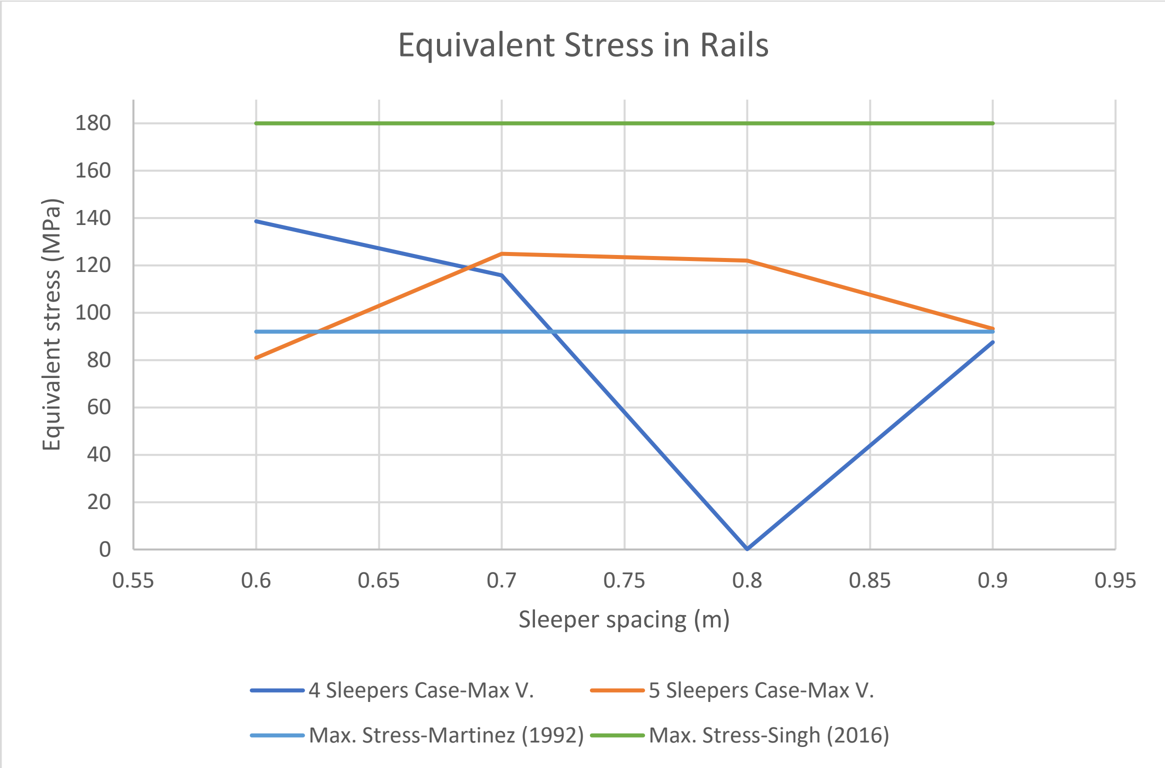


Figure 62. Maximum stress in rails compared to the permissible value.

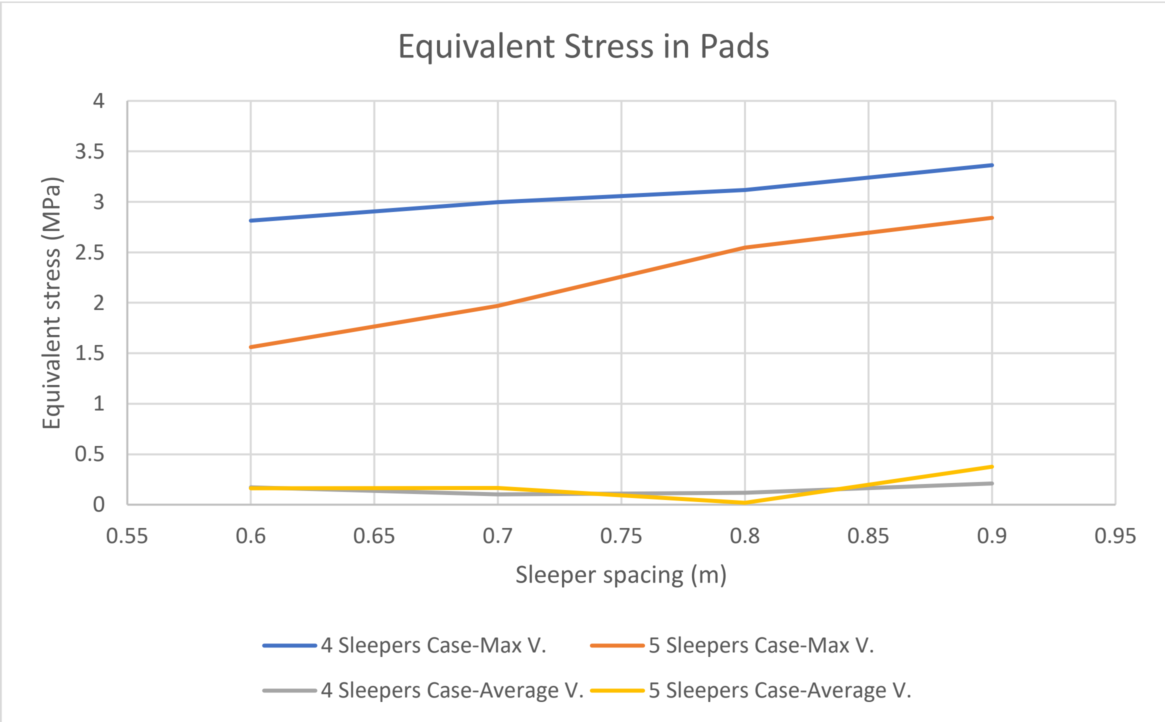


Figure 63. Maximum stress in pads compared to the permissible value.

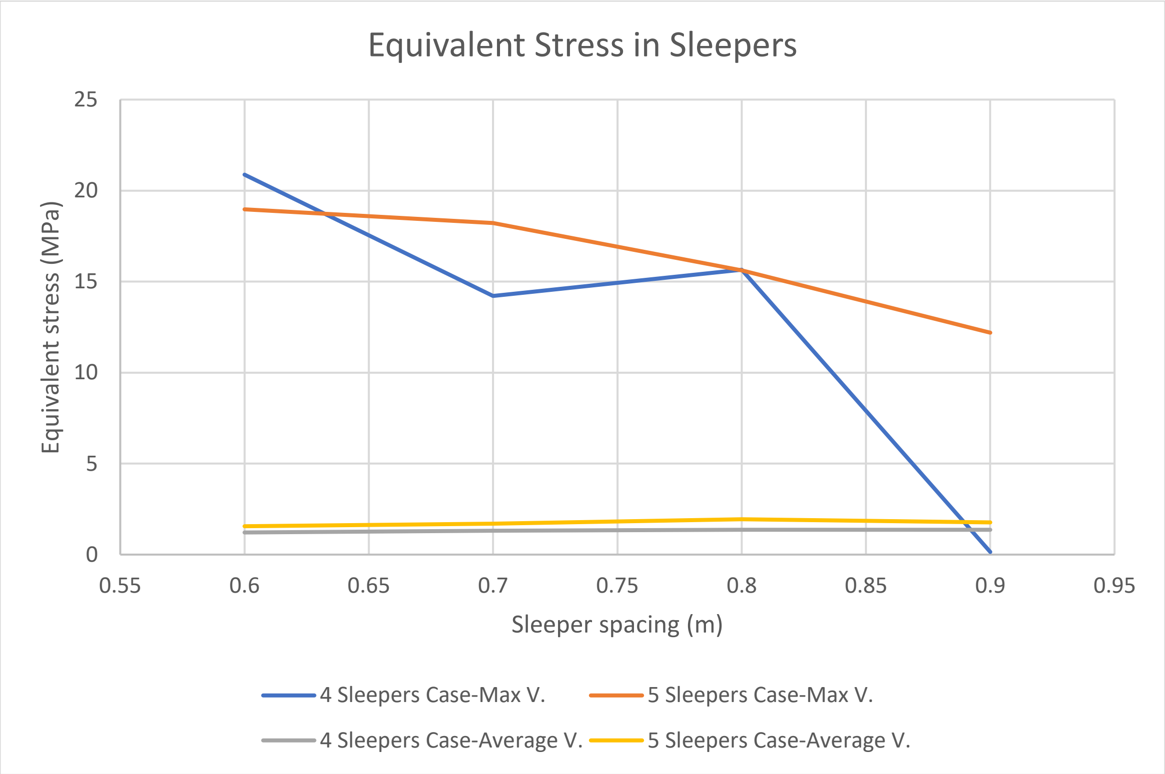


Figure 64. Maximum stress in sleepers compared to the permissible value.

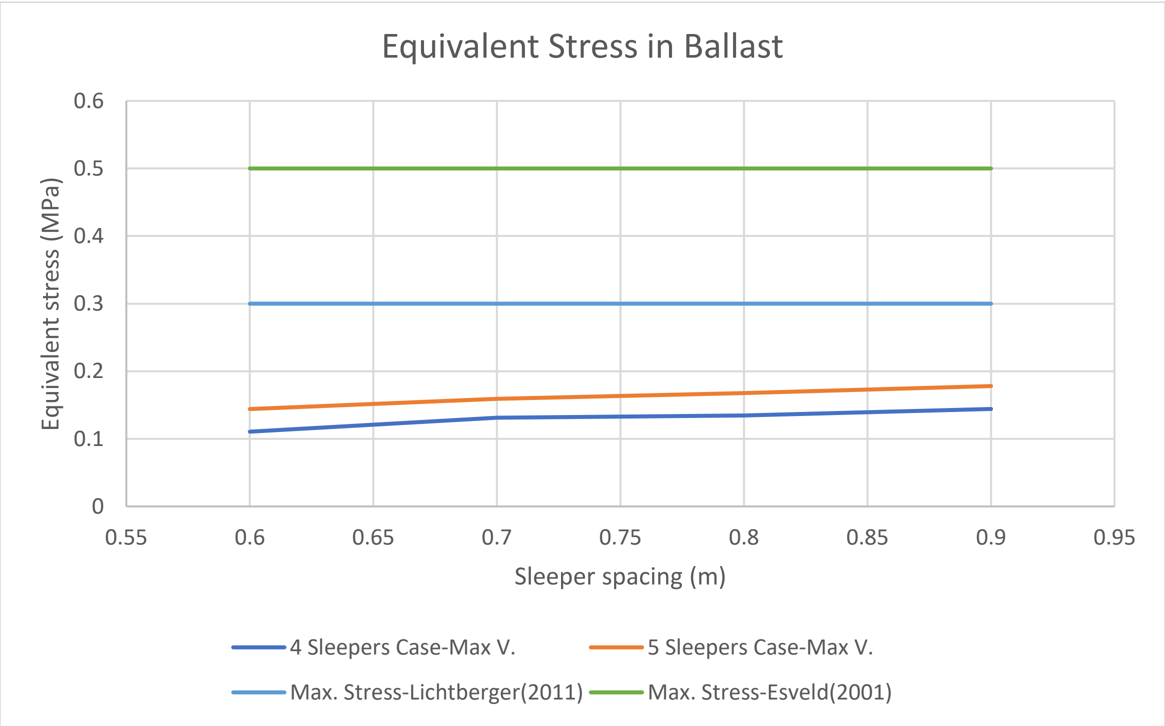


Figure 65. Maximum stress in ballast compared to the permissible value.

The representative figures in the case of deformation for rails, sleepers, pads, and ballast respectively (from figure 59 to 62), for distinct spacing distance between supports demonstrate in undoubtedly means that the maximum vertical displacement that these elements can go through are below the admissible value that it has been recommended in the bibliography.

When it comes to the case of equivalent stress, the elements of the track as sleepers, pads and ballast, it is noticeable that the maximum values obtained from the 3D simulation are way below the limit values that have been suggested (though some of them don't show the admissible value in the graph due to being a very significant value that it goes beyond the scale of the figure) however the figure 63 (case of rails) has a different outcome, since one of the recommended value by Martinez limits in the case of load on support (5 sleepers) the optimal distance to what it seems 0.63m and in the case of load between supports (4 sleepers) to 7.25m , at the same time another recommended value by Singh allows even higher distance since all the values obtained are below its suggested value.

6.4. ANALYSIS OF THE BEHAVIOUR OF THE TRACK ELEMENTS IN FUNCTION OF SLEEPER SPACING

For a better interpretation of the different data, the following summary graphs have been made from the data obtained. They show the spacing between sleepers on the abscissa axis and the different variables, stress, and deformation of each element on the ordinate axis for the two cases of study, the load acting on a sleeper (support) or between two sleepers (span). A linear regression has been added for each series of points so that it is possible to obtain more data for different sleeper spacing assumptions. This will only be possible when the R^2 coefficient has a value close to unity. The graphs are shown below as follows:

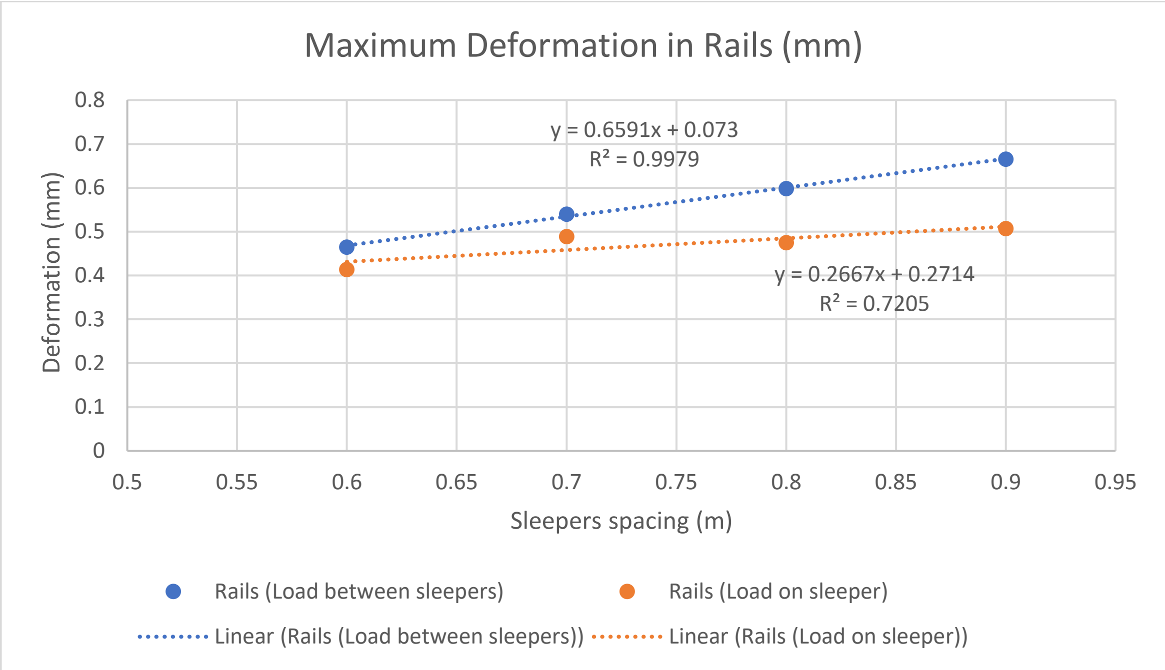


Figure 66. Rails deformation graph.

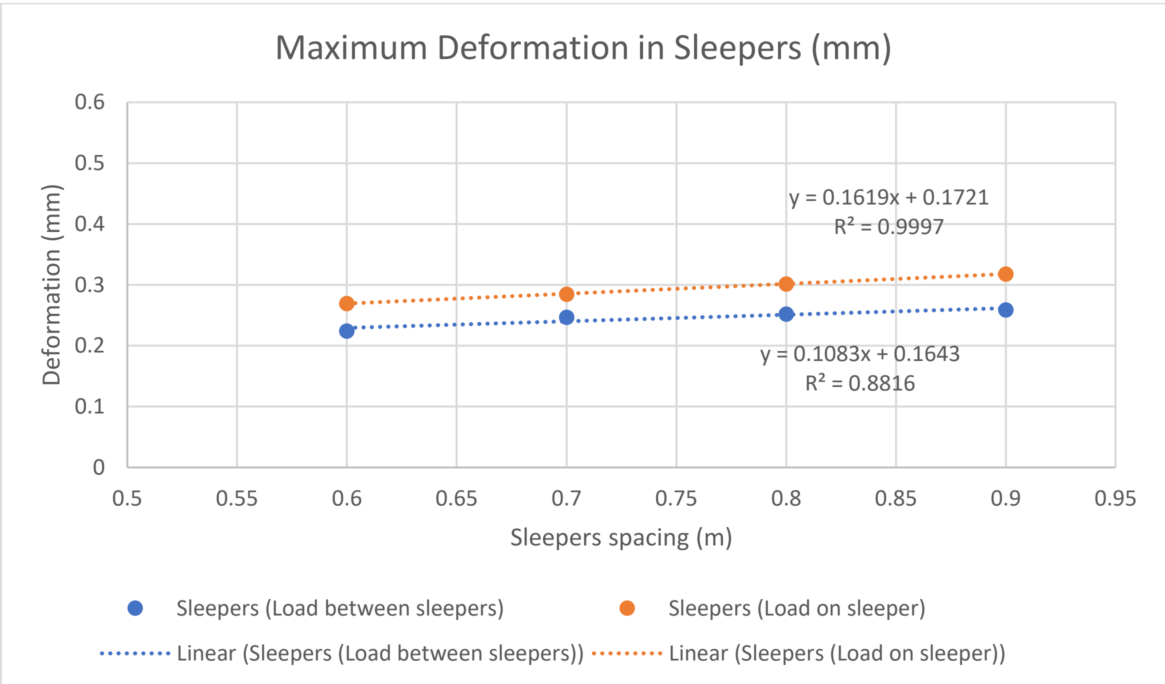


Figure 67. Sleepers deformation graph.

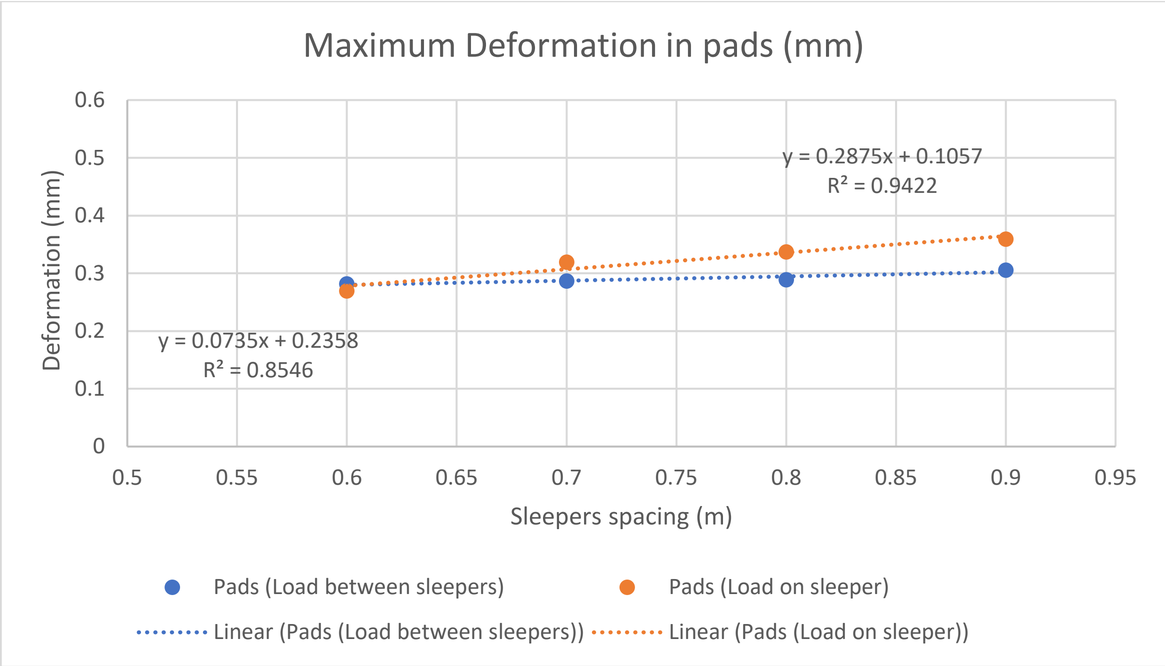


Figure 68. Pads deformation graph.

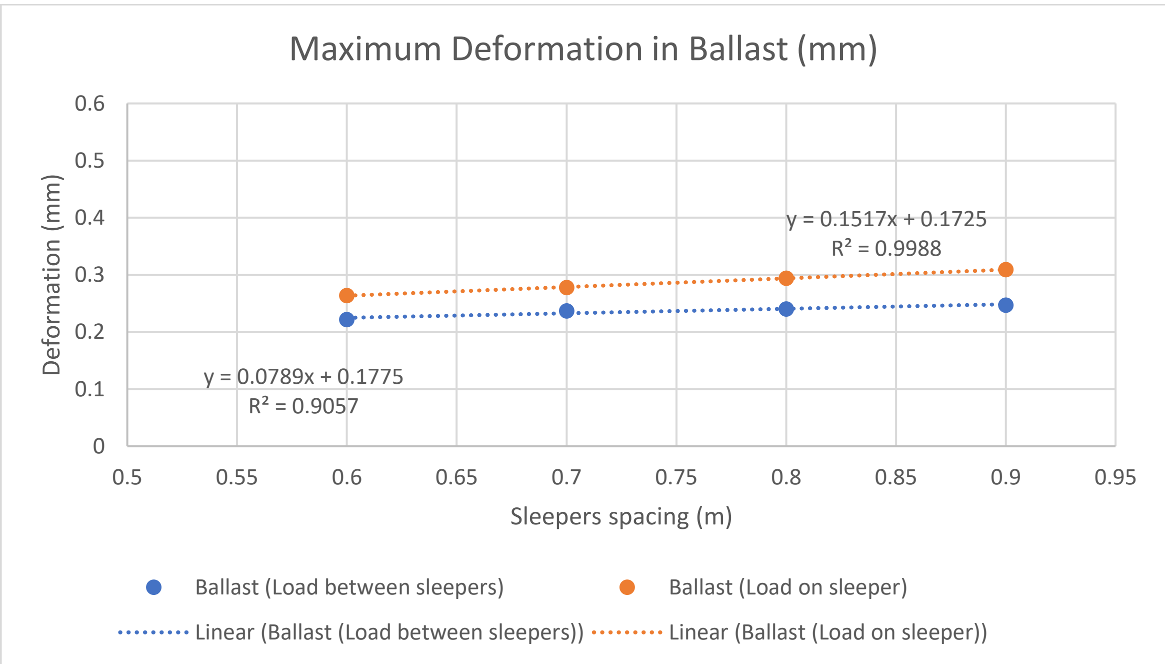


Figure 69. Ballast deformation graph.

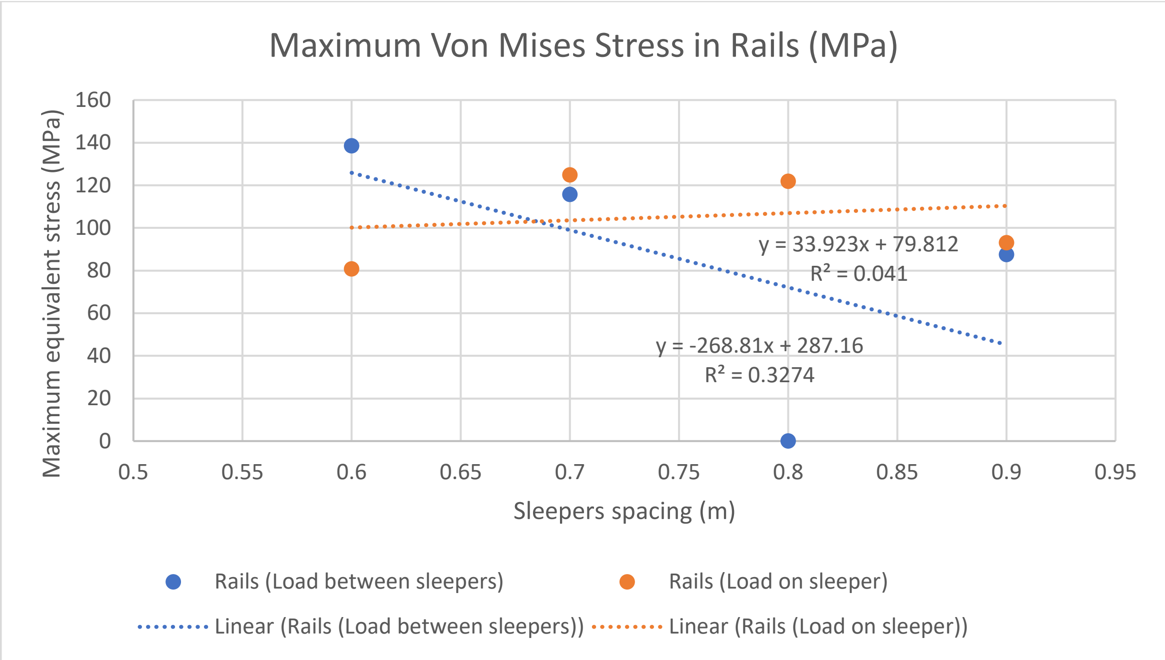


Figure 70. Rails stress graph.

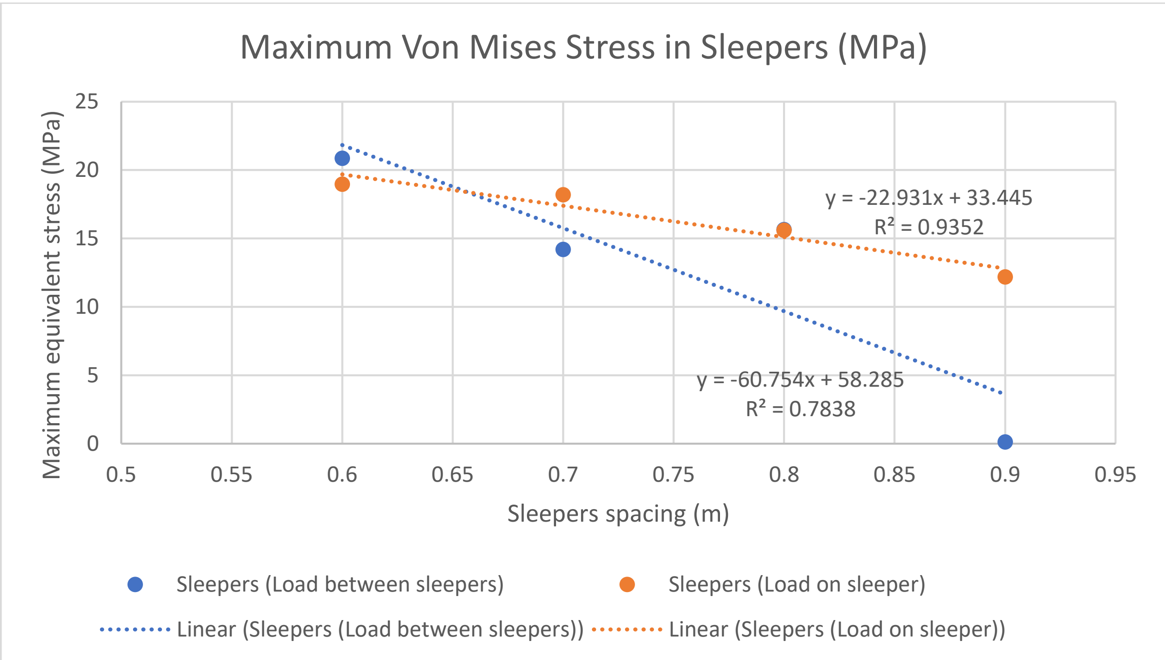


Figure 71. Sleepers tress graph.

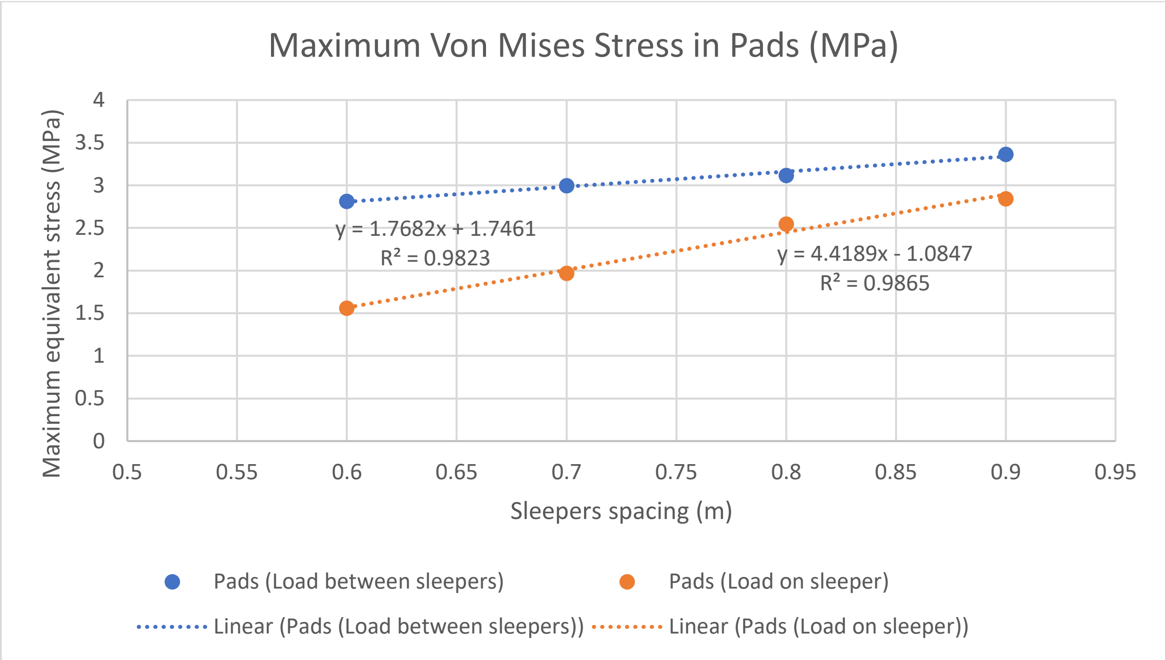


Figure 72. Pads stress graph.

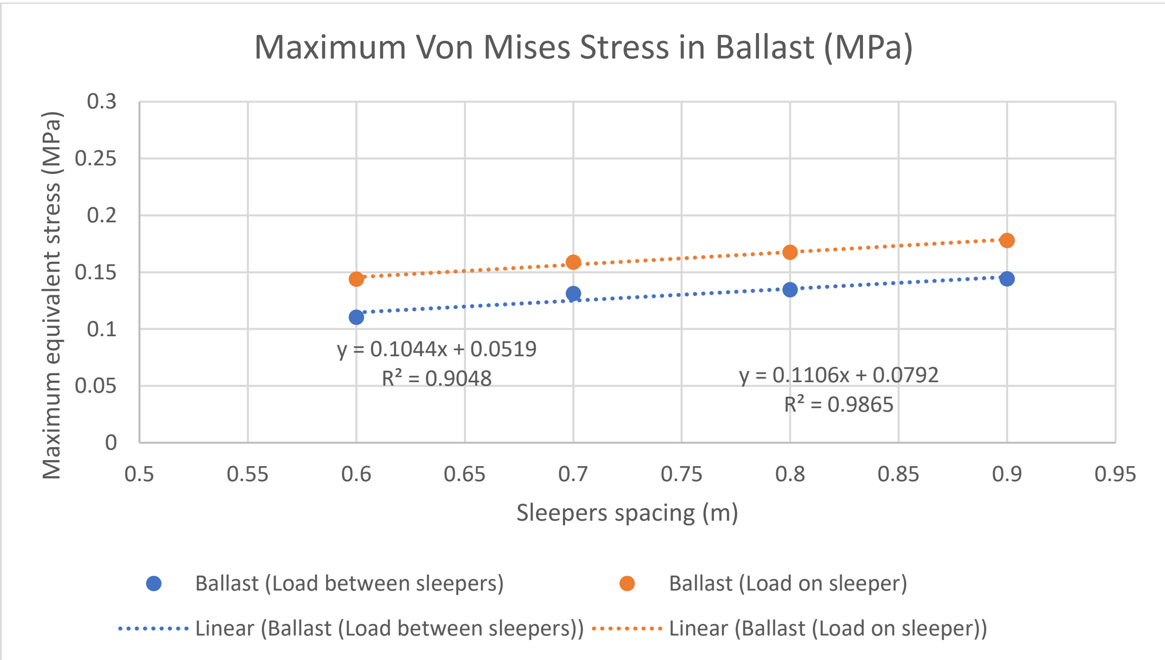


Figure 73. Ballast stress graph.

The figures 67, 68, 69, and 70, represent the maximum displacement (deformation in the program) experienced by the elements of the track (rails, sleepers, pads, and ballast, respectively) for different spacing distances between sleepers. It can be observed that the performed fit is of acceptable-good quality since its R^2 value is close to unity in all study cases. It should be noted that in all cases the displacement has higher values in the load hypothesis coinciding with the central sleeper of the model.

The parameters that characterize the trendlines of each series of points are shown below, which will allow extrapolating and obtaining new data for other distances between supports, as long as that their adjustment is of sufficient quality.

Table 14. The trendline parameters for maximum deformation graphs.

Displacement	Load between sleepers		Load on sleeper	
	Trendline Equation	R^2	Trendline Equation	R^2
Rails	y = 0.6591x + 0.073	0.9979	y = 0.2667x + 0.2714	0.7205
Sleepers	y = 0.1083x + 0.1643	0.8816	y = 0.1619x + 0.1721	0.9997
Pads	y = 0.0735x + 0.2358	0.8546	y = 0.2875x + 0.1057	0.9422
Ballast	y = 0.0789x + 0.1775	0.9057	y = 0.1517x + 0.1725	0.9988

The figures 71, 72, 73, and 74 show the maximum stress experienced by the elements of the track (rails, sleepers, pads, and ballast, respectively) for different spacing distances between sleepers. It can be observed that the performed fit is of acceptable quality since its R^2 value is close to unity in the most cases. This problem is mainly given by the data acquired from the model that has a load applied between sleepers when the spacing is of 800 mm, it seems that this is a unique case that should be studied separately. All in all, the trendline fit for the pads, ballast and sleepers is good, therefore, it is easy to predict how the stresses will evolve as a function of spacing. Without forgetting to mention that those latter elements reach higher values when the rolling load is coincided with the support, just the opposite of what happens to the rail. The following table presents the data corresponding to the trendlines of each series of points that will allow extrapolating and obtaining new data for other distances between supports, as long as that they provide an adjustment that would be of sufficient quality.

Table 15. The trendline parameters for maximum tension graphs

Stress	Load between sleepers		Load on sleeper	
	Trendline Equation	R^2	Trendline Equation	R^2
Rails	y = -268.81x + 287.16	0.3274	y = 33.923x + 79.812	0.0410
Sleepers	y = -60.754x + 58.285	0.7838	y = -22.931x + 33.445	0.9352
Pads	y = 1.7682x + 1.7461	0.9823	y = 4.4189x - 1.0847	0.9865
Ballast	y = 0.1044x + 0.0519	0.9048	y = 0.1106x + 0.0792	0.9865

After an analysis of maximums in the superstructure elements of the track, a uniform trend has been observed for both deformations and stresses for both load application points (between sleepers and on sleeper). The tendency for these displacements and stresses is to rise with increasing sleeper spacing. Comparing the values obtained with their strength values, it can be seen that the strength of the material is well above the maximum value obtained in the simulation.

In general, the fits are good with R^2 values close to 1 for all the elements in the case of deformations for both load application points. In the case of stresses, the tendency is to increase as the separation increases. In this case, there is a greater dispersion than in deformations so that the values of the fits are worse (R^2 far from 1) mostly in case of rails. In this case, there is a considerable decrease in the stress in the elements such as rails and sleepers for both load application points.

The stress results experience an apparently unusual behaviour when the point of application is between the support (sleeper) and the sleepers are spaced 0.8 m apart. Tension decreases for elements as rails and sleepers analysed.

There is a more drastic decrease in the case of stress for the 0.8 m spacing. This phenomenon suggests that, for this distance, the other elements such as the rail and sleepers contribute to reducing this stress. This may be due to a distribution of the tension energies between other elements. It is precisely this fact that makes it difficult to obtain a stress law for the elements analysed. Another possible explanation could be that there is a variation in the contact surface between the elements at this distance, resulting in a decrease in the stress and, consequently, in the deformation of the elements.

A first approximation, in view of the settings, is that it is possible to predict the deformations in all the elements of the track, but not the stresses. On the other hand, an in-depth study seems necessary to be able to make new hypotheses for the case of 0.8 m spacing (between supports) and at close range around that spacing (e.g., from 0.75 m to 0.85 m).

VII. CONCLUSIONS AND FUTURE LINES OF RESEARCH

Within the framework of the research project "Optimal Distance between Sleepers in Conventional and high-speed TRACKs" (ODSTRACK), whose main function is to study the behaviour of the elements of a railway track depending on the spacing between sleepers, the behaviour of the superstructure elements has been analysed statically.

Within the framework of the ***ODSTRACK project** [1]*, and a continuation to the work developed in [2], a 3D finite element model has been created in which has been used two positions of a load and four spacings between supports (sleepers) have been analysed. For each load condition, the maximum values of stresses and deformations in the main elements of track such as rails, sleepers, pads, and ballast were obtained.

Basically, it has been proven that these elements can withstand a separation from 0.6 m to 0.9 m distance between sleeper axes [2] and, on the other hand, an attempt has been made to obtain regression models for the fastenings' elements in terms of stresses and deformations.

In view of the results obtained, it can be said that the material is able to withstand, due to its characteristics, an increase in the distance precisely from 0.73 m to 0.8 m. Therefore, from a static point of view, the superstructure elements of the track are able to withstand this increase in the distance between sleepers.

With regard to the deformation analysis, it can be concluded that it is possible to predict the deformation in the track elements as a function of the sleeper spacing by means of a linear regression. This is not the case for the stress values because of their low correlation with the spacing.

On the other hand, an apparently anomalous behaviour of the stress has been observed when the spacing is 0.8 m. In this case, the stress values decrease instead of increasing as indicated by the tendency of the rest of the points studied. The explanation may lie in a distribution of the deformation energies between other elements such as the rail or the sleeper or just an influence of misconduct contact between the elements while running the simulations.

As a next line of research, it is advisable to study the behaviour more precisely at distances close to 0.8 m, especially for the case of load between supports, and to check whether the other elements of the track structure, such as the sleeper or the rail, will present inconsistent value of stress for 0.8 m distance. It is also necessary to carry out an analysis in a long term and a fatigue analysis for these track elements when sleeper spacing varies.

A laboratory study of this element is necessary in addition to the proposed numerical analyses in order to compare these with real results. In view of this study, it is recommended that a dynamic and vibration study be carried out as future lines of research in order to obtain a more global behavioural model.

VIII. ACKNOWLEDGEMENTS

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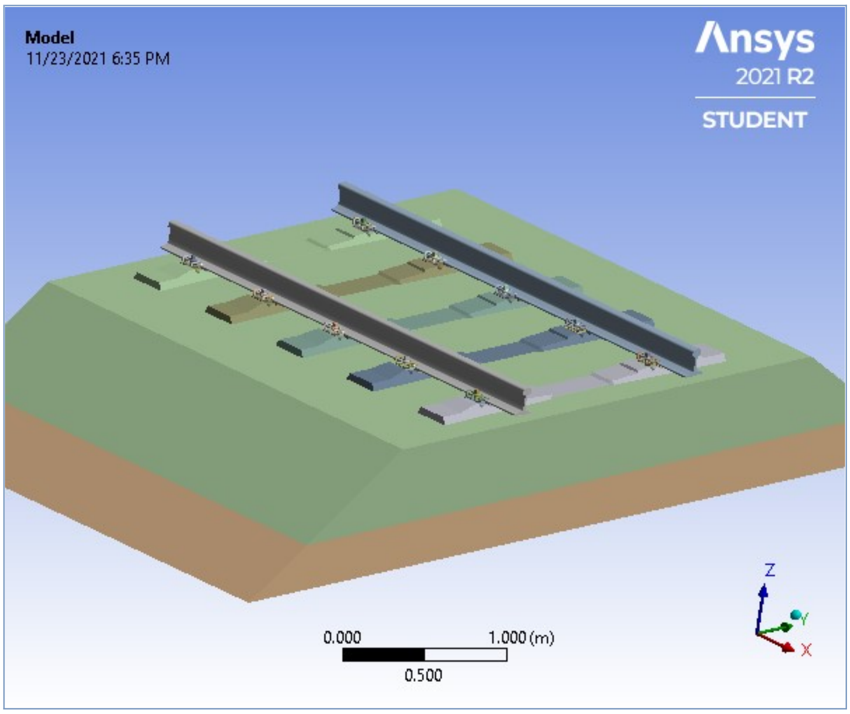
X. ANNEXES

The following is an example of a report obtained from the finite element program using ANSYS21 R2.

Project*

First Saved	Friday, November 5, 2021
Last Saved	Friday, November 12, 2021
Product Version	2021 R2
Save Project Before Solution	No
Save Project After Solution	No



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Units

TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (B4)

Geometry

TABLE 2
Model (B4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\Mon PC\Desktop\TFM\ANSYS MODELS\600 mm\600 mm-Solved_files\import_files\600 mm con SUJECCIONES ANSYS.sat
Type	ACIS
Length Unit	Inches
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	3. m
Length Y	6.034 m
Length Z	1.0221 m
Properties	
Volume	11.73 m³
Mass	20699 kg
Scale Factor Value	1.
Statistics	
Bodies	99
Active Bodies	99
Nodes	745000
Elements	388262
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	No
Parameters	Independent

Parameter Key	ANS;DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3
Model (B4) > Geometry > Parts

Object Name	*Rail1*	*Rail2*	*Ballast*	*Sub-ballast*	*Vaina1*	*Vaina2*	*Vaina3*	*Vaina4*	*Clip1*	*Clip2*	*Clip3*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Rails and Tirafondos		Ballast	Sub-Ballast	Vainas				Clip		
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	3. m				3.6001e-002 m		3.5998e-002 m	3.6001e-002 m	0.17346 m		
Length Y	0.15011 m		5.134 m	6.034 m	3.8348e-002 m	5.1189e-002 m	5.1515e-002 m	3.8525e-002 m	9.5382e-002 m	9.4407e-002 m	9.5382e-002 m
Length Z	0.17578 m		0.5 m	0.3 m	0.14204 m	0.14385 m		0.14204 m	5.546e-002 m	5.9953e-002 m	5.5457e-002 m
Properties											
Volume	2.3026e-002 m^3		6.0578 m^3	5.0256 m^3	3.2178e-005 m^3	3.2244e-005 m^3		3.2178e-005 m^3	6.2901e-005 m^3	6.2898e-005 m^3	6.29e-005 m^3
Mass	180.75 kg		10904 kg	8040.9 kg	3.0569e-002 kg	3.0632e-002 kg		3.057e-002 kg	0.49063 kg	0.4906 kg	0.49062 kg
Centroid X	28.767 m		28.768 m	28.767 m	29.967 m						
Centroid Y	16.621 m	18.135 m	17.378 m		16.518 m	16.707 m	18.049 m	18.238 m	18.237 m	16.717 m	16.52 m
Centroid Z	-32.089 m		-32.499 m	-32.874 m	-32.244 m	-32.253 m		-32.244 m	-32.144 m	-32.154 m	-32.144 m
Moment of Inertia Ip1	0.83586 kg·m^2	0.83587 kg·m^2	19201 kg·m^2	21090 kg·m^2	5.9947e-005 kg·m^2	5.9993e-005 kg·m^2	5.9992e-005 kg·m^2	5.9948e-005 kg·m^2	3.8734e-004 kg·m^2	3.8733e-004 kg·m^2	
Moment of Inertia Ip2	136.28 kg·m^2		8412.1 kg·m^2	6090.8 kg·m^2	5.9922e-005 kg·m^2	5.9969e-005 kg·m^2	5.9968e-005 kg·m^2	5.9924e-005 kg·m^2	1.1209e-003 kg·m^2	1.1208e-003 kg·m^2	1.1209e-003 kg·m^2
Moment of Inertia Ip3	135.68 kg·m^2		27191 kg·m^2	27060 kg·m^2	4.5076e-006 kg·m^2	4.5154e-006 kg·m^2		4.5077e-006 kg·m^2	1.4566e-003 kg·m^2	1.4564e-003 kg·m^2	1.4566e-003 kg·m^2
Statistics											
Nodes	10561	11230	81421	47923	9496	9146	9053	9441	2610	2619	2572
Elements	5877	6246	53878	10260	4902	4713	4647	4853	1217	1226	1193
Mesh Metric	None										

TABLE 4
Model (B4) > Geometry > Parts

Object Name	*Clip4*	*Tirafondo1*	*Tirafondo2*	*Tirafondo3*	*Tirafondo4*	*Codo-Pad1*	*Codo-Pad2*	*Codo-Pad3*	*Codo-Pad4*	*Pad1*	*Pad2*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness											

Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Clip	Rails and Tirafondos				Codo-Pads				Pads	
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.17347 m	6.2564e-002 m	6.2561e-002 m	6.2564e-002 m		0.11 m				0.18 m	
Length Y	9.4407e-002 m	6.2564e-002 m		6.2562e-002 m		8.1581e-002 m	8.1131e-002 m	8.1581e-002 m	8.1131e-002 m	0.1599 m	
Length Z	5.995e-002 m	0.19828 m	0.19841 m	0.19695 m	0.19897 m	4.1582e-002 m	3.7009e-002 m	4.1582e-002 m	3.7009e-002 m	2.2374e-002 m	2.2371e-002 m
Properties											
Volume	6.2897e-005 m³	8.305e-005 m³	8.3049e-005 m³	8.305e-005 m³	8.3051e-005 m³	1.2971e-004 m³				1.7695e-004 m³	1.7691e-004 m³
Mass	0.4906 kg	0.65194 kg	0.65193 kg	0.65195 kg		0.17641 kg				0.1504 kg	0.15038 kg
Centroid X	29.967 m										
Centroid Y	18.04 m	16.717 m	16.516 m	18.039 m	18.241 m	16.732 m	16.502 m	18.024 m	18.254 m	16.617 m	18.14 m
Centroid Z	-32.154 m	-32.182 m	-32.172 m	-32.182 m	-32.172 m	-32.177 m	-32.166 m	-32.177 m	-32.166 m	-32.174 m	
Moment of Inertia Ip1	3.8732e-004 kg·m²	1.8999e-003 kg·m²		1.9e-003 kg·m²	1.8999e-003 kg·m²	1.0757e-004 kg·m²				2.7731e-004 kg·m²	2.7724e-004 kg·m²
Moment of Inertia Ip2	1.1207e-003 kg·m²	1.8971e-003 kg·m²		1.8972e-003 kg·m²		1.8892e-004 kg·m²				4.7469e-004 kg·m²	4.7462e-004 kg·m²
Moment of Inertia Ip3	1.4564e-003 kg·m²	7.0609e-005 kg·m²	7.0606e-005 kg·m²	7.061e-005 kg·m²	7.0609e-005 kg·m²	2.8251e-004 kg·m²	2.825e-004 kg·m²		2.8251e-004 kg·m²	7.4969e-004 kg·m²	7.4954e-004 kg·m²
Statistics											
Nodes	2577	7044	6681	7331	6717	3873	3848	3815	3751	5457	5599
Elements	1196	3601	3385	3779	3409	2104	2080	2054	2005	2640	2720
Mesh Metric	None										

TABLE 5
Model (B4) > Geometry > Parts

Object Name	*Sleeper1*	*Vaina5*	*Vaina6*	*Vaina7*	*Vaina8*	*Clip5*	*Clip6*	*Clip7*	*Clip8*	*Tirafondo5*	*Tirafondo6*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Sleepers	Vainas				Clip				Rails and Tirafondos	
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.3 m	3.5998e-002 m	3.6001e-002 m			0.17346 m		0.17347 m	0.17346 m	6.2564e-002 m	
Length Y	2.5 m	3.8348e-002 m	5.1191e-002 m	5.1515e-002 m	3.8526e-002 m	9.5382e-002 m	9.4407e-002 m	9.5382e-002 m	9.4407e-002 m	6.2562e-002 m	
Length Z	0.236 m	0.14204 m	0.14385 m		0.14204 m	5.5457e-002 m	5.9953e-002 m	5.546e-002 m	5.9953e-002 m	0.19828 m	0.19841 m
Properties											
Volume	0.1186 m³	3.2177e-005 m³	3.2243e-005 m³	3.2244e-005 m³	3.2179e-005 m³	6.29e-005 m³	6.2898e-005 m³	6.29e-005 m³	6.2896e-005 m³	8.305e-005 m³	8.3051e-005 m³
Mass	272.78 kg	3.0568e-002 kg	3.0631e-002 kg	3.0632e-002 kg	3.057e-002 kg	0.49062 kg	0.4906 kg	0.49062 kg	0.49059 kg	0.65194 kg	0.65195 kg
Centroid X	29.967 m	29.367 m									
Centroid Y	17.378 m	16.518 m	16.707 m	18.049 m	18.238 m	18.237 m	16.717 m	16.52 m	18.04 m	16.717 m	16.516 m
Centroid Z	-32.296 m	-32.244 m	-32.253 m		-32.244 m	-32.144 m	-32.154 m	-32.144 m	-32.154 m	-32.182 m	-32.172 m
Moment of Inertia Ip1	159.38 kg·m²	5.9945e-005 kg·m²	5.9991e-005 kg·m²		5.9951e-005 kg·m²	3.8732e-004 kg·m²	3.8733e-004 kg·m²		3.8732e-004 kg·m²	1.8999e-003 kg·m²	
Moment of Inertia Ip2	2.3122 kg·m²	5.992e-005 kg·m²	5.9966e-005 kg·m²		5.9926e-005 kg·m²	1.1209e-003 kg·m²	1.1208e-003 kg·m²	1.1209e-003 kg·m²	1.1207e-003 kg·m²	1.8972e-003 kg·m²	
Moment of Inertia Ip3	159.81 kg·m²	4.5075e-006 kg·m²	4.5152e-006 kg·m²	4.5153e-006 kg·m²	4.5079e-006 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	7.0608e-005 kg·m²	7.0611e-005 kg·m²
Statistics											
Nodes	17013	9540	9112	9055	9438	2616	2603	2582	2607	7054	6754

Elements	10587	4934	4694	4652	4851	1223	1212	1198	1220	3603	3432
Mesh Metric	None										

TABLE 6
Model (B4) > Geometry > Parts

Object Name	*Tirafondo7*	*Tirafondo8*	*Codo-Pad5*	*Codo-Pad6*	*Codo-Pad7*	*Codo-Pad8*	*Pad3*	*Pad4*	*Sleeper2*	*Vaina9*	*Vaina10*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Rails and Tirafondos		Codo-Pads				Pads		Sleepers	Vainas	
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	6.2564e-002 m		0.11 m				0.18 m		0.3 m	3.6001e-002 m	
Length Y	6.2562e-002 m	6.2564e-002 m	8.1581e-002 m	8.1131e-002 m	8.1581e-002 m	8.1131e-002 m	0.1599 m		2.5 m	3.8348e-002 m	5.1191e-002 m
Length Z	0.19695 m	0.19897 m	4.1582e-002 m	3.7009e-002 m	4.1582e-002 m	3.7009e-002 m	2.2374e-002 m	2.2371e-002 m	0.236 m	0.14204 m	0.14385 m
Properties											
Volume	8.305e-005 m^3	8.3051e-005 m^3	1.2971e-004 m^3				1.7695e-004 m^3	1.7691e-004 m^3	0.1186 m^3	3.2178e-005 m^3	3.2244e-005 m^3
Mass	0.65194 kg	0.65195 kg	0.17641 kg	0.1764 kg	0.17641 kg	0.1764 kg	0.15041 kg	0.15038 kg	272.78 kg	3.0569e-002 kg	3.0632e-002 kg
Centroid X	29.367 m									28.767 m	
Centroid Y	18.039 m	18.241 m	16.732 m	16.502 m	18.024 m	18.254 m	16.617 m	18.14 m	17.378 m	16.518 m	16.707 m
Centroid Z	-32.182 m	-32.172 m	-32.177 m	-32.166 m	-32.177 m	-32.166 m	-32.174 m		-32.296 m	-32.244 m	-32.253 m
Moment of Inertia Ip1	1.8999e-003 kg·m^2		1.0757e-004 kg·m^2	1.0756e-004 kg·m^2	1.0757e-004 kg·m^2	1.0756e-004 kg·m^2	2.7733e-004 kg·m^2	2.7724e-004 kg·m^2	159.38 kg·m^2	5.9948e-005 kg·m^2	5.9991e-005 kg·m^2
Moment of Inertia Ip2	1.8971e-003 kg·m^2		1.8892e-004 kg·m^2				4.7473e-004 kg·m^2	4.7463e-004 kg·m^2	2.3121 kg·m^2	5.9923e-005 kg·m^2	5.9967e-005 kg·m^2
Moment of Inertia Ip3	7.0609e-005 kg·m^2		2.8251e-004 kg·m^2	2.825e-004 kg·m^2			7.4975e-004 kg·m^2	7.4955e-004 kg·m^2	159.81 kg·m^2	4.5077e-006 kg·m^2	4.5153e-006 kg·m^2
Statistics											
Nodes	7268	6751	3746	3820	3800	3834	5472	5609	17246	9575	9144
Elements	3730	3434	2002	2053	2043	2069	2650	2724	10768	4959	4714
Mesh Metric	None										

TABLE 7
Model (B4) > Geometry > Parts

Object Name	*Vaina11*	*Vaina12*	*Clip9*	*Clip10*	*Clip11*	*Clip12*	*Tirafondo9*	*Tirafondo10*	*Tirafondo11*	*Tirafondo12*	*Codo-Pad9*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Vainas		Clip				Rails and Tirafondos				Codo-Pads
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	3.6001e-002 m		0.17346 m				6.2564e-002 m				0.11 m
Length Y	5.1513e-002 m	3.8525e-002 m	9.5382e-002 m	9.4407e-002 m	9.5382e-002 m	9.4407e-002 m	6.2562e-002 m	6.2564e-002 m	6.2562e-002 m		8.1581e-002 m
Length Z	0.14385 m	0.14204 m	5.546e-002 m	5.995e-002 m	5.546e-002 m	5.9953e-002 m	0.19828 m	0.19841 m	0.19695 m	0.19897 m	4.1582e-002 m
Properties											
Volume	3.2244e-005 m^3	3.2178e-005 m^3	6.29e-005 m^3	6.2896e-005 m^3	6.29e-005 m^3	6.2897e-005 m^3	8.3051e-005 m^3	8.305e-005 m^3	8.3051e-005 m^3		1.2971e-004 m^3

Mass	3.0632e-002 kg	3.0569e-002 kg	0.49062 kg	0.49059 kg	0.49062 kg	0.4906 kg	0.65195 kg	0.65194 kg	0.65195 kg		0.17641 kg
Centroid X	28.767 m										
Centroid Y	18.049 m	18.238 m	18.237 m	16.717 m	16.52 m	18.04 m	16.717 m	16.516 m	18.039 m	18.241 m	16.732 m
Centroid Z	-32.253 m	-32.244 m	-32.144 m	-32.154 m	-32.144 m	-32.154 m	-32.182 m	-32.172 m	-32.182 m	-32.172 m	-32.177 m
Moment of Inertia Ip1	5.9992e-005 kg·m²	5.9947e-005 kg·m²	3.8733e-004 kg·m²	3.8732e-004 kg·m²	3.8733e-004 kg·m²		1.9e-003 kg·m²	1.8999e-003 kg·m²		1.9e-003 kg·m²	1.0756e-004 kg·m²
Moment of Inertia Ip2	5.9968e-005 kg·m²	5.9923e-005 kg·m²	1.1209e-003 kg·m²	1.1207e-003 kg·m²	1.1209e-003 kg·m²	1.1207e-003 kg·m²	1.8972e-003 kg·m²				1.8892e-004 kg·m²
Moment of Inertia Ip3	4.5154e-006 kg·m²	4.5077e-006 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	7.061e-005 kg·m²		7.0611e-005 kg·m²		2.8251e-004 kg·m²
Statistics											
Nodes	9074	9441	2630	2590	2602	2572	7044	6717	7167	6691	3847
Elements	4665	4853	1235	1207	1215	1191	3601	3406	3669	3393	2078
Mesh Metric	None										

TABLE 8
Model (B4) > Geometry > Parts

Object Name	*Codo-Pad10*	*Codo-Pad11*	*Codo-Pad12*	*Pad5*	*Pad6*	*Sleeper3*	*Vaina13*	*Vaina14*	*Vaina15*	*Vaina16*	*Clip13*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Codo-Pads			Pads		Sleepers	Vainas				Clip
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.11 m			0.18 m		0.3 m	3.6001e-002 m	3.5998e-002 m	3.6001e-002 m		0.17346 m
Length Y	8.1131e-002 m	8.1581e-002 m	8.1131e-002 m	0.1599 m		2.5 m	3.8348e-002 m	5.1189e-002 m	5.1515e-002 m	3.8526e-002 m	9.5382e-002 m
Length Z	3.7009e-002 m	4.1582e-002 m	3.7009e-002 m	2.2374e-002 m	2.2371e-002 m	0.236 m	0.14204 m	0.14385 m		0.14204 m	5.546e-002 m
Properties											
Volume	1.2971e-004 m³			1.7695e-004 m³	1.769e-004 m³	0.1186 m³	3.2177e-005 m³	3.2244e-005 m³	3.2245e-005 m³	3.2178e-005 m³	6.2899e-005 m³
Mass	0.17641 kg			0.15041 kg	0.15037 kg	272.78 kg	3.0568e-002 kg	3.0632e-002 kg		3.0569e-002 kg	0.49062 kg
Centroid X	28.767 m						28.167 m				
Centroid Y	16.502 m	18.024 m	18.254 m	16.617 m	18.14 m	17.378 m	16.518 m	16.707 m	18.049 m	18.238 m	18.237 m
Centroid Z	-32.166 m	-32.177 m	-32.166 m	-32.174 m		-32.296 m	-32.244 m	-32.253 m		-32.244 m	-32.144 m
Moment of Inertia Ip1	1.0756e-004 kg·m²			2.7732e-004 kg·m²	2.7722e-004 kg·m²	159.38 kg·m²	5.9946e-005 kg·m²	5.9991e-005 kg·m²		5.9951e-005 kg·m²	3.8733e-004 kg·m²
Moment of Inertia Ip2	1.8892e-004 kg·m²	1.8891e-004 kg·m²	1.8892e-004 kg·m²	4.7471e-004 kg·m²	4.7457e-004 kg·m²	2.3121 kg·m²	5.9921e-005 kg·m²	5.9967e-005 kg·m²		5.9926e-005 kg·m²	1.1209e-003 kg·m²
Moment of Inertia Ip3	2.825e-004 kg·m²	2.8249e-004 kg·m²	2.825e-004 kg·m²	7.4971e-004 kg·m²	7.4948e-004 kg·m²	159.81 kg·m²	4.5076e-006 kg·m²	4.5153e-006 kg·m²		4.5078e-006 kg·m²	1.4566e-003 kg·m²
Statistics											
Nodes	3811	3804	3828	5452	5611	17060	9501	9146	9113	9441	2559
Elements	2049	2047	2065	2637	2727	10625	4908	4713	4687	4853	1182
Mesh Metric	None										

TABLE 9
Model (B4) > Geometry > Parts

Object Name	*Clip14*	*Clip15*	*Clip16*	*Tirafondo13*	*Tirafondo14*	*Tirafondo15*	*Tirafondo16*	*Codo-Pad13*	*Codo-Pad14*	*Codo-Pad15*	*Codo-Pad16*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Clip			Rails and Tirafondos				Codo-Pads			

Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.17346 m			6.2561e-002 m	6.2564e-002 m		6.2561e-002 m	0.11 m			
Length Y	9.4407e-002 m	9.5382e-002 m	9.4407e-002 m	6.2562e-002 m		6.2564e-002 m		8.1581e-002 m	8.1131e-002 m	8.1581e-002 m	8.1131e-002 m
Length Z	5.9953e-002 m	5.5457e-002 m	5.9953e-002 m	0.19828 m	0.19841 m	0.19695 m	0.19897 m	4.1582e-002 m	3.7009e-002 m	4.1582e-002 m	3.7009e-002 m
Properties											
Volume	6.2897e-005 m³	6.2901e-005 m³	6.2898e-005 m³	8.3051e-005 m³			8.3049e-005 m³	1.2971e-004 m³			
Mass	0.49059 kg	0.49062 kg	0.4906 kg	0.65195 kg			0.65193 kg	0.1764 kg	0.17641 kg		
Centroid X	28.167 m										
Centroid Y	16.717 m	16.52 m	18.04 m	16.717 m	16.516 m	18.039 m	18.241 m	16.732 m	16.502 m	18.024 m	18.254 m
Centroid Z	-32.154 m	-32.144 m	-32.154 m	-32.182 m	-32.172 m	-32.182 m	-32.172 m	-32.177 m	-32.166 m	-32.177 m	-32.166 m
Moment of Inertia Ip1	3.8732e-004 kg·m²	3.8733e-004 kg·m²		1.8999e-003 kg·m²				1.0756e-004 kg·m²			1.0757e-004 kg·m²
Moment of Inertia Ip2	1.1207e-003 kg·m²	1.1209e-003 kg·m²	1.1208e-003 kg·m²	1.8972e-003 kg·m²		1.8971e-003 kg·m²		1.8891e-004 kg·m²		1.8892e-004 kg·m²	1.8891e-004 kg·m²
Moment of Inertia Ip3	1.4564e-003 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	7.0611e-005 kg·m²	7.0609e-005 kg·m²	7.0611e-005 kg·m²	7.0606e-005 kg·m²	2.8249e-004 kg·m²		2.825e-004 kg·m²	
Statistics											
Nodes	2617	2636	2575	7156	6703	7098	6685	3793	3877	3764	3896
Elements	1228	1239	1191	3665	3396	3620	3389	2040	2100	2019	2118
Mesh Metric	None										

TABLE 10
Model (B4) > Geometry > Parts

Object Name	*Pad7*	*Pad8*	*Sleeper4*	*Vaina17*	*Vaina18*	*Vaina19*	*Vaina20*	*Clip17*	*Clip18*	*Clip19*	*Clip20*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Pads		Sleepers	Vainas				Clip			
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.18 m		0.3 m	3.5998e-002 m		3.6001e-002 m		0.17346 m			
Length Y	0.1599 m		2.5 m	3.8346e-002 m	5.1191e-002 m	5.1515e-002 m	3.8525e-002 m	9.5382e-002 m	9.4407e-002 m	9.5382e-002 m	9.4407e-002 m
Length Z	2.2374e-002 m	2.2371e-002 m	0.236 m	0.14204 m	0.14385 m		0.14204 m	5.5457e-002 m	5.9953e-002 m	5.546e-002 m	5.9953e-002 m
Properties											
Volume	1.7695e-004 m³	1.7691e-004 m³	0.1186 m³	3.2178e-005 m³	3.2244e-005 m³		3.2178e-005 m³	6.29e-005 m³	6.2897e-005 m³	6.29e-005 m³	6.2897e-005 m³
Mass	0.15041 kg	0.15037 kg	272.78 kg	3.0569e-002 kg	3.0632e-002 kg		3.0569e-002 kg	0.49062 kg	0.4906 kg	0.49062 kg	0.4906 kg
Centroid X	28.167 m			27.567 m							
Centroid Y	16.617 m	18.14 m	17.378 m	16.518 m	16.707 m	18.049 m	18.238 m	18.237 m	16.717 m	16.52 m	18.04 m
Centroid Z	-32.174 m		-32.296 m	-32.244 m	-32.253 m		-32.244 m	-32.144 m	-32.154 m	-32.144 m	-32.154 m
Moment of Inertia Ip1	2.7733e-004 kg·m²	2.7723e-004 kg·m²	159.38 kg·m²	5.9947e-005 kg·m²	5.9993e-005 kg·m²		5.9948e-005 kg·m²	3.8732e-004 kg·m²	3.8733e-004 kg·m²		3.8732e-004 kg·m²
Moment of Inertia Ip2	4.7474e-004 kg·m²	4.7457e-004 kg·m²	2.3121 kg·m²	5.9922e-005 kg·m²	5.9969e-005 kg·m²		5.9923e-005 kg·m²	1.1209e-003 kg·m²	1.1207e-003 kg·m²	1.1209e-003 kg·m²	1.1207e-003 kg·m²
Moment of Inertia Ip3	7.4976e-004 kg·m²	7.4949e-004 kg·m²	159.81 kg·m²	4.5076e-006 kg·m²	4.5155e-006 kg·m²	4.5154e-006 kg·m²	4.5077e-006 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²
Statistics											
Nodes	5490	5597	17359	9517	9111	9053	9438	2605	2601	2551	2529
Elements	2662	2717	10843	4922	4692	4647	4851	1214	1216	1173	1160
Mesh Metric	None										

TABLE 11
Model (B4) > Geometry > Parts

Object Name	*Tirafondo17*	*Tirafondo18*	*Tirafondo19*	*Tirafondo20*	*Codo-Pad17*	*Codo-Pad18*	*Codo-Pad19*	*Codo-Pad20*	*Pad9*	*Pad10*	*Sleeper5*
State	Meshed										
Graphics Properties											

Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Rails and Tirafondos				Codo-Pads				Pads		Sleepers
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	6.2561e-002 m			6.2564e-002 m	0.11 m				0.18 m		0.3 m
Length Y	6.2562e-002 m	6.2564e-002 m		6.2562e-002 m	8.1581e-002 m	8.1131e-002 m	8.1581e-002 m	8.1131e-002 m	0.1599 m		2.5 m
Length Z	0.19828 m	0.19841 m	0.19695 m	0.19897 m	4.1582e-002 m	3.7009e-002 m	4.1582e-002 m	3.7009e-002 m	2.2374e-002 m	2.2371e-002 m	0.236 m
Properties											
Volume	8.305e-005 m³	8.3052e-005 m³	8.305e-005 m³	8.3051e-005 m³	1.2971e-004 m³				1.7695e-004 m³	1.7691e-004 m³	0.1186 m³
Mass	0.65194 kg	0.65195 kg	0.65194 kg	0.65195 kg	0.1764 kg				0.15041 kg	0.15038 kg	272.78 kg
Centroid X	27.567 m										
Centroid Y	16.717 m	16.516 m	18.039 m	18.241 m	16.732 m	16.502 m	18.024 m	18.254 m	16.617 m	18.14 m	17.378 m
Centroid Z	-32.182 m	-32.172 m	-32.182 m	-32.172 m	-32.177 m	-32.166 m	-32.177 m	-32.166 m	-32.174 m		-32.296 m
Moment of Inertia Ip1	1.8999e-003 kg·m²			1.9e-003 kg·m²	1.0756e-004 kg·m²	1.0757e-004 kg·m²	1.0756e-004 kg·m²		2.7733e-004 kg·m²	2.7724e-004 kg·m²	159.38 kg·m²
Moment of Inertia Ip2	1.8972e-003 kg·m²		1.8971e-003 kg·m²	1.8972e-003 kg·m²	1.8891e-004 kg·m²				4.7474e-004 kg·m²	4.7463e-004 kg·m²	2.3121 kg·m²
Moment of Inertia Ip3	7.0609e-005 kg·m²		7.0608e-005 kg·m²	7.0609e-005 kg·m²	2.825e-004 kg·m²		2.8249e-004 kg·m²		7.4976e-004 kg·m²	7.4955e-004 kg·m²	159.81 kg·m²
Statistics											
Nodes	7204	6659	7240	6665	3787	3756	3876	3834	5440	5613	17170
Elements	3705	3361	3712	3372	2030	2011	2098	2072	2628	2729	10699
Mesh Metric	None										

TABLE 12
Model (B4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	8
Material Assignments	8

TABLE 13
Model (B4) > Materials > Pads Assignment

Object Name	*Pads Assignment*	*Vainas Assignment*	*Rails and Tirafondos Assignment*	*Clip Assignment*	*Codo-Pads Assignment*	*Sleepers Assignment*	*Ballast Assignment*	*Sub-Ballast Assignment*
State	Fully Defined							
General								
Scoping Method	Geometry Selection							
Geometry	10 Bodies	20 Bodies	22 Bodies	20 Bodies		5 Bodies	1 Body	
Definition								
Material Name	Pads	Vainas	Rails and Tirafondos	Clip	Codo-Pads	Sleepers	Ballast	Sub-Ballast
Nonlinear Effects	Yes							
Thermal Strain Effects	Yes							
Reference Temperature	By Environment							
Suppressed	No							

Coordinate Systems

TABLE 14
Model (B4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. m

Origin Y	0. m
Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Connections

TABLE 15
Model (B4) > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes

TABLE 16
Model (B4) > Connections > Contacts

Object Name	*Contacts*
State	Fully Defined
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	1.7039e-002 m
Use Range	No
Face/Face	Yes
Face-Face Angle Tolerance	75. °
Face Overlap Tolerance	Off
Cylindrical Faces	Include
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
Statistics	
Connections	336
Active Connections	336

TABLE 17
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region*	*Contact Region 2*	*Contact Region 3*	*Contact Region 4*	*Contact Region 5*	*Contact Region 6*	*Contact Region 7*	*Contact Region 8*	*Contact Region 9*	*Contact Region 10*	*Contact Region 11*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	2 Faces		3 Faces						2 Faces		3 Faces
Target	8 Faces		1 Face				3 Faces	1 Face	8 Faces		1 Face
Contact Bodies	Rail1										
Target Bodies	Clip2	Clip3	Tirafondo1	Tirafondo2	Codo-Pad1	Codo-Pad2	Pad1	Sleeper1	Clip6	Clip7	Tirafondo5
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry	None										

Correction	
Target Geometry Correction	None

TABLE 18
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 12*	*Contact Region 13*	*Contact Region 14*	*Contact Region 15*	*Contact Region 16*	*Contact Region 17*	*Contact Region 18*	*Contact Region 19*	*Contact Region 20*	*Contact Region 21*	*Contact Region 22*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces					2 Faces		3 Faces			
Target	1 Face			3 Faces	1 Face	8 Faces		1 Face			
Contact Bodies	Rail1										
Target Bodies	Tirafondo6	Codo-Pad5	Codo-Pad6	Pad3	Sleeper2	Clip10	Clip11	Tirafondo9	Tirafondo10	Codo-Pad9	Codo-Pad10
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 19
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 23*	*Contact Region 24*	*Contact Region 25*	*Contact Region 26*	*Contact Region 27*	*Contact Region 28*	*Contact Region 29*	*Contact Region 30*	*Contact Region 31*	*Contact Region 32*	*Contact Region 33*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces		2 Faces		3 Faces						2 Faces
Target	3 Faces	1 Face	8 Faces		1 Face				3 Faces	1 Face	8 Faces
Contact Bodies	Rail1										
Target Bodies	Pad5	Sleeper3	Clip14	Clip15	Tirafondo13	Tirafondo14	Codo-Pad13	Codo-Pad14	Pad7	Sleeper4	Clip18
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											

Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 20
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 34*	*Contact Region 35*	*Contact Region 36*	*Contact Region 37*	*Contact Region 38*	*Contact Region 39*	*Contact Region 40*	*Contact Region 41*	*Contact Region 42*	*Contact Region 43*	*Contact Region 44*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	2 Faces	3 Faces						2 Faces		3 Faces	
Target	8 Faces	1 Face				3 Faces	1 Face	8 Faces		1 Face	
Contact Bodies	Rail1							Rail2			
Target Bodies	Clip19	Tirafondo17	Tirafondo18	Codo-Pad17	Codo-Pad18	Pad9	Sleeper5	Clip1	Clip4	Tirafondo3	Tirafondo4
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 21
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 45*	*Contact Region 46*	*Contact Region 47*	*Contact Region 48*	*Contact Region 49*	*Contact Region 50*	*Contact Region 51*	*Contact Region 52*	*Contact Region 53*	*Contact Region 54*	*Contact Region 55*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces				2 Faces		3 Faces				
Target	1 Face		3 Faces	1 Face	8 Faces		1 Face				3 Faces
Contact Bodies	Rail2										
Target Bodies	Codo-Pad3	Codo-Pad4	Pad2	Sleeper1	Clip5	Clip8	Tirafondo7	Tirafondo8	Codo-Pad7	Codo-Pad8	Pad4
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										

Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 22
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 56*	*Contact Region 57*	*Contact Region 58*	*Contact Region 59*	*Contact Region 60*	*Contact Region 61*	*Contact Region 62*	*Contact Region 63*	*Contact Region 64*	*Contact Region 65*	*Contact Region 66*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces	2 Faces		3 Faces						2 Faces	
Target	1 Face	8 Faces		1 Face				3 Faces	1 Face	8 Faces	
Contact Bodies	Rail2										
Target Bodies	Sleeper2	Clip9	Clip12	Tirafondo11	Tirafondo12	Codo-Pad11	Codo-Pad12	Pad6	Sleeper3	Clip13	Clip16
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 23
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 67*	*Contact Region 68*	*Contact Region 69*	*Contact Region 70*	*Contact Region 71*	*Contact Region 72*	*Contact Region 73*	*Contact Region 74*	*Contact Region 75*	*Contact Region 76*	*Contact Region 77*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces						2 Faces		3 Faces		
Target	1 Face				3 Faces	1 Face	8 Faces		1 Face		
Contact Bodies	Rail2										
Target Bodies	Tirafondo15	Tirafondo16	Codo-Pad15	Codo-Pad16	Pad8	Sleeper4	Clip17	Clip20	Tirafondo19	Tirafondo20	Codo-Pad19
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal											

Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 24
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 78*	*Contact Region 79*	*Contact Region 80*	*Contact Region 81*	*Contact Region 82*	*Contact Region 83*	*Contact Region 84*	*Contact Region 85*	*Contact Region 86*	*Contact Region 87*	*Contact Region 88*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces			1 Face	17 Faces					10 Faces	1 Face
Target	1 Face	3 Faces	1 Face		17 Faces					6 Faces	2 Faces
Contact Bodies	Rail2			Ballast						Vaina1	
Target Bodies	Codo-Pad20	Pad10	Sleeper5	Sub-ballast	Sleeper1	Sleeper2	Sleeper3	Sleeper4	Sleeper5	Tirafondo2	Codo-Pad2
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 25
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 89*	*Contact Region 90*	*Contact Region 91*	*Contact Region 92*	*Contact Region 93*	*Contact Region 94*	*Contact Region 95*	*Contact Region 96*	*Contact Region 97*	*Contact Region 98*	*Contact Region 99*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces
Target	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	2 Faces
Contact Bodies	Vaina1	Vaina2			Vaina3			Vaina4			Clip1
Target Bodies	Sleeper1	Tirafondo1	Codo-Pad1	Sleeper1	Tirafondo3	Codo-Pad3	Sleeper1	Tirafondo4	Codo-Pad4	Sleeper1	Tirafondo4
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip											

Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 26
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 100*	*Contact Region 101*	*Contact Region 102*	*Contact Region 103*	*Contact Region 104*	*Contact Region 105*	*Contact Region 106*	*Contact Region 107*	*Contact Region 108*	*Contact Region 109*	*Contact Region 110*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	20 Faces	4 Faces	6 Faces	11 Faces	16 Faces	6 Faces		10 Faces	20 Faces	4 Faces	6 Faces
Target	10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces		10 Faces	1 Face	3 Faces
Contact Bodies	Clip1			Clip2				Clip3			
Target Bodies	Codo-Pad4	Pad2	Sleeper1	Tirafondo1	Codo-Pad1	Pad1	Sleeper1	Tirafondo2	Codo-Pad2	Pad1	Sleeper1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 27
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 111*	*Contact Region 112*	*Contact Region 113*	*Contact Region 114*	*Contact Region 115*	*Contact Region 116*	*Contact Region 117*	*Contact Region 118*	*Contact Region 119*	*Contact Region 120*	*Contact Region 121*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	11 Faces	16 Faces	6 Faces	5 Faces	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces	
Target	2 Faces	9 Faces	1 Face	2 Faces	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces	5 Faces
Contact Bodies	Clip4				Tirafondo1			Tirafondo2			Tirafondo3
Target Bodies	Tirafondo3	Codo-Pad3	Pad2	Sleeper1	Codo-Pad1	Pad1	Sleeper1	Codo-Pad2	Pad1	Sleeper1	Codo-Pad3
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection											

Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 28
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 122*	*Contact Region 123*	*Contact Region 124*	*Contact Region 125*	*Contact Region 126*	*Contact Region 127*	*Contact Region 128*	*Contact Region 129*	*Contact Region 130*	*Contact Region 131*	*Contact Region 132*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	4 Faces	2 Faces	1 Face	3 Faces		6 Faces	3 Faces	7 Faces	3 Faces	6 Faces
Target	1 Face	3 Faces	4 Faces	1 Face	2 Faces	9 Faces	7 Faces	9 Faces	8 Faces	9 Faces	7 Faces
Contact Bodies	Tirafondo3		Tirafondo4			Codo-Pad1		Codo-Pad2		Codo-Pad3	
Target Bodies	Pad2	Sleeper1	Codo-Pad4	Pad2	Sleeper1	Pad1	Sleeper1	Pad1	Sleeper1	Pad2	Sleeper1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 29
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 133*	*Contact Region 134*	*Contact Region 135*	*Contact Region 136*	*Contact Region 137*	*Contact Region 138*	*Contact Region 139*	*Contact Region 140*	*Contact Region 141*	*Contact Region 142*	*Contact Region 143*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces	7 Faces			10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces
Target	9 Faces	8 Faces	3 Faces		6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces
Contact Bodies	Codo-Pad4		Pad1	Pad2	Vaina5			Vaina6			Vaina7
Target Bodies	Pad2	Sleeper1			Tirafondo6	Codo-Pad6	Sleeper2	Tirafondo5	Codo-Pad5	Sleeper2	Tirafondo7
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										

Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 30
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 144*	*Contact Region 145*	*Contact Region 146*	*Contact Region 147*	*Contact Region 148*	*Contact Region 149*	*Contact Region 150*	*Contact Region 151*	*Contact Region 152*	*Contact Region 153*	*Contact Region 154*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	20 Faces	4 Faces	6 Faces	11 Faces	16 Faces
Target	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	2 Faces	10 Faces	1 Face	3 Faces	2 Faces	9 Faces
Contact Bodies	Vaina7		Vaina8			Clip5				Clip6	
Target Bodies	Codo-Pad7	Sleeper2	Tirafondo8	Codo-Pad8	Sleeper2	Tirafondo8	Codo-Pad8	Pad4	Sleeper2	Tirafondo5	Codo-Pad5
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 31
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 155*	*Contact Region 156*	*Contact Region 157*	*Contact Region 158*	*Contact Region 159*	*Contact Region 160*	*Contact Region 161*	*Contact Region 162*	*Contact Region 163*	*Contact Region 164*	*Contact Region 165*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	6 Faces		10 Faces	20 Faces	4 Faces	6 Faces	11 Faces	16 Faces	6 Faces	5 Faces	2 Faces
Target	1 Face	2 Faces		10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces	4 Faces
Contact Bodies	Clip6		Clip7				Clip8				Tirafondo5
Target Bodies	Pad3	Sleeper2	Tirafondo6	Codo-Pad6	Pad3	Sleeper2	Tirafondo7	Codo-Pad7	Pad4	Sleeper2	Codo-Pad5
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										

Behavior	Program Controlled
Trim Contact	Program Controlled
Trim Tolerance	1.7039e-002 m
Suppressed	No
Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 32
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 166*	*Contact Region 167*	*Contact Region 168*	*Contact Region 169*	*Contact Region 170*	*Contact Region 171*	*Contact Region 172*	*Contact Region 173*	*Contact Region 174*	*Contact Region 175*	*Contact Region 176*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	4 Faces	2 Faces	1 Face	3 Faces	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces
Target	1 Face	3 Faces	4 Faces	1 Face	2 Faces	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces
Contact Bodies	Tirafondo5		Tirafondo6			Tirafondo7			Tirafondo8		
Target Bodies	Pad3	Sleeper2	Codo-Pad6	Pad3	Sleeper2	Codo-Pad7	Pad4	Sleeper2	Codo-Pad8	Pad4	Sleeper2
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 33
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 177*	*Contact Region 178*	*Contact Region 179*	*Contact Region 180*	*Contact Region 181*	*Contact Region 182*	*Contact Region 183*	*Contact Region 184*	*Contact Region 185*	*Contact Region 186*	*Contact Region 187*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces	6 Faces	3 Faces	7 Faces	3 Faces	6 Faces	3 Faces	7 Faces			10 Faces
Target	9 Faces	7 Faces	9 Faces	8 Faces	9 Faces	7 Faces	9 Faces	8 Faces	3 Faces		6 Faces
Contact Bodies	Codo-Pad5		Codo-Pad6		Codo-Pad7		Codo-Pad8		Pad3	Pad4	Vaina9
Target Bodies	Pad3	Sleeper2	Pad3	Sleeper2	Pad4	Sleeper2	Pad4	Sleeper2			Tirafondo10
Protected	No										

Definition	
Type	Bonded
Scope Mode	Automatic
Behavior	Program Controlled
Trim Contact	Program Controlled
Trim Tolerance	1.7039e-002 m
Suppressed	No
Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 34
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 188*	*Contact Region 189*	*Contact Region 190*	*Contact Region 191*	*Contact Region 192*	*Contact Region 193*	*Contact Region 194*	*Contact Region 195*	*Contact Region 196*	*Contact Region 197*	*Contact Region 198*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces
Target	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces
Contact Bodies	Vaina9		Vaina10			Vaina11			Vaina12		
Target Bodies	Codo-Pad10	Sleeper3	Tirafondo9	Codo-Pad9	Sleeper3	Tirafondo11	Codo-Pad11	Sleeper3	Tirafondo12	Codo-Pad12	Sleeper3
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 35
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 199*	*Contact Region 200*	*Contact Region 201*	*Contact Region 202*	*Contact Region 203*	*Contact Region 204*	*Contact Region 205*	*Contact Region 206*	*Contact Region 207*	*Contact Region 208*	*Contact Region 209*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	10 Faces	20 Faces	4 Faces	6 Faces	11 Faces	16 Faces	6 Faces		10 Faces	20 Faces	4 Faces

Target	2 Faces	10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces		10 Faces	1 Face
Contact Bodies	Clip9				Clip10				Clip11		
Target Bodies	Tirafondo12	Codo-Pad12	Pad6	Sleeper3	Tirafondo9	Codo-Pad9	Pad5	Sleeper3	Tirafondo10	Codo-Pad10	Pad5
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 36
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 210*	*Contact Region 211*	*Contact Region 212*	*Contact Region 213*	*Contact Region 214*	*Contact Region 215*	*Contact Region 216*	*Contact Region 217*	*Contact Region 218*	*Contact Region 219*	*Contact Region 220*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	6 Faces	11 Faces	16 Faces	6 Faces	5 Faces	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces
Target	3 Faces	2 Faces	9 Faces	1 Face	2 Faces	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces
Contact Bodies	Clip11	Clip12				Tirafondo9			Tirafondo10		
Target Bodies	Sleeper3	Tirafondo11	Codo-Pad11	Pad6	Sleeper3	Codo-Pad9	Pad5	Sleeper3	Codo-Pad10	Pad5	Sleeper3
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 37
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 221*	*Contact Region 222*	*Contact Region 223*	*Contact Region 224*	*Contact Region 225*	*Contact Region 226*	*Contact Region 227*	*Contact Region 228*	*Contact Region 229*	*Contact Region 230*	*Contact Region 231*
State	Fully Defined										

Scope											
Scoping Method	Geometry Selection										
Contact	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces		6 Faces	3 Faces	7 Faces	3 Faces
Target	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces	9 Faces	7 Faces	9 Faces	8 Faces	9 Faces
Contact Bodies	Tirafondo11			Tirafondo12			Codo-Pad9		Codo-Pad10		Codo-Pad11
Target Bodies	Codo-Pad11	Pad6	Sleeper3	Codo-Pad12	Pad6	Sleeper3	Pad5	Sleeper3	Pad5	Sleeper3	Pad6
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 38
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 232*	*Contact Region 233*	*Contact Region 234*	*Contact Region 235*	*Contact Region 236*	*Contact Region 237*	*Contact Region 238*	*Contact Region 239*	*Contact Region 240*	*Contact Region 241*	*Contact Region 242*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	6 Faces	3 Faces	7 Faces			10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces
Target	7 Faces	9 Faces	8 Faces	3 Faces		6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces
Contact Bodies	Codo-Pad11	Codo-Pad12		Pad5	Pad6	Vaina13			Vaina14		
Target Bodies	Sleeper3	Pad6	Sleeper3			Tirafondo14	Codo-Pad14	Sleeper4	Tirafondo13	Codo-Pad13	Sleeper4
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 39
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 243*	*Contact Region 244*	*Contact Region 245*	*Contact Region 246*	*Contact Region 247*	*Contact Region 248*	*Contact Region 249*	*Contact Region 250*	*Contact Region 251*	*Contact Region 252*	*Contact Region 253*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	20 Faces	4 Faces	6 Faces	11 Faces
Target	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	2 Faces	10 Faces	1 Face	3 Faces	2 Faces
Contact Bodies	Vaina15			Vaina16			Clip13				Clip14
Target Bodies	Tirafondo15	Codo-Pad15	Sleeper4	Tirafondo16	Codo-Pad16	Sleeper4	Tirafondo16	Codo-Pad16	Pad8	Sleeper4	Tirafondo13
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 40
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 254*	*Contact Region 255*	*Contact Region 256*	*Contact Region 257*	*Contact Region 258*	*Contact Region 259*	*Contact Region 260*	*Contact Region 261*	*Contact Region 262*	*Contact Region 263*	*Contact Region 264*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	16 Faces	6 Faces		10 Faces	20 Faces	4 Faces	6 Faces	11 Faces	16 Faces	6 Faces	5 Faces
Target	9 Faces	1 Face	2 Faces		10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces
Contact Bodies	Clip14			Clip15				Clip16			
Target Bodies	Codo-Pad13	Pad7	Sleeper4	Tirafondo14	Codo-Pad14	Pad7	Sleeper4	Tirafondo15	Codo-Pad15	Pad8	Sleeper4
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact											

Geometry Correction	None
Target Geometry Correction	None

TABLE 41
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 265*	*Contact Region 266*	*Contact Region 267*	*Contact Region 268*	*Contact Region 269*	*Contact Region 270*	*Contact Region 271*	*Contact Region 272*	*Contact Region 273*	*Contact Region 274*	*Contact Region 275*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces	2 Faces	1 Face	4 Faces	2 Faces	1 Face
Target	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces	4 Faces	1 Face	3 Faces	4 Faces	1 Face
Contact Bodies	Tirafondo13			Tirafondo14			Tirafondo15			Tirafondo16	
Target Bodies	Codo-Pad13	Pad7	Sleeper4	Codo-Pad14	Pad7	Sleeper4	Codo-Pad15	Pad8	Sleeper4	Codo-Pad16	Pad8
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 42
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 276*	*Contact Region 277*	*Contact Region 278*	*Contact Region 279*	*Contact Region 280*	*Contact Region 281*	*Contact Region 282*	*Contact Region 283*	*Contact Region 284*	*Contact Region 285*	*Contact Region 286*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces		6 Faces	3 Faces	7 Faces	3 Faces	6 Faces	3 Faces	7 Faces		
Target	2 Faces	9 Faces	7 Faces	9 Faces	8 Faces	9 Faces	7 Faces	9 Faces	8 Faces	3 Faces	
Contact Bodies	Tirafondo16	Codo-Pad13		Codo-Pad14		Codo-Pad15		Codo-Pad16		Pad7	Pad8
Target Bodies	Sleeper4	Pad7	Sleeper4	Pad7	Sleeper4	Pad8	Sleeper4	Pad8	Sleeper4		
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										

Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 43
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 287*	*Contact Region 288*	*Contact Region 289*	*Contact Region 290*	*Contact Region 291*	*Contact Region 292*	*Contact Region 293*	*Contact Region 294*	*Contact Region 295*	*Contact Region 296*	*Contact Region 297*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face
Target	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces
Contact Bodies	Vaina17			Vaina18			Vaina19			Vaina20	
Target Bodies	Tirafondo18	Codo-Pad18	Sleeper5	Tirafondo17	Codo-Pad17	Sleeper5	Tirafondo19	Codo-Pad19	Sleeper5	Tirafondo20	Codo-Pad20
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 44
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 298*	*Contact Region 299*	*Contact Region 300*	*Contact Region 301*	*Contact Region 302*	*Contact Region 303*	*Contact Region 304*	*Contact Region 305*	*Contact Region 306*	*Contact Region 307*	*Contact Region 308*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	12 Faces	10 Faces	20 Faces	4 Faces	6 Faces	11 Faces	16 Faces	6 Faces		10 Faces	20 Faces
Target	4 Faces	2 Faces	10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces		10 Faces
Contact Bodies	Vaina20	Clip17				Clip18				Clip19	
Target Bodies	Sleeper5	Tirafondo20	Codo-Pad20	Pad10	Sleeper5	Tirafondo17	Codo-Pad17	Pad9	Sleeper5	Tirafondo18	Codo-Pad18
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										

Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 45
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 309*	*Contact Region 310*	*Contact Region 311*	*Contact Region 312*	*Contact Region 313*	*Contact Region 314*	*Contact Region 315*	*Contact Region 316*	*Contact Region 317*	*Contact Region 318*	*Contact Region 319*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	4 Faces	6 Faces	11 Faces	16 Faces	6 Faces	5 Faces	2 Faces	1 Face	4 Faces	2 Faces	1 Face
Target	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces	4 Faces	1 Face	3 Faces	4 Faces	1 Face
Contact Bodies	Clip19		Clip20				Tirafondo17			Tirafondo18	
Target Bodies	Pad9	Sleeper5	Tirafondo19	Codo-Pad19	Pad10	Sleeper5	Codo-Pad17	Pad9	Sleeper5	Codo-Pad18	Pad9
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 46
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 320*	*Contact Region 321*	*Contact Region 322*	*Contact Region 323*	*Contact Region 324*	*Contact Region 325*	*Contact Region 326*	*Contact Region 327*	*Contact Region 328*	*Contact Region 329*	*Contact Region 330*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces		6 Faces	3 Faces	7 Faces
Target	2 Faces	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces	9 Faces	7 Faces	9 Faces	8 Faces
Contact Bodies	Tirafondo18	Tirafondo19			Tirafondo20			Codo-Pad17		Codo-Pad18	
Target Bodies	Sleeper5	Codo-Pad19	Pad10	Sleeper5	Codo-Pad20	Pad10	Sleeper5	Pad9	Sleeper5	Pad9	Sleeper5
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.7039e-002 m										
Suppressed	No										
Advanced											

Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 47
Model (B4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 331*	*Contact Region 332*	*Contact Region 333*	*Contact Region 334*	*Contact Region 335*	*Contact Region 336*
State	Fully Defined					
Scope						
Scoping Method	Geometry Selection					
Contact	3 Faces	6 Faces	3 Faces	7 Faces		
Target	9 Faces	7 Faces	9 Faces	8 Faces	3 Faces	
Contact Bodies	Codo-Pad19		Codo-Pad20		Pad9	Pad10
Target Bodies	Pad10	Sleeper5	Pad10	Sleeper5		
Protected	No					
Definition						
Type	Bonded					
Scope Mode	Automatic					
Behavior	Program Controlled					
Trim Contact	Program Controlled					
Trim Tolerance	1.7039e-002 m					
Suppressed	No					
Advanced						
Formulation	Program Controlled					
Small Sliding	Program Controlled					
Detection Method	Program Controlled					
Penetration Tolerance	Program Controlled					
Elastic Slip Tolerance	Program Controlled					
Normal Stiffness	Program Controlled					
Update Stiffness	Program Controlled					
Pinball Region	Program Controlled					
Geometric Modification						
Contact Geometry Correction	None					
Target Geometry Correction	None					

Mesh

TABLE 48
Model (B4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	Default
Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	6.8157 m
Average Surface Area	2.711e-002 m²
Minimum Edge Length	1.8821e-004 m
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium

Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	745000
Elements	388262

TABLE 49
Model (B4) > Mesh > Mesh Controls

Object Name	*Pads 0.01 m*	*Vainas 0.01 m*	*Tirafondos 0.01 m*	*Clips 0.01 m*	*Codo-Pads 0.01 m*	*Sleepers 0.05 m*	*Rails 0.1 m*	*Ballast 0.1 m*	*Sub-ballast 0.1 m*
State	Fully Defined								
Scope									
Scoping Method	Geometry Selection								
Geometry	10 Bodies	20 Bodies				5 Bodies	2 Bodies	1 Body	
Definition									
Suppressed	No								
Type	Element Size								
Element Size	1.e-002 m					5.e-002 m	0.1 m		
Advanced									
Defeature Size	Default								
Behavior	Soft								

Named Selections

TABLE 50
Model (B4) > Named Selections > Named Selections

Object Name	*Pads*	*Vainas*	*Clips*	*Tirafondos*	*Codo-Pads*	*Sleepers*	*Rails*	*Ballast*	*Sub-ballast*	*Application Point 1*	*Application Point 2*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Geometry	10 Bodies	20 Bodies				5 Bodies	2 Bodies	1 Body		1 Node	
Definition											
Send to Solver	Yes										
Protected	Program Controlled										
Visible	Yes										
Program Controlled Inflation	Exclude										
Statistics											
Type	Manual										
Total Selection	10 Bodies	20 Bodies				5 Bodies	2 Bodies	1 Body		1 Node	
Suppressed	0										
Used by Mesh Worksheet	No										

Static Structural (B5)

TABLE 51
Model (B4) > Analysis

Object Name	*Static Structural (B5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 52
Model (B4) > Static Structural (B5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined

Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Off
Output Controls	
Stress	Yes
Surface Stress	No
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	C:\Users\Mon PC\Desktop\TFM\ANSYS MODELS\600 mm\600 mm-Solved_files\dp0\SYS-1\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	mks

TABLE 53
Model (B4) > Static Structural (B5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	0. m/s² (ramped)
Y Component	0. m/s² (ramped)
Z Component	-9.8066 m/s² (ramped)
Suppressed	No
Direction	-Z Direction

FIGURE 1
Model (B4) > Static Structural (B5) > Standard Earth Gravity

TABLE 54
Model (B4) > Static Structural (B5) > Loads

Object Name	*Fixed Support*	*Nodal Force 2*	*Nodal Force 1*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection	Named Selection	
Geometry	1 Face		
Named Selection		Application Point 2	Application Point 1
Definition			
Type	Fixed Support	Force	
Suppressed	No		
Coordinate System		Nodal Coordinate System	
X Component		0. N (ramped)	
Y Component		0. N (ramped)	
Z Component		-1.1e+005 N (ramped)	
Divide Load by Nodes		Yes	

FIGURE 2
Model (B4) > Static Structural (B5) > Nodal Force 2

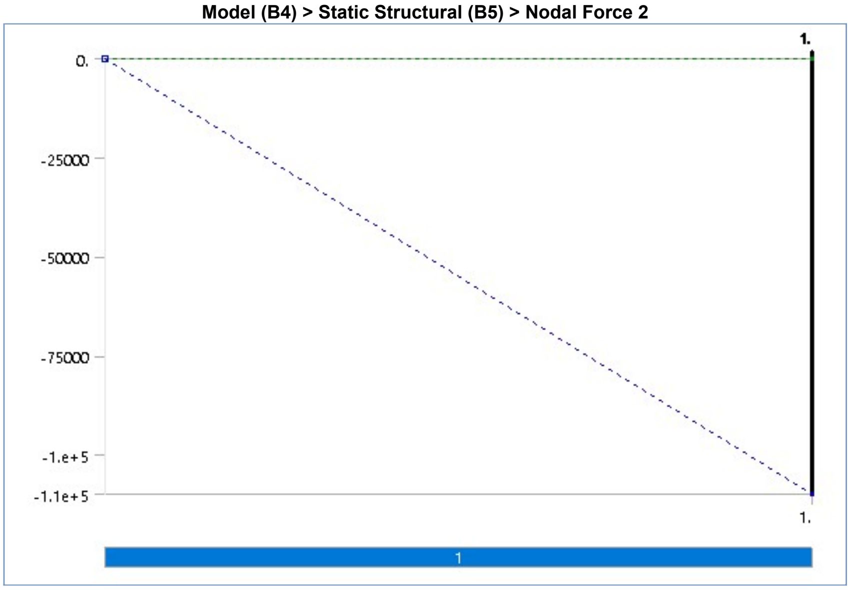


FIGURE 3
Model (B4) > Static Structural (B5) > Nodal Force 1

Solution (B6)

TABLE 55
Model (B4) > Static Structural (B5) > Solution

Object Name	*Solution (B6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	5 m 19 s
MAPDL Memory Used	10.815 GB
MAPDL Result File Size	346.81 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 56
Model (B4) > Static Structural (B5) > Solution (B6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 57
Model (B4) > Static Structural (B5) > Solution (B6) > Results

Object Name	*Total Deformation*	*Equivalent Stress*	*Maximum Deformation Rails*	*Equivalent Stress Rails*	*Maximum Deformation Sleepers*	*Equivalent Stress Sleepers*	*Maximum Deformation Pads*	*Equivalent Stress Pads*	*Maximum Deformation Ballast*	*Equivalent Stress Ballast*
State	Solved									
Scope										
Scoping Method	Geometry Selection									
Geometry	All Bodies		2 Bodies		5 Bodies		10 Bodies		1 Body	
Definition										
Type	Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	Equivalent (von-Mises) Stress
By	Time									
Display Time	Last									
Calculate Time History	Yes									

Identifier										
Suppressed	No									
Results										
Minimum	0. m	126.86 Pa	1.1204e-006 m	6800.5 Pa	9.859e-006 m	717.64 Pa	2.0531e-006 m	675.66 Pa	1.8023e-006 m	165.11 Pa
Maximum	4.1386e-004 m	1.3198e+008 Pa	4.1386e-004 m	8.0919e+007 Pa	2.6954e-004 m	1.897e+007 Pa	2.6958e-004 m	1.5608e+006 Pa	2.6407e-004 m	1.4407e+005 Pa
Average	8.6057e-005 m	1.0478e+006 Pa	9.9874e-005 m	5.2758e+006 Pa	8.9643e-005 m	5.5179e+005 Pa	1.0213e-004 m	71680 Pa	3.9882e-005 m	16442 Pa
Minimum Occurs On	Sub-ballast	Vaina2	Rail2		Sleeper5		Pad10	Pad2	Ballast	
Maximum Occurs On	Rail1	Tirafondo9	Rail1		Sleeper3		Pad5	Pad3	Ballast	
Information										
Time	1. s									
Load Step	1									
Substep	1									
Iteration Number	1									
Integration Point Results										
Display Option		Averaged		Averaged		Averaged		Averaged		Averaged
Average Across Bodies		No		No		No		No		No

FIGURE 4
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

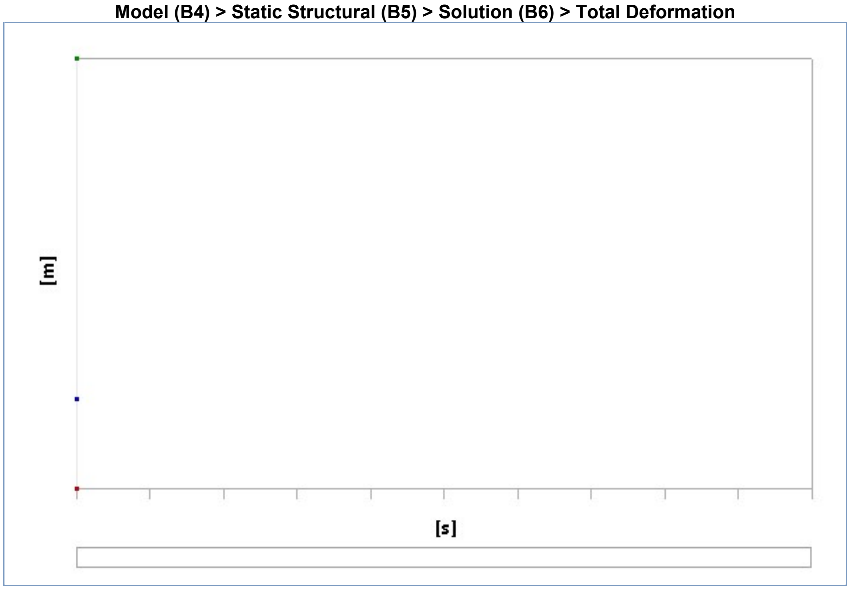


TABLE 58
Model (B4) > Static Structural (B5) > Solution (B6) > Total Deformation

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	0.	4.1386e-004	8.6057e-005

FIGURE 5
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

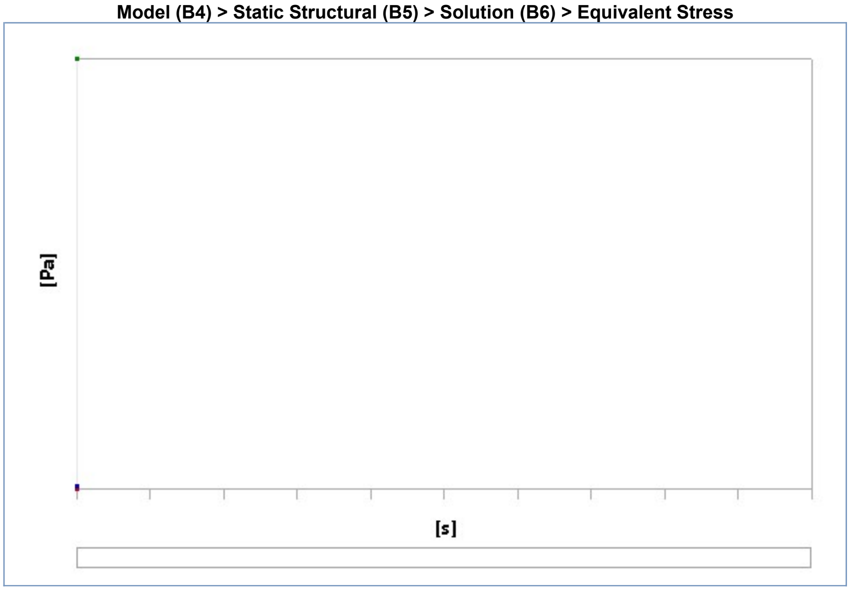


TABLE 59
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	126.86	1.3198e+008	1.0478e+006

FIGURE 6
Model (B4) > Static Structural (B5) > Solution (B6) > Maximum Deformation Rails

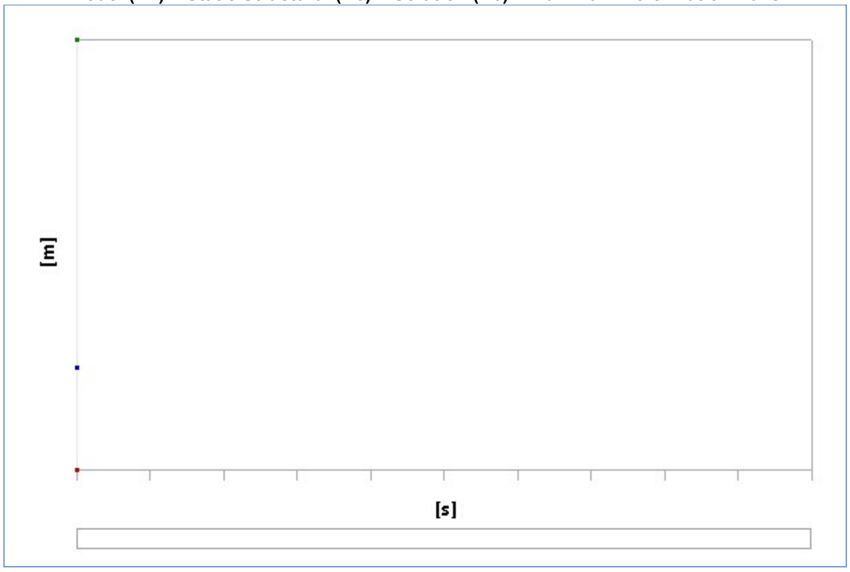


TABLE 60
Model (B4) > Static Structural (B5) > Solution (B6) > Maximum Deformation Rails

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	1.1204e-006	4.1386e-004	9.9874e-005

FIGURE 7
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress Rails

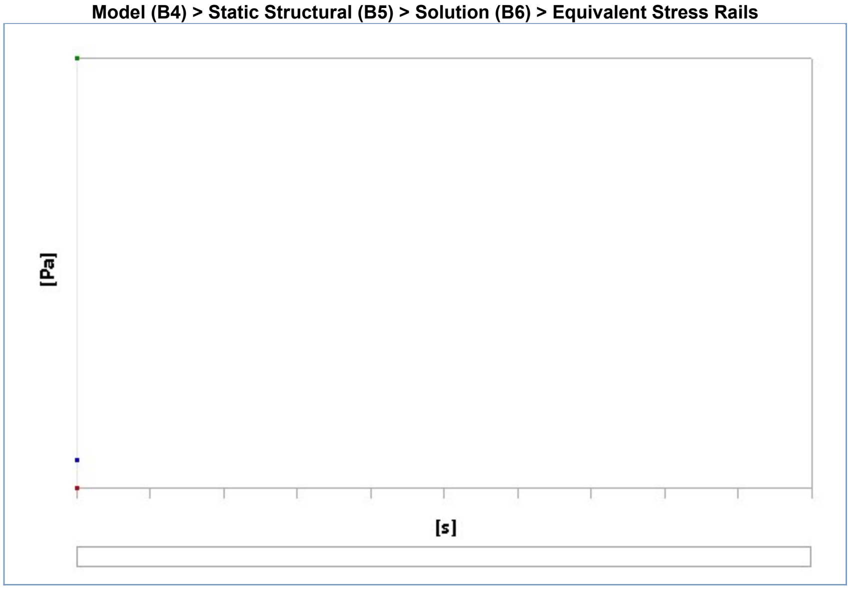


TABLE 61
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress Rails

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	6800.5	8.0919e+007	5.2758e+006

FIGURE 8
Model (B4) > Static Structural (B5) > Solution (B6) > Maximum Deformation Sleepers

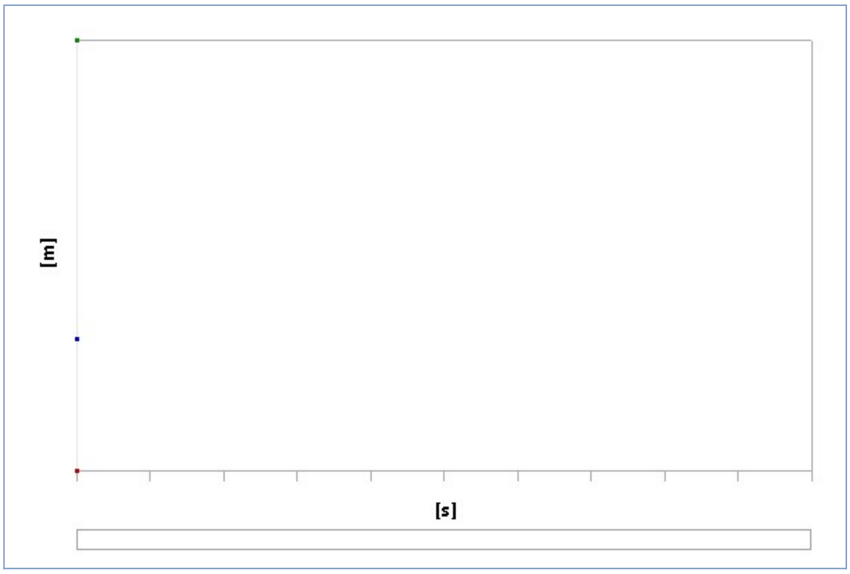


TABLE 62
Model (B4) > Static Structural (B5) > Solution (B6) > Maximum Deformation Sleepers

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	9.859e-006	2.6954e-004	8.9643e-005

FIGURE 9
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress Sleepers

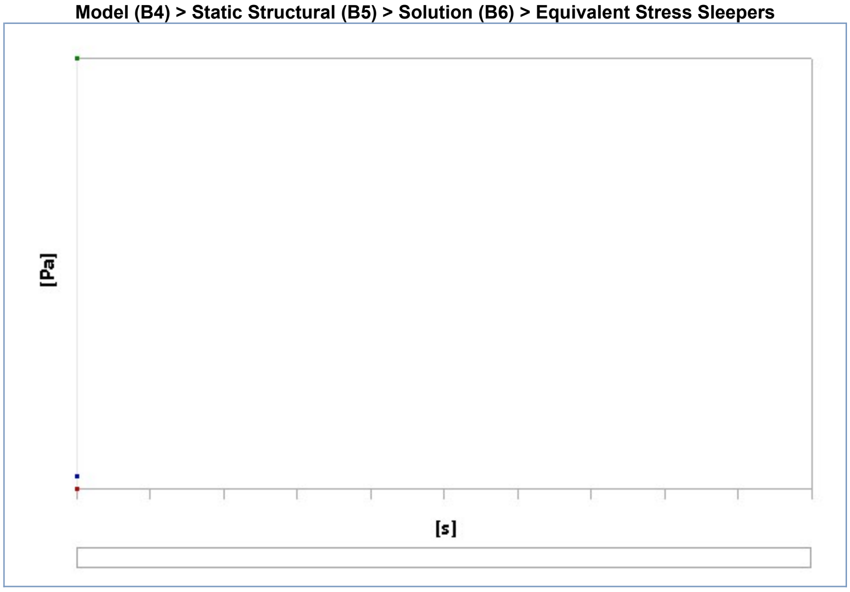


TABLE 63
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress Sleepers

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	717.64	1.897e+007	5.5179e+005

FIGURE 10
Model (B4) > Static Structural (B5) > Solution (B6) > Maximum Deformation Pads

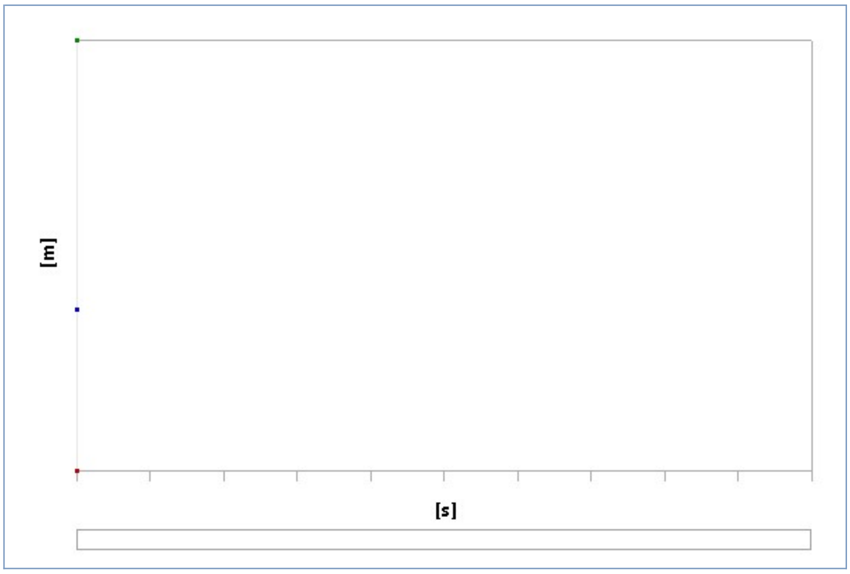


TABLE 64
Model (B4) > Static Structural (B5) > Solution (B6) > Maximum Deformation Pads

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	2.0531e-006	2.6958e-004	1.0213e-004

FIGURE 11
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress Pads

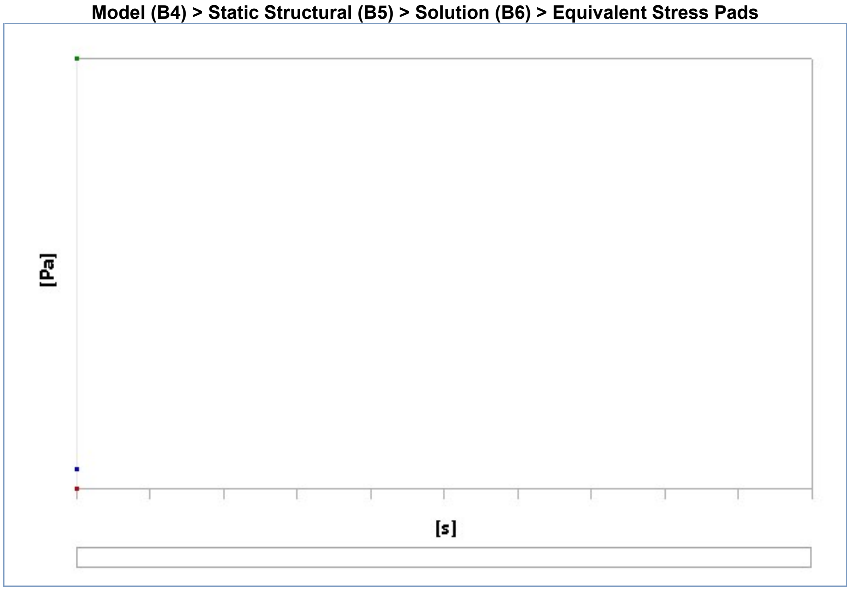


TABLE 65
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress Pads

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	675.66	1.5608e+006	71680

FIGURE 12
Model (B4) > Static Structural (B5) > Solution (B6) > Maximum Deformation Ballast

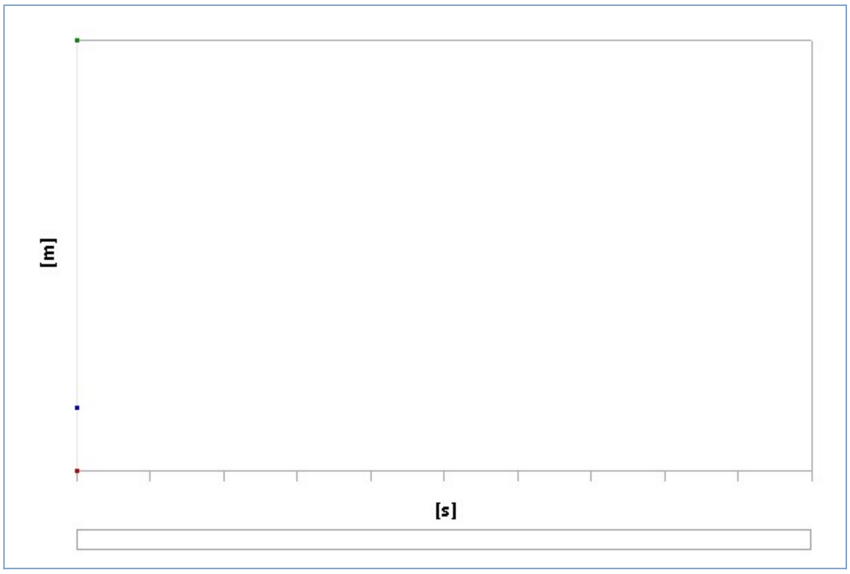


TABLE 66
Model (B4) > Static Structural (B5) > Solution (B6) > Maximum Deformation Ballast

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	1.8023e-006	2.6407e-004	3.9882e-005

FIGURE 13
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress Ballast

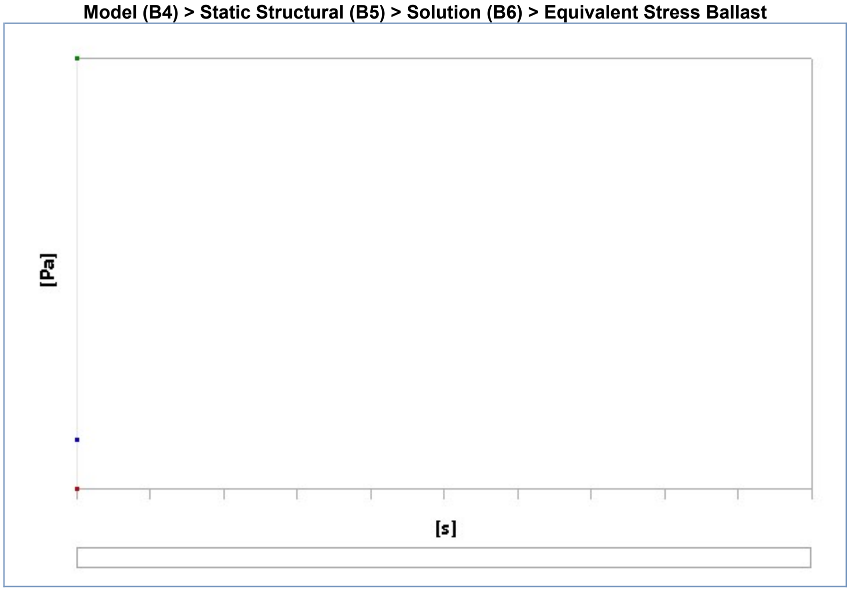


TABLE 67
Model (B4) > Static Structural (B5) > Solution (B6) > Equivalent Stress Ballast

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	165.11	1.4407e+005	16442

Material Data

Rails and Tirafondos

TABLE 68
Rails and Tirafondos > Constants

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

TABLE 69
Rails and Tirafondos > Color

Red	Green	Blue
132	139	179

TABLE 70
Rails and Tirafondos > Compressive Ultimate Strength

Compressive Ultimate Strength Pa

0

TABLE 71
Rails and Tirafondos > Compressive Yield Strength

Compressive Yield Strength Pa
2.5e+008

TABLE 72
Rails and Tirafondos > Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+008

TABLE 73
Rails and Tirafondos > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
4.6e+008

TABLE 74
Rails and Tirafondos > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 75
Rails and Tirafondos > S-N Curve

Alternating Stress Pa	Cycles	Mean Stress Pa
3.999e+009	10	0
2.827e+009	20	0
1.896e+009	50	0
1.413e+009	100	0
1.069e+009	200	0
4.41e+008	2000	0
2.62e+008	10000	0
2.14e+008	20000	0
1.38e+008	1.e+005	0
1.14e+008	2.e+005	0
8.62e+007	1.e+006	0

TABLE 76
Rails and Tirafondos > Strain-Life Parameters

Strength Coefficient Pa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient Pa	Cyclic Strain Hardening Exponent
9.2e+008	-0.106	0.213	-0.47	1.e+009	0.2

TABLE 77
Rails and Tirafondos > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
2.e+011	0.3	1.6667e+011	7.6923e+010	

TABLE 78
Rails and Tirafondos > Isotropic Relative Permeability

Relative Permeability
10000

Ballast

TABLE 79
Ballast > Constants

Density	1800 kg m^-3

TABLE 80
Ballast > Color

Red	Green	Blue
159	206	130

TABLE 81
Ballast > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
1.7e+008	0.3	1.4167e+008	6.5385e+007	

Sub-Ballast

TABLE 82
Sub-Ballast > Constants

Density	1600 kg m^-3

TABLE 83
Sub-Ballast > Color

Red	Green	Blue
132	176	224

TABLE 84
Sub-Ballast > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C

5.e+008	0.25	3.3333e+008	2.e+008	

Vainas

TABLE 85
Vainas > Constants

Density	950 kg m^-3
Coefficient of Thermal Expansion	2.3e-004 C^-1
Specific Heat	2300 J kg^-1 C^-1
Thermal Conductivity	0.28 W m^-1 C^-1

TABLE 86
Vainas > Color

Red	Green	Blue
130	154	176

TABLE 87
Vainas > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
0

TABLE 88
Vainas > Compressive Yield Strength

Compressive Yield Strength Pa
0

TABLE 89
Vainas > Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+007

TABLE 90
Vainas > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
3.3e+007

TABLE 91
Vainas > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 92
Vainas > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
1.1e+009	0.42	2.2917e+009	3.8732e+008	

Clip

TABLE 93
Clip > Constants

Density	7800 kg m^-3

TABLE 94
Clip > Color

Red	Green	Blue
219	198	144

TABLE 95
Clip > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
1.8e+011	0.3	1.5e+011	6.9231e+010	

Codo-Pads

TABLE 96
Codo-Pads > Constants

Density	1360 kg m^-3

TABLE 97
Codo-Pads > Color

Red	Green	Blue
101	239	242

TABLE 98
Codo-Pads > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
5.2e+009	0.34	5.4167e+009	1.9403e+009	

Pads

TABLE 99
Pads > Constants

Density	850 kg m^-3

TABLE 100
Pads > Color

Red	Green	Blue
255	204	250

TABLE 101
Pads > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
1.e+008	0.49	1.6667e+009	3.3557e+007	

Sleepers

TABLE 102
Sleepers > Constants

Density	2300 kg m^-3
Coefficient of Thermal Expansion	1.4e-005 C^-1
Specific Heat	780 J kg^-1 C^-1
Thermal Conductivity	0.72 W m^-1 C^-1

TABLE 103
Sleepers > Color

Red	Green	Blue
180	173	167

TABLE 104
Sleepers > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
4.1e+007

TABLE 105
Sleepers > Compressive Yield Strength

Compressive Yield Strength Pa
0

TABLE 106
Sleepers > Tensile Yield Strength

Tensile Yield Strength Pa
0

TABLE 107
Sleepers > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
5.e+006

TABLE 108
Sleepers > Isotropic Secant Coefficient of Thermal Expansion

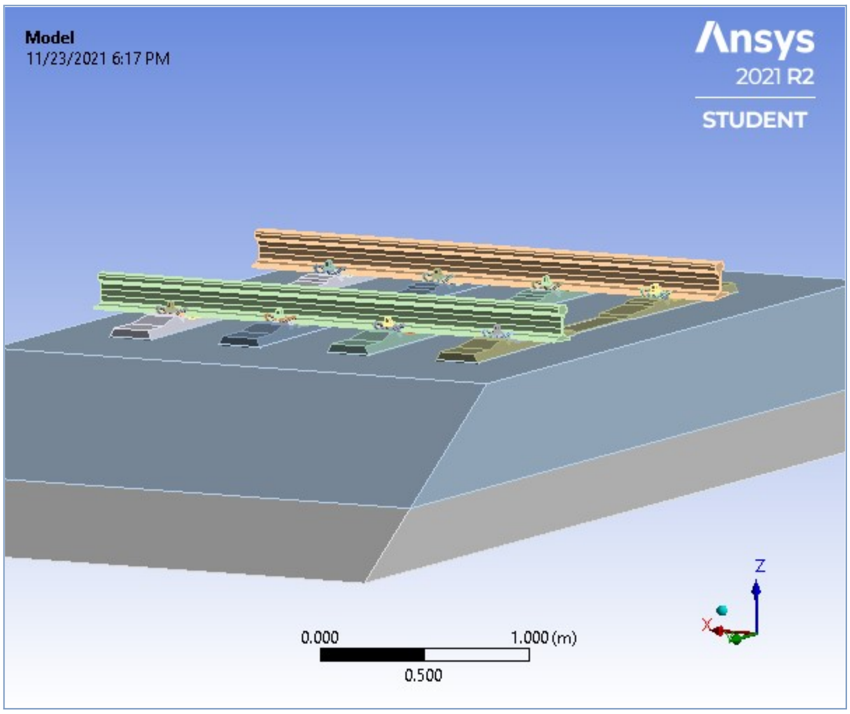
Zero-Thermal-Strain Reference Temperature C
22

TABLE 109
Sleepers > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
3.e+010	0.18	1.5625e+010	1.2712e+010	

Project*

First Saved	Saturday, October 23, 2021
Last Saved	Friday, November 12, 2021
Product Version	2021 R2
Save Project Before Solution	No
Save Project After Solution	No



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Units

TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

Geometry

TABLE 2
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\Mon PC\Desktop\TFM\ANSYS MODELS\600 mm\600 mm-Solved_files\import_files\600 mm con SUJECCIONES ANSYS-4Sleepers.sat
Type	ACIS
Length Unit	Inches
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	2.7307 m
Length Y	6.034 m
Length Z	1.0221 m
Properties	
Volume	10.666 m³
Mass	18768 kg
Scale Factor Value	1.
Statistics	
Bodies	80
Active Bodies	80
Nodes	725851
Elements	377029
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	No
Parameters	Independent

Parameter Key	ANS;DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 3
Model (A4) > Geometry > Parts

Object Name	*Subballast*	*Ballast*	*Rail1*	*Rail2*	*Vaina1*	*Vaina2*	*Vaina3*	*Vaina4*	*Clip1*	*Clip2*	*Clip3*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Sub-Ballast	Ballast	Rails and Tirafondos		Vainas				Clip		
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	2.7307 m		2.5407 m		3.6001e-002 m	3.5999e-002 m			0.17346 m		
Length Y	6.034 m	5.134 m	0.15011 m		3.8348e-002 m	5.1191e-002 m	5.1515e-002 m	3.8525e-002 m	9.5382e-002 m	9.4407e-002 m	9.5382e-002 m
Length Z	0.3 m	0.5 m	0.17578 m		0.14204 m	0.14385 m		0.14204 m	5.546e-002 m	5.9953e-002 m	5.5457e-002 m
Properties											
Volume	4.5745 m³	5.5713 m³	1.9501e-002 m³		3.2177e-005 m³	3.2244e-005 m³		3.2177e-005 m³	6.29e-005 m³	6.2898e-005 m³	6.29e-005 m³
Mass	7319.3 kg	10028 kg	153.08 kg		3.0569e-002 kg	3.0632e-002 kg		3.0568e-002 kg	0.49062 kg	0.4906 kg	0.49062 kg
Centroid X	23.642 m	23.64 m	23.737 m		24.567 m						
Centroid Y	17.378 m		18.135 m	16.621 m	16.518 m	16.707 m	18.049 m	18.238 m	18.237 m	16.717 m	16.52 m
Centroid Z	-32.874 m	-32.497 m	-32.089 m		-32.244 m	-32.253 m		-32.244 m	-32.144 m	-32.154 m	-32.144 m
Moment of Inertia Ip1	19197 kg·m²	17539 kg·m²	0.70791 kg·m²		5.9947e-005 kg·m²	5.9992e-005 kg·m²		5.9945e-005 kg·m²	3.8733e-004 kg·m²		
Moment of Inertia Ip2	4603.1 kg·m²	6551.2 kg·m²	82.957 kg·m²		5.9922e-005 kg·m²	5.9968e-005 kg·m²	5.9967e-005 kg·m²	5.9921e-005 kg·m²	1.1209e-003 kg·m²	1.1208e-003 kg·m²	1.1209e-003 kg·m²
Moment of Inertia Ip3	23690 kg·m²	23698 kg·m²	82.454 kg·m²		4.5076e-006 kg·m²	4.5154e-006 kg·m²		4.5076e-006 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	1.4566e-003 kg·m²
Statistics											
Nodes	44805	75305	9745	8690	16111	16145	15894	16200	2628	2573	2608
Elements	9576	49880	5359	4720	8276	8296	8143	8337	1234	1189	1217
Mesh Metric	None										

TABLE 4
Model (A4) > Geometry > Parts

Object Name	*Clip4*	*Tirafondo1*	*Tirafondo2*	*Tirafondo3*	*Tirafondo4*	*Codo-Pad1*	*Codo-Pad2*	*Codo-Pad3*	*Codo-Pad4*	*Pad1*	*Pad2*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										

Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Clip	Rails and Tirafondos				Codo-Pads				Pads	
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.17346 m	6.2564e-002 m	6.2562e-002 m	6.2564e-002 m		0.11 m				0.18 m	
Length Y	9.4407e-002 m	6.2564e-002 m		6.2562e-002 m		8.1581e-002 m	8.1131e-002 m	8.1581e-002 m	8.1131e-002 m	0.1599 m	
Length Z	5.995e-002 m	0.19828 m	0.19841 m	0.19695 m	0.19897 m	4.1582e-002 m	3.7009e-002 m	4.1582e-002 m	3.7009e-002 m	2.2374e-002 m	2.2371e-002 m
Properties											
Volume	6.2897e-005 m³	8.3051e-005 m³	8.3049e-005 m³	8.3051e-005 m³	8.305e-005 m³	1.2971e-004 m³				1.7695e-004 m³	1.7691e-004 m³
Mass	0.49059 kg	0.65195 kg	0.65194 kg	0.65195 kg	0.65194 kg	0.17641 kg				0.15041 kg	0.15037 kg
Centroid X	24.567 m										
Centroid Y	18.04 m	16.717 m	16.516 m	18.039 m	18.241 m	16.732 m	16.502 m	18.024 m	18.254 m	16.617 m	18.14 m
Centroid Z	-32.154 m	-32.182 m	-32.172 m	-32.182 m	-32.172 m	-32.177 m	-32.166 m	-32.177 m	-32.166 m	-32.174 m	
Moment of Inertia Ip1	3.8732e-004 kg·m²	1.9e-003 kg·m²	1.8999e-003 kg·m²	1.9e-003 kg·m²	1.8999e-003 kg·m²	1.0757e-004 kg·m²				2.7732e-004 kg·m²	2.7723e-004 kg·m²
Moment of Inertia Ip2	1.1207e-003 kg·m²	1.8972e-003 kg·m²	1.8971e-003 kg·m²	1.8972e-003 kg·m²		1.8893e-004 kg·m²	1.8892e-004 kg·m²	1.8893e-004 kg·m²	1.8892e-004 kg·m²	4.7472e-004 kg·m²	4.7459e-004 kg·m²
Moment of Inertia Ip3	1.4564e-003 kg·m²	7.0611e-005 kg·m²	7.0607e-005 kg·m²	7.0612e-005 kg·m²	7.0611e-005 kg·m²	2.8251e-004 kg·m²		2.8252e-004 kg·m²	2.825e-004 kg·m²	7.4972e-004 kg·m²	7.4951e-004 kg·m²
Statistics											
Nodes	2578	7345	6977	7419	6922	3858	3806	3794	3793	5468	5617
Elements	1195	3797	3576	3833	3531	2091	2048	2037		2640	2739
Mesh Metric	None										

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*Sleeper1*	*Vaina5*	*Vaina6*	*Vaina7*	*Vaina8*	*Clip5*	*Clip6*	*Clip7*	*Clip8*	*Tirafondo5*	*Tirafondo6*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Sleepers	Vainas				Clip				Rails and Tirafondos	
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.3 m	3.5999e-002 m		3.6001e-002 m	3.5999e-002 m	0.17346 m				6.2562e-002 m	6.2564e-002 m
Length Y	2.5 m	3.8348e-002 m	5.1189e-002 m	5.1513e-002 m	3.8525e-002 m	9.5382e-002 m	9.4407e-002 m	9.5382e-002 m	9.4407e-002 m	6.2564e-002 m	6.2562e-002 m
Length Z	0.236 m	0.14204 m	0.14385 m		0.14204 m	5.5457e-002 m	5.9953e-002 m	5.546e-002 m	5.9953e-002 m	0.19828 m	0.19841 m
Properties											
Volume	0.1186 m³	3.2177e-005 m³	3.2244e-005 m³		3.2177e-005 m³	6.29e-005 m³	6.2897e-005 m³	6.29e-005 m³	6.2896e-005 m³	8.3051e-005 m³	
Mass	272.78 kg	3.0568e-002 kg	3.0632e-002 kg		3.0568e-002 kg	0.49062 kg	0.4906 kg	0.49062 kg	0.49059 kg	0.65195 kg	
Centroid X	24.567 m	23.967 m									
Centroid Y	17.378 m	16.518 m	16.707 m	18.049 m	18.238 m	18.237 m	16.717 m	16.52 m	18.04 m	16.717 m	16.516 m
Centroid Z	-32.296 m	-32.244 m	-32.253 m		-32.244 m	-32.144 m	-32.154 m	-32.144 m	-32.154 m	-32.182 m	-32.172 m
Moment of Inertia Ip1	159.38 kg·m²	5.9946e-005 kg·m²	5.9993e-005 kg·m²	5.9992e-005 kg·m²	5.9946e-005 kg·m²	3.8732e-004 kg·m²	3.8733e-004 kg·m²			1.8999e-003 kg·m²	1.9e-003 kg·m²
Moment of Inertia Ip2	2.3121 kg·m²	5.9922e-005 kg·m²	5.9968e-005 kg·m²		5.9921e-005 kg·m²	1.1209e-003 kg·m²	1.1207e-003 kg·m²	1.1209e-003 kg·m²	1.1207e-003 kg·m²	1.8971e-003 kg·m²	1.8972e-003 kg·m²
Moment of Inertia Ip3	159.81 kg·m²	4.5076e-006 kg·m²	4.5153e-006 kg·m²	4.5154e-006 kg·m²	4.5076e-006 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	7.0609e-005 kg·m²	7.0611e-005 kg·m²
Statistics											
Nodes	17420	16095	15991	15886	16177	2567	2545	2600	2564	7340	6980
Elements	10868	8265	8190	8137	8320	1184	1172	1212	1187	3789	3581
Mesh Metric	None										

TABLE 6
Model (A4) > Geometry > Parts

Object Name	*Tirafondo7*	*Tirafondo8*	*Codo-Pad5*	*Codo-Pad6*	*Codo-Pad7*	*Codo-Pad8*	*Pad3*	*Pad4*	*Sleeper2*	*Vaina9*	*Vaina10*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Rails and Tirafondos		Codo-Pads				Pads		Sleepers	Vainas	
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	6.2564e-002 m	6.2562e-002 m	0.11 m				0.18 m		0.3 m	3.5999e-002 m	3.6001e-002 m
Length Y	6.2562e-002 m	6.2564e-002 m	8.1581e-002 m	8.1131e-002 m	8.1581e-002 m	8.1131e-002 m	0.1599 m		2.5 m	3.8348e-002 m	5.1191e-002 m
Length Z	0.19695 m	0.19897 m	4.1582e-002 m	3.7009e-002 m	4.1582e-002 m	3.7009e-002 m	2.2374e-002 m	2.2371e-002 m	0.236 m	0.14204 m	0.14385 m
Properties											
Volume	8.3051e-005 m^3	8.305e-005 m^3	1.2971e-004 m^3				1.7695e-004 m^3	1.7691e-004 m^3	0.1186 m^3	3.2178e-005 m^3	3.2244e-005 m^3
Mass	0.65195 kg	0.65194 kg	0.1764 kg			0.17641 kg	0.15041 kg	0.15037 kg	272.78 kg	3.0569e-002 kg	3.0632e-002 kg
Centroid X	23.967 m									23.367 m	
Centroid Y	18.039 m	18.241 m	16.732 m	16.502 m	18.024 m	18.254 m	16.617 m	18.14 m	17.378 m	16.518 m	16.707 m
Centroid Z	-32.182 m	-32.172 m	-32.177 m	-32.166 m	-32.177 m	-32.166 m	-32.174 m		-32.296 m	-32.244 m	-32.253 m
Moment of Inertia Ip1	1.9e-003 kg·m^2	1.8999e-003 kg·m^2	1.0756e-004 kg·m^2				2.7732e-004 kg·m^2	2.7723e-004 kg·m^2	159.38 kg·m^2	5.9947e-005 kg·m^2	5.9993e-005 kg·m^2
Moment of Inertia Ip2	1.8972e-003 kg·m^2	1.8971e-003 kg·m^2	1.8891e-004 kg·m^2				4.7473e-004 kg·m^2	4.746e-004 kg·m^2	2.3121 kg·m^2	5.9923e-005 kg·m^2	5.9968e-005 kg·m^2
Moment of Inertia Ip3	7.0611e-005 kg·m^2	7.0608e-005 kg·m^2	2.8249e-004 kg·m^2		2.825e-004 kg·m^2	2.8249e-004 kg·m^2	7.4974e-004 kg·m^2	7.4952e-004 kg·m^2	159.81 kg·m^2	4.5077e-006 kg·m^2	4.5154e-006 kg·m^2
Statistics											
Nodes	7389	6945	3818	3852	3762	3827	5479	5624	17615	16083	15992
Elements	3814	3550	2059	2082	2013	2062	2649	2744	11019	8256	8191
Mesh Metric	None										

TABLE 7
Model (A4) > Geometry > Parts

Object Name	*Vaina11*	*Vaina12*	*Clip9*	*Clip10*	*Clip11*	*Clip12*	*Tirafondo9*	*Tirafondo10*	*Tirafondo11*	*Tirafondo12*	*Codo-Pad9*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Vainas		Clip				Rails and Tirafondos				Codo-Pads
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	3.5999e-002 m		0.17346 m				6.2562e-002 m			6.2564e-002 m	0.11 m
Length Y	5.1515e-002 m	3.8525e-002 m	9.5382e-002 m	9.4407e-002 m	9.5382e-002 m	9.4408e-002 m	6.2564e-002 m		6.2562e-002 m		8.1581e-002 m
Length Z	0.14385 m	0.14204 m	5.546e-002 m	5.995e-002 m	5.546e-002 m	5.9953e-002 m	0.19828 m	0.19841 m	0.19695 m	0.19897 m	4.1582e-002 m
Properties											
Volume	3.2244e-005 m^3	3.2178e-005 m^3	6.2899e-005 m^3	6.2897e-005 m^3	6.29e-005 m^3	6.2897e-005 m^3	8.3049e-005 m^3	8.305e-005 m^3		8.3051e-005 m^3	1.2971e-004 m^3
Mass	3.0632e-	3.0569e-	0.49062	0.49059	0.49062	0.4906 kg	0.65194 kg			0.65195 kg	0.17641

	002 kg	002 kg	kg	kg	kg						kg
Centroid X	23.367 m										
Centroid Y	18.049 m	18.238 m	18.237 m	16.717 m	16.52 m	18.04 m	16.717 m	16.516 m	18.039 m	18.241 m	16.732 m
Centroid Z	-32.253 m	-32.244 m	-32.144 m	-32.154 m	-32.144 m	-32.154 m	-32.182 m	-32.172 m	-32.182 m	-32.172 m	-32.177 m
Moment of Inertia Ip1	5.9993e-005 kg·m²	5.9947e-005 kg·m²	3.8732e-004 kg·m²		3.8733e-004 kg·m²		1.8999e-003 kg·m²				1.0756e-004 kg·m²
Moment of Inertia Ip2	5.9969e-005 kg·m²	5.9923e-005 kg·m²	1.1209e-003 kg·m²	1.1207e-003 kg·m²	1.1209e-003 kg·m²	1.1207e-003 kg·m²	1.8971e-003 kg·m²		1.8972e-003 kg·m²		1.8891e-004 kg·m²
Moment of Inertia Ip3	4.5154e-006 kg·m²	4.5077e-006 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	1.4566e-003 kg·m²	1.4564e-003 kg·m²	7.0608e-005 kg·m²	7.0607e-005 kg·m²	7.0608e-005 kg·m²	7.0609e-005 kg·m²	2.8249e-004 kg·m²
Statistics											
Nodes	15875	16131	2598	2564	2583	2610	7234	6948	7295	6968	3834
Elements	8128	8299	1211	1185	1197	1218	3723	3553	3741	3567	2075
Mesh Metric	None										

TABLE 8
Model (A4) > Geometry > Parts

Object Name	*Codo-Pad10*	*Codo-Pad11*	*codo-Pad12*	*Pad5*	*Pad6*	*Sleeper3*	*Vaina13*	*Vaina14*	*Vaina15*	*Vaina16*	*Clip13*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Codo-Pads			Pads		Sleepers	Vainas				Clip
Nonlinear Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.11 m			0.18 m		0.3 m	3.6001e-002 m	3.5999e-002 m			0.17346 m
Length Y	8.1131e-002 m	8.1581e-002 m	8.1131e-002 m	0.1599 m		2.5 m	3.8346e-002 m	5.1191e-002 m	5.1515e-002 m	3.8525e-002 m	9.5382e-002 m
Length Z	3.7009e-002 m	4.1582e-002 m	3.7009e-002 m	2.2374e-002 m	2.2371e-002 m	0.236 m	0.14204 m	0.14385 m		0.14204 m	5.546e-002 m
Properties											
Volume	1.2971e-004 m³			1.7695e-004 m³	1.7691e-004 m³	0.1186 m³	3.2178e-005 m³	3.2244e-005 m³		3.2177e-005 m³	6.29e-005 m³
Mass	0.17641 kg			0.15041 kg	0.15037 kg	272.78 kg	3.0569e-002 kg	3.0632e-002 kg		3.0568e-002 kg	0.49062 kg
Centroid X	23.367 m						22.767 m				
Centroid Y	16.502 m	18.024 m	18.254 m	16.617 m	18.14 m	17.378 m	16.518 m	16.707 m	18.049 m	18.238 m	18.237 m
Centroid Z	-32.166 m	-32.177 m	-32.166 m	-32.174 m		-32.296 m	-32.244 m	-32.253 m		-32.244 m	-32.144 m
Moment of Inertia Ip1	1.0756e-004 kg·m²			2.7732e-004 kg·m²	2.7723e-004 kg·m²	159.38 kg·m²	5.9948e-005 kg·m²	5.9991e-005 kg·m²	5.9994e-005 kg·m²	5.9946e-005 kg·m²	3.8733e-004 kg·m²
Moment of Inertia Ip2	1.8892e-004 kg·m²	1.8891e-004 kg·m²		4.7472e-004 kg·m²	4.7461e-004 kg·m²	2.3122 kg·m²	5.9924e-005 kg·m²	5.9967e-005 kg·m²	5.9969e-005 kg·m²	5.9922e-005 kg·m²	1.1209e-003 kg·m²
Moment of Inertia Ip3	2.825e-004 kg·m²	2.8249e-004 kg·m²	2.825e-004 kg·m²	7.4972e-004 kg·m²	7.4953e-004 kg·m²	159.81 kg·m²	4.5077e-006 kg·m²	4.5153e-006 kg·m²	4.5154e-006 kg·m²	4.5076e-006 kg·m²	1.4566e-003 kg·m²
Statistics											
Nodes	3854	3759	3842	5468	5599	17279	16033	16153	15898	16114	2594
Elements	2083	2015	2078	2640	2720	10793	8220	8302	8150	8286	1211
Mesh Metric	None										

TABLE 9
Model (A4) > Geometry > Parts

Object Name	*Clip14*	*Clip15*	*Clip16*	*Tirafondo13*	*Tirafondo14*	*Tirafondo15*	*Tirafondo16*	*Codo-Pad13*	*Codo-Pad14*	*Codo-Pad15*	*Codo-Pad16*
State	Meshed										
Graphics Properties											
Visible	Yes										
Transparency	1										
Definition											
Suppressed	No										
Stiffness Behavior	Flexible										
Coordinate System	Default Coordinate System										
Reference Temperature	By Environment										
Treatment	None										
Material											
Assignment	Clip			Rails and Tirafondos				Codo-Pads			
Nonlinear											

Effects	Yes										
Thermal Strain Effects	Yes										
Bounding Box											
Length X	0.17346 m			6.2564e-002 m	6.2562e-002 m	6.2564e-002 m	6.2562e-002 m	0.11 m			
Length Y	9.4408e-002 m	9.5382e-002 m	9.4407e-002 m	6.2562e-002 m			6.2564e-002 m	8.158e-002 m	8.1131e-002 m	8.1581e-002 m	8.1131e-002 m
Length Z	5.9953e-002 m	5.5457e-002 m	5.9953e-002 m	0.19828 m	0.19841 m	0.19695 m	0.19897 m	4.1582e-002 m	3.7009e-002 m	4.1582e-002 m	3.7009e-002 m
Properties											
Volume	6.2896e-005 m^3	6.29e-005 m^3	6.2897e-005 m^3	8.3051e-005 m^3	8.305e-005 m^3	8.3051e-005 m^3	8.305e-005 m^3	1.2971e-004 m^3	1.297e-004 m^3	1.2971e-004 m^3	1.297e-004 m^3
Mass	0.49059 kg	0.49062 kg	0.4906 kg	0.65195 kg	0.65194 kg	0.65195 kg		0.17641 kg	0.1764 kg	0.17641 kg	0.1764 kg
Centroid X	22.767 m										
Centroid Y	16.717 m	16.52 m	18.04 m	16.717 m	16.516 m	18.039 m	18.241 m	16.732 m	16.502 m	18.024 m	18.254 m
Centroid Z	-32.154 m	-32.144 m	-32.154 m	-32.182 m	-32.172 m	-32.182 m	-32.172 m	-32.177 m	-32.166 m	-32.177 m	-32.166 m
Moment of Inertia Ip1	3.8732e-004 kg·m^2	3.8733e-004 kg·m^2	3.8732e-004 kg·m^2	1.8999e-003 kg·m^2				1.0756e-004 kg·m^2			
Moment of Inertia Ip2	1.1207e-003 kg·m^2	1.1209e-003 kg·m^2	1.1208e-003 kg·m^2	1.8971e-003 kg·m^2		1.8972e-003 kg·m^2	1.8971e-003 kg·m^2	1.8891e-004 kg·m^2	1.889e-004 kg·m^2	1.8892e-004 kg·m^2	1.8891e-004 kg·m^2
Moment of Inertia Ip3	1.4564e-003 kg·m^2	1.4566e-003 kg·m^2	1.4564e-003 kg·m^2	7.0608e-005 kg·m^2	7.061e-005 kg·m^2	7.0609e-005 kg·m^2	7.0607e-005 kg·m^2	2.8249e-004 kg·m^2	2.8248e-004 kg·m^2	2.825e-004 kg·m^2	2.8249e-004 kg·m^2
Statistics											
Nodes	2577	2585	2545	7352	7021	7288	6968	3786	3857	3773	3792
Elements	1196	1202	1170	3792	3607	3744	3568	2033	2088	2025	2037
Mesh Metric	None										

TABLE 10
Model (A4) > Geometry > Parts

Object Name	*Pad7*	*Pad8*	*Sleeper4*
State	Meshed		
Graphics Properties			
Visible	Yes		
Transparency	1		
Definition			
Suppressed	No		
Stiffness Behavior	Flexible		
Coordinate System	Default Coordinate System		
Reference Temperature	By Environment		
Treatment	None		
Material			
Assignment	Pads		Sleepers
Nonlinear Effects	Yes		
Thermal Strain Effects	Yes		
Bounding Box			
Length X	0.18 m		0.3 m
Length Y	0.1599 m		2.5 m
Length Z	2.2374e-002 m	2.2371e-002 m	0.236 m
Properties			
Volume	1.7695e-004 m^3	1.7691e-004 m^3	0.1186 m^3
Mass	0.15041 kg	0.15037 kg	272.78 kg
Centroid X	22.767 m		
Centroid Y	16.617 m	18.14 m	17.378 m
Centroid Z	-32.174 m		-32.296 m
Moment of Inertia Ip1	2.7732e-004 kg·m^2	2.7723e-004 kg·m^2	159.38 kg·m^2
Moment of Inertia Ip2	4.7471e-004 kg·m^2	4.7459e-004 kg·m^2	2.3121 kg·m^2
Moment of Inertia Ip3	7.4972e-004 kg·m^2	7.4951e-004 kg·m^2	159.81 kg·m^2
Statistics			
Nodes	5479	5581	17182
Elements	2649	2710	10718
Mesh Metric	None		

TABLE 11
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	8
Material Assignments	8

TABLE 12
Model (A4) > Materials > Clip Assignment

Object Name	*Clip Assignment*	*Codo-Pads Assignment*	*Pads Assignment*	*Sub-Ballast Assignment*	*Ballast Assignment*	*Rails and Tirafondos Assignment*	*Sleepers Assignment*	*Vainas Assignment*
State	Fully Defined							
General								
Scoping Method	Geometry Selection							
Geometry	16 Bodies	14 Bodies	8 Bodies	1 Body		18 Bodies	4 Bodies	16 Bodies
Definition								

Material Name	Clip	Codo-Pads	Pads	Sub-Ballast	Ballast	Rails and Tirafondos	Sleepers	Vainas
Nonlinear Effects	Yes							
Thermal Strain Effects	Yes							
Reference Temperature	By Environment							
Suppressed	No							

Coordinate Systems

TABLE 13
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. m
Origin Y	0. m
Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Connections

TABLE 14
Model (A4) > Connections

Object Name	*Connections*
State	Fully Defined
Auto Detection	
Generate Automatic Connection On Refresh	Yes
Transparency	
Enabled	Yes

TABLE 15
Model (A4) > Connections > Contacts

Object Name	*Contacts*
State	Fully Defined
Definition	
Connection Type	Contact
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Auto Detection	
Tolerance Type	Slider
Tolerance Slider	0.
Tolerance Value	1.6754e-002 m
Use Range	No
Face/Face	Yes
Face-Face Angle Tolerance	75. °
Face Overlap Tolerance	Off
Cylindrical Faces	Include
Face/Edge	No
Edge/Edge	No
Priority	Include All
Group By	Bodies
Search Across	Bodies
Statistics	
Connections	269
Active Connections	269

TABLE 16
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region*	*Contact Region 2*	*Contact Region 3*	*Contact Region 4*	*Contact Region 5*	*Contact Region 6*	*Contact Region 7*	*Contact Region 8*	*Contact Region 9*	*Contact Region 10*	*Contact Region 11*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	17 Faces				2 Faces		3 Faces			
Target	1 Face	17 Faces				8 Faces		1 Face			
Contact Bodies	Subballast	Ballast				Rail1					
Target Bodies	Ballast	Sleeper1	Sleeper2	Sleeper3	Sleeper4	Clip1	Clip4	Tirafondo3	Tirafondo4	Codo-Pad3	Codo-Pad4
Protected	No										
Definition											
Type	Bonded										

Scope Mode	Automatic
Behavior	Program Controlled
Trim Contact	Program Controlled
Trim Tolerance	1.6754e-002 m
Suppressed	No
Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 17
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 12*	*Contact Region 13*	*Contact Region 14*	*Contact Region 15*	*Contact Region 16*	*Contact Region 17*	*Contact Region 18*	*Contact Region 19*	*Contact Region 20*	*Contact Region 21*	*Contact Region 22*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces		2 Faces		3 Faces						2 Faces
Target	3 Faces	1 Face	8 Faces		1 Face				3 Faces	1 Face	8 Faces
Contact Bodies	Rail1										
Target Bodies	Pad2	Sleeper1	Clip5	Clip8	Tirafondo7	Tirafondo8	Codo-Pad7	Codo-Pad8	Pad4	Sleeper2	Clip9
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 18
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 23*	*Contact Region 24*	*Contact Region 25*	*Contact Region 26*	*Contact Region 27*	*Contact Region 28*	*Contact Region 29*	*Contact Region 30*	*Contact Region 31*	*Contact Region 32*	*Contact Region 33*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	2 Faces	3 Faces						2 Faces		3 Faces	
Target	8 Faces	1 Face				3 Faces	1 Face	8 Faces		1 Face	
Contact Bodies	Rail1										
Target Bodies	Clip12	Tirafondo11	Tirafondo12	Codo-Pad11	codo-Pad12	Pad6	Sleeper3	Clip13	Clip16	Tirafondo15	Tirafondo16

Protected	No
Definition	
Type	Bonded
Scope Mode	Automatic
Behavior	Program Controlled
Trim Contact	Program Controlled
Trim Tolerance	1.6754e-002 m
Suppressed	No
Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 19
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 34*	*Contact Region 35*	*Contact Region 36*	*Contact Region 37*	*Contact Region 38*	*Contact Region 39*	*Contact Region 40*	*Contact Region 41*	*Contact Region 42*	*Contact Region 43*	*Contact Region 44*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces				2 Faces		3 Faces				
Target	1 Face		3 Faces	1 Face	8 Faces		1 Face				3 Faces
Contact Bodies	Rail1				Rail2						
Target Bodies	Codo-Pad15	Codo-Pad16	Pad8	Sleeper4	Clip2	Clip3	Tirafondo1	Tirafondo2	Codo-Pad1	Codo-Pad2	Pad1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 20
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 45*	*Contact Region 46*	*Contact Region 47*	*Contact Region 48*	*Contact Region 49*	*Contact Region 50*	*Contact Region 51*	*Contact Region 52*	*Contact Region 53*	*Contact Region 54*	*Contact Region 55*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces	2 Faces		3 Faces						2 Faces	
Target	1 Face	8 Faces		1 Face				3 Faces	1 Face	8 Faces	
Contact Bodies	Rail2										

Target Bodies	Sleeper1	Clip6	Clip7	Tirafondo5	Tirafondo6	Codo-Pad5	Codo-Pad6	Pad3	Sleeper2	Clip10	Clip11
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 21
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 56*	*Contact Region 57*	*Contact Region 58*	*Contact Region 59*	*Contact Region 60*	*Contact Region 61*	*Contact Region 62*	*Contact Region 63*	*Contact Region 64*	*Contact Region 65*	*Contact Region 66*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces						2 Faces		3 Faces		
Target	1 Face				3 Faces	1 Face	8 Faces		1 Face		
Contact Bodies	Rail2										
Target Bodies	Tirafondo9	Tirafondo10	Codo-Pad9	Codo-Pad10	Pad5	Sleeper3	Clip14	Clip15	Tirafondo13	Tirafondo14	Codo-Pad13
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 22
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 67*	*Contact Region 68*	*Contact Region 69*	*Contact Region 70*	*Contact Region 71*	*Contact Region 72*	*Contact Region 73*	*Contact Region 74*	*Contact Region 75*	*Contact Region 76*	*Contact Region 77*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces			10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face

Target	1 Face	3 Faces	1 Face	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces
Contact Bodies	Rail2			Vaina1			Vaina2			Vaina3	
Target Bodies	Codo-Pad14	Pad7	Sleeper4	Tirafondo2	Codo-Pad2	Sleeper1	Tirafondo1	Codo-Pad1	Sleeper1	Tirafondo3	Codo-Pad3
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 23
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 78*	*Contact Region 79*	*Contact Region 80*	*Contact Region 81*	*Contact Region 82*	*Contact Region 83*	*Contact Region 84*	*Contact Region 85*	*Contact Region 86*	*Contact Region 87*	*Contact Region 88*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	20 Faces	4 Faces	6 Faces	10 Faces	16 Faces	4 Faces
Target	4 Faces	6 Faces	2 Faces	4 Faces	2 Faces	10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face
Contact Bodies	Vaina3	Vaina4			Clip1				Clip2		
Target Bodies	Sleeper1	Tirafondo4	Codo-Pad4	Sleeper1	Tirafondo4	Codo-Pad4	Pad2	Sleeper1	Tirafondo1	Codo-Pad1	Pad1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 24
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 89*	*Contact Region 90*	*Contact Region 91*	*Contact Region 92*	*Contact Region 93*	*Contact Region 94*	*Contact Region 95*	*Contact Region 96*	*Contact Region 97*	*Contact Region 98*	*Contact Region 99*
State	Fully Defined										
Scope											
Scoping											

Method	Geometry Selection										
Contact	5 Faces	10 Faces	20 Faces	4 Faces	6 Faces	10 Faces	16 Faces	4 Faces	5 Faces	2 Faces	1 Face
Target	2 Faces		10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces	4 Faces	1 Face
Contact Bodies	Clip2	Clip3				Clip4				Tirafondo1	
Target Bodies	Sleeper1	Tirafondo2	Codo-Pad2	Pad1	Sleeper1	Tirafondo3	Codo-Pad3	Pad2	Sleeper1	Codo-Pad1	Pad1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 25
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 100*	*Contact Region 101*	*Contact Region 102*	*Contact Region 103*	*Contact Region 104*	*Contact Region 105*	*Contact Region 106*	*Contact Region 107*	*Contact Region 108*	*Contact Region 109*	*Contact Region 110*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	4 Faces	2 Faces	1 Face	3 Faces	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces	
Target	3 Faces	4 Faces	1 Face	2 Faces	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces	9 Faces
Contact Bodies	Tirafondo1	Tirafondo2			Tirafondo3			Tirafondo4			Codo-Pad1
Target Bodies	Sleeper1	Codo-Pad2	Pad1	Sleeper1	Codo-Pad3	Pad2	Sleeper1	Codo-Pad4	Pad2	Sleeper1	Pad1
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 26
Model (A4) > Connections > Contacts > Contact Regions

	Contact	*Contact*	*Contact*	*Contact*	*Contact*	*Contact*	*Contact*	*Contact*	*Contact*	*Contact*	*Contact*

Object Name	*Region 111*	*Region 112*	*Region 113*	*Region 114*	*Region 115*	*Region 116*	*Region 117*	*Region 118*	*Region 119*	*Region 120*	*Region 121*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	6 Faces	3 Faces	7 Faces	3 Faces	6 Faces	3 Faces	7 Faces			10 Faces	1 Face
Target	7 Faces	9 Faces	8 Faces	9 Faces	7 Faces	9 Faces	8 Faces	3 Faces		6 Faces	2 Faces
Contact Bodies	Codo-Pad1	Codo-Pad2		Codo-Pad3		Codo-Pad4		Pad1	Pad2	Vaina5	
Target Bodies	Sleeper1	Pad1	Sleeper1	Pad2	Sleeper1	Pad2	Sleeper1			Tirafondo6	Codo-Pad6
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 27
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 122*	*Contact Region 123*	*Contact Region 124*	*Contact Region 125*	*Contact Region 126*	*Contact Region 127*	*Contact Region 128*	*Contact Region 129*	*Contact Region 130*	*Contact Region 131*	*Contact Region 132*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces
Target	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	2 Faces
Contact Bodies	Vaina5	Vaina6			Vaina7			Vaina8			Clip5
Target Bodies	Sleeper2	Tirafondo5	Codo-Pad5	Sleeper2	Tirafondo7	Codo-Pad7	Sleeper2	Tirafondo8	Codo-Pad8	Sleeper2	Tirafondo8
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry	None										

Correction	

TABLE 28
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 133*	*Contact Region 134*	*Contact Region 135*	*Contact Region 136*	*Contact Region 137*	*Contact Region 138*	*Contact Region 139*	*Contact Region 140*	*Contact Region 141*	*Contact Region 142*	*Contact Region 143*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	20 Faces	4 Faces	6 Faces	10 Faces	16 Faces	4 Faces	5 Faces	10 Faces	20 Faces	4 Faces	6 Faces
Target	10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces		10 Faces	1 Face	3 Faces
Contact Bodies	Clip5			Clip6				Clip7			
Target Bodies	Codo-Pad8	Pad4	Sleeper2	Tirafondo5	Codo-Pad5	Pad3	Sleeper2	Tirafondo6	Codo-Pad6	Pad3	Sleeper2
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 29
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 144*	*Contact Region 145*	*Contact Region 146*	*Contact Region 147*	*Contact Region 148*	*Contact Region 149*	*Contact Region 150*	*Contact Region 151*	*Contact Region 152*	*Contact Region 153*	*Contact Region 154*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	10 Faces	16 Faces	4 Faces	5 Faces	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces	
Target	2 Faces	9 Faces	1 Face	2 Faces	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces	5 Faces
Contact Bodies	Clip8				Tirafondo5			Tirafondo6			Tirafondo7
Target Bodies	Tirafondo7	Codo-Pad7	Pad4	Sleeper2	Codo-Pad5	Pad3	Sleeper2	Codo-Pad6	Pad3	Sleeper2	Codo-Pad7
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact											

Geometry Correction	None
Target Geometry Correction	None

TABLE 30
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 155*	*Contact Region 156*	*Contact Region 157*	*Contact Region 158*	*Contact Region 159*	*Contact Region 160*	*Contact Region 161*	*Contact Region 162*	*Contact Region 163*	*Contact Region 164*	*Contact Region 165*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	4 Faces	2 Faces	1 Face	3 Faces		6 Faces	3 Faces	7 Faces	3 Faces	6 Faces
Target	1 Face	3 Faces	4 Faces	1 Face	2 Faces	9 Faces	7 Faces	9 Faces	8 Faces	9 Faces	7 Faces
Contact Bodies	Tirafondo7		Tirafondo8			Codo-Pad5		Codo-Pad6		Codo-Pad7	
Target Bodies	Pad4	Sleeper2	Codo-Pad8	Pad4	Sleeper2	Pad3	Sleeper2	Pad3	Sleeper2	Pad4	Sleeper2
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 31
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 166*	*Contact Region 167*	*Contact Region 168*	*Contact Region 169*	*Contact Region 170*	*Contact Region 171*	*Contact Region 172*	*Contact Region 173*	*Contact Region 174*	*Contact Region 175*	*Contact Region 176*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces	7 Faces			10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces
Target	9 Faces	8 Faces	3 Faces		6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces
Contact Bodies	Codo-Pad8		Pad3	Pad4	Vaina9			Vaina10			Vaina11
Target Bodies	Pad4	Sleeper2			Tirafondo10	Codo-Pad10	Sleeper3	Tirafondo9	Codo-Pad9	Sleeper3	Tirafondo11
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update	Program Controlled										

Stiffness	
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 32
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 177*	*Contact Region 178*	*Contact Region 179*	*Contact Region 180*	*Contact Region 181*	*Contact Region 182*	*Contact Region 183*	*Contact Region 184*	*Contact Region 185*	*Contact Region 186*	*Contact Region 187*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	20 Faces	4 Faces	6 Faces	10 Faces	16 Faces
Target	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	2 Faces	10 Faces	1 Face	3 Faces	2 Faces	9 Faces
Contact Bodies	Vaina11		Vaina12			Clip9				Clip10	
Target Bodies	Codo-Pad11	Sleeper3	Tirafondo12	codo-Pad12	Sleeper3	Tirafondo12	codo-Pad12	Pad6	Sleeper3	Tirafondo9	Codo-Pad9
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 33
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 188*	*Contact Region 189*	*Contact Region 190*	*Contact Region 191*	*Contact Region 192*	*Contact Region 193*	*Contact Region 194*	*Contact Region 195*	*Contact Region 196*	*Contact Region 197*	*Contact Region 198*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	4 Faces	5 Faces	10 Faces	20 Faces	4 Faces	6 Faces	10 Faces	16 Faces	4 Faces	5 Faces	2 Faces
Target	1 Face	2 Faces		10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces	4 Faces
Contact Bodies	Clip10		Clip11				Clip12				Tirafondo9
Target Bodies	Pad5	Sleeper3	Tirafondo10	Codo-Pad10	Pad5	Sleeper3	Tirafondo11	Codo-Pad11	Pad6	Sleeper3	Codo-Pad9
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration	Program Controlled										

Tolerance	
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 34
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 199*	*Contact Region 200*	*Contact Region 201*	*Contact Region 202*	*Contact Region 203*	*Contact Region 204*	*Contact Region 205*	*Contact Region 206*	*Contact Region 207*	*Contact Region 208*	*Contact Region 209*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	4 Faces	2 Faces	1 Face	3 Faces		1 Face	4 Faces	2 Faces	1 Face	3 Faces
Target	1 Face	3 Faces	4 Faces	1 Face	2 Faces	5 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces
Contact Bodies	Tirafondo9		Tirafondo10			Tirafondo11			Tirafondo12		
Target Bodies	Pad5	Sleeper3	Codo-Pad10	Pad5	Sleeper3	Codo-Pad11	Pad6	Sleeper3	codo-Pad12	Pad6	Sleeper3
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 35
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 210*	*Contact Region 211*	*Contact Region 212*	*Contact Region 213*	*Contact Region 214*	*Contact Region 215*	*Contact Region 216*	*Contact Region 217*	*Contact Region 218*	*Contact Region 219*	*Contact Region 220*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	3 Faces	6 Faces	3 Faces	7 Faces	3 Faces	6 Faces	3 Faces	7 Faces			10 Faces
Target	9 Faces	7 Faces	9 Faces	8 Faces	9 Faces	7 Faces	9 Faces	8 Faces	3 Faces		6 Faces
Contact Bodies	Codo-Pad9		Codo-Pad10		Codo-Pad11		codo-Pad12		Pad5	Pad6	Vaina13
Target Bodies	Pad5	Sleeper3	Pad5	Sleeper3	Pad6	Sleeper3	Pad6	Sleeper3			Tirafondo14
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										

Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 36
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 221*	*Contact Region 222*	*Contact Region 223*	*Contact Region 224*	*Contact Region 225*	*Contact Region 226*	*Contact Region 227*	*Contact Region 228*	*Contact Region 229*	*Contact Region 230*	*Contact Region 231*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces	10 Faces	1 Face	12 Faces
Target	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces	6 Faces	2 Faces	4 Faces
Contact Bodies	Vaina13		Vaina14			Vaina15			Vaina16		
Target Bodies	Codo-Pad14	Sleeper4	Tirafondo13	Codo-Pad13	Sleeper4	Tirafondo15	Codo-Pad15	Sleeper4	Tirafondo16	Codo-Pad16	Sleeper4
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 37
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 232*	*Contact Region 233*	*Contact Region 234*	*Contact Region 235*	*Contact Region 236*	*Contact Region 237*	*Contact Region 238*	*Contact Region 239*	*Contact Region 240*	*Contact Region 241*	*Contact Region 242*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	10 Faces	20 Faces	4 Faces	6 Faces	10 Faces	16 Faces	4 Faces	5 Faces	10 Faces	20 Faces	4 Faces
Target	2 Faces	10 Faces	1 Face	3 Faces	2 Faces	9 Faces	1 Face	2 Faces		10 Faces	1 Face
Contact Bodies	Clip13				Clip14				Clip15		
Target Bodies	Tirafondo16	Codo-Pad16	Pad8	Sleeper4	Tirafondo13	Codo-Pad13	Pad7	Sleeper4	Tirafondo14	Codo-Pad14	Pad7
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										

Trim Contact	Program Controlled
Trim Tolerance	1.6754e-002 m
Suppressed	No
Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 38
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 243*	*Contact Region 244*	*Contact Region 245*	*Contact Region 246*	*Contact Region 247*	*Contact Region 248*	*Contact Region 249*	*Contact Region 250*	*Contact Region 251*	*Contact Region 252*	*Contact Region 253*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	6 Faces	10 Faces	16 Faces	4 Faces	5 Faces	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces
Target	3 Faces	2 Faces	9 Faces	1 Face	2 Faces	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces
Contact Bodies	Clip15	Clip16				Tirafondo13			Tirafondo14		
Target Bodies	Sleeper4	Tirafondo15	Codo-Pad15	Pad8	Sleeper4	Codo-Pad13	Pad7	Sleeper4	Codo-Pad14	Pad7	Sleeper4
Protected	No										
Definition											
Type	Bonded										
Scope Mode	Automatic										
Behavior	Program Controlled										
Trim Contact	Program Controlled										
Trim Tolerance	1.6754e-002 m										
Suppressed	No										
Advanced											
Formulation	Program Controlled										
Small Sliding	Program Controlled										
Detection Method	Program Controlled										
Penetration Tolerance	Program Controlled										
Elastic Slip Tolerance	Program Controlled										
Normal Stiffness	Program Controlled										
Update Stiffness	Program Controlled										
Pinball Region	Program Controlled										
Geometric Modification											
Contact Geometry Correction	None										
Target Geometry Correction	None										

TABLE 39
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 254*	*Contact Region 255*	*Contact Region 256*	*Contact Region 257*	*Contact Region 258*	*Contact Region 259*	*Contact Region 260*	*Contact Region 261*	*Contact Region 262*	*Contact Region 263*	*Contact Region 264*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Contact	2 Faces	1 Face	4 Faces	2 Faces	1 Face	3 Faces		6 Faces	3 Faces	7 Faces	3 Faces
Target	4 Faces	1 Face	3 Faces	4 Faces	1 Face	2 Faces	9 Faces	7 Faces	9 Faces	8 Faces	9 Faces
Contact Bodies	Tirafondo15			Tirafondo16			Codo-Pad13		Codo-Pad14		Codo-Pad15
Target Bodies	Codo-Pad15	Pad8	Sleeper4	Codo-Pad16	Pad8	Sleeper4	Pad7	Sleeper4	Pad7	Sleeper4	Pad8

Protected	No
Definition	
Type	Bonded
Scope Mode	Automatic
Behavior	Program Controlled
Trim Contact	Program Controlled
Trim Tolerance	1.6754e-002 m
Suppressed	No
Advanced	
Formulation	Program Controlled
Small Sliding	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	
Contact Geometry Correction	None
Target Geometry Correction	None

TABLE 40
Model (A4) > Connections > Contacts > Contact Regions

Object Name	*Contact Region 265*	*Contact Region 266*	*Contact Region 267*	*Contact Region 268*	*Contact Region 269*
State	Fully Defined				
Scope					
Scoping Method	Geometry Selection				
Contact	6 Faces	3 Faces	7 Faces		
Target	7 Faces	9 Faces	8 Faces	3 Faces	
Contact Bodies	Codo-Pad15	Codo-Pad16		Pad7	Pad8
Target Bodies	Sleeper4	Pad8	Sleeper4		
Protected	No				
Definition					
Type	Bonded				
Scope Mode	Automatic				
Behavior	Program Controlled				
Trim Contact	Program Controlled				
Trim Tolerance	1.6754e-002 m				
Suppressed	No				
Advanced					
Formulation	Program Controlled				
Small Sliding	Program Controlled				
Detection Method	Program Controlled				
Penetration Tolerance	Program Controlled				
Elastic Slip Tolerance	Program Controlled				
Normal Stiffness	Program Controlled				
Update Stiffness	Program Controlled				
Pinball Region	Program Controlled				
Geometric Modification					
Contact Geometry Correction	None				
Target Geometry Correction	None				

Mesh

TABLE 41
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	Default
Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	6.7016 m

Average Surface Area	3.0057e-002 m²
Minimum Edge Length	1.8821e-004 m
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Aggressive Mechanical
Target Quality	Default (0.050000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No
Statistics	
Nodes	725851
Elements	377029

TABLE 42
Model (A4) > Mesh > Mesh Controls

Object Name	*Subballast 0.1 m*	*Ballast 0.1 m*	*Sleepers 0.05 m*	*Pads 0.01 m*	*Codo-Pads 0.01 m*	*Rails 0.1 m*	*Clips 0.01 m*	*Tirafondos 0.01 m*
State	Fully Defined							
Scope								
Scoping Method	Geometry Selection							
Geometry	1 Body		4 Bodies	8 Bodies	16 Bodies	2 Bodies	16 Bodies	
Definition								
Suppressed	No							
Type	Element Size							
Element Size	0.1 m		5.e-002 m	1.e-002 m		0.1 m	1.e-002 m	
Advanced								
Defeature Size	Default							
Behavior	Soft							

Named Selections

TABLE 43
Model (A4) > Named Selections > Named Selections

Object Name	*Subballast*	*Ballast*	*Rails*	*Sleepers*	*Pads*	*Codo-Pads*	*Clips*	*Tirafondos*	*Vainas*	*Application point 1*	*Application Point 2*
State	Fully Defined										
Scope											
Scoping Method	Geometry Selection										
Geometry	1 Body		2 Bodies	4 Bodies	8 Bodies	16 Bodies				1 Node	
Definition											
Send to Solver	Yes										
Protected	Program Controlled										
Visible	Yes										
Program Controlled Inflation	Exclude										
Statistics											
Type	Manual										
Total Selection	1 Body		2 Bodies	4 Bodies	8 Bodies	16 Bodies				1 Node	
Suppressed	0										
Used by Mesh Worksheet	No										

Static Structural (A5)

TABLE 44
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 45
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart Points	Program Controlled
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Off
Output Controls	
Stress	Yes
Surface Stress	No
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	C:\Users\Mon PC\Desktop\TFM\ANSYS MODELS\600 mm\600 mm-Solved_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	mks

TABLE 46
Model (A4) > Static Structural (A5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	0. m/s² (ramped)
Y Component	0. m/s² (ramped)
Z Component	-9.8066 m/s² (ramped)
Suppressed	No
Direction	-Z Direction

FIGURE 1
Model (A4) > Static Structural (A5) > Standard Earth Gravity

TABLE 47
Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Nodal Force 1*	*Nodal Force 2*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection	Named Selection	
Geometry	1 Face		
Named Selection		Application point 1	Application Point 2
Definition			
Type	Fixed Support	Force	
Suppressed	No		
Coordinate System		Nodal Coordinate System	
X Component		0. N (ramped)	
Y Component		0. N (ramped)	
Z Component		-1.1e+005 N (ramped)	
Divide Load by Nodes		Yes	

FIGURE 2
Model (A4) > Static Structural (A5) > Nodal Force 1

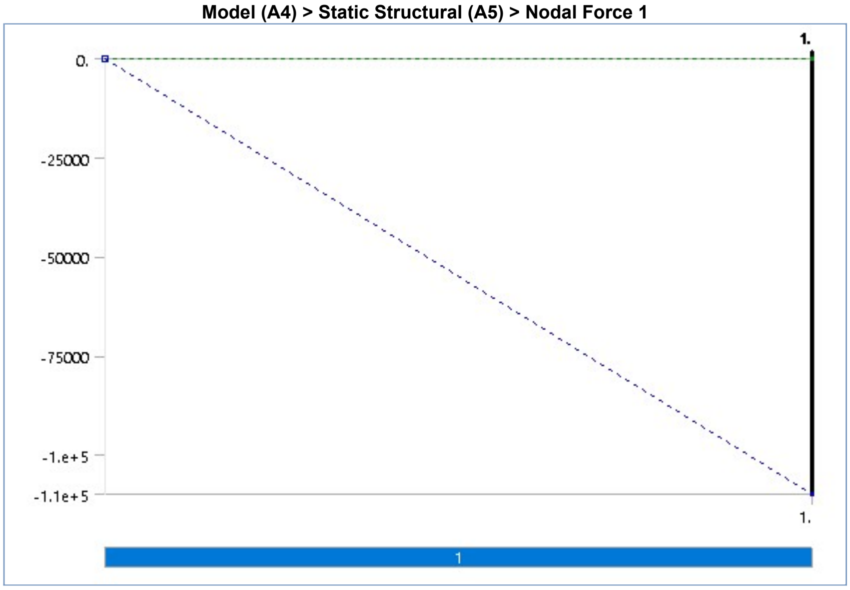

FIGURE 3
Model (A4) > Static Structural (A5) > Nodal Force 2

Solution (A6)

TABLE 48
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	5 m 18 s
MAPDL Memory Used	9.9277 GB
MAPDL Result File Size	332.81 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 49
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 50
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*Equivalent Stress*	*Maximum Deformation Rails*	*Equivalent Stress Rails*	*Maximum Deformation Sleepers*	*Equivalent Stress Sleepers*	*Maximum Deformation Pads*	*Equivalent Stress Pads*	*Maximum Deformation Ballast*	*Equivalent Stress Ballast*
State	Solved									
Scope										
Scoping Method	Geometry Selection									
Geometry	All Bodies		2 Bodies		4 Bodies		8 Bodies		1 Body	
Definition										
Type	Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	Equivalent (von-Mises) Stress	Total Deformation	Equivalent (von-Mises) Stress
By	Time									
Display Time	Last									
Calculate Time History	Yes									

Identifier										
Suppressed	No									
Results										
Minimum	0. m	95.637 Pa	2.2649e-006 m	4271.6 Pa	2.452e-005 m	4140.2 Pa	1.3341e-005 m	1711.3 Pa	1.8493e-006 m	181.79 Pa
Maximum	4.6528e-004 m	1.3862e+008 Pa	4.6528e-004 m	1.3862e+008 Pa	2.2443e-004 m	2.0876e+007 Pa	2.8192e-004 m	2.8138e+006 Pa	2.2179e-004 m	1.1064e+005 Pa
Average	1.0544e-004 m	1.1956e+006 Pa	1.271e-004 m	6.2811e+006 Pa	1.0892e-004 m	6.6663e+005 Pa	1.2669e-004 m	2.0202e+005 Pa	4.3881e-005 m	17906 Pa
Minimum Occurs On	Subballast	Vaina16	Rail2		Sleeper1		Pad2	Pad7	Ballast	
Maximum Occurs On	Rail1	Rail2	Rail1	Rail2	Sleeper3	Sleeper2	Pad6	Pad4	Ballast	
Information										
Time	1. s									
Load Step	1									
Substep	1									
Iteration Number	1									
Integration Point Results										
Display Option		Averaged		Averaged		Averaged		Averaged		Averaged
Average Across Bodies		No		No		No		No		No

FIGURE 4
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

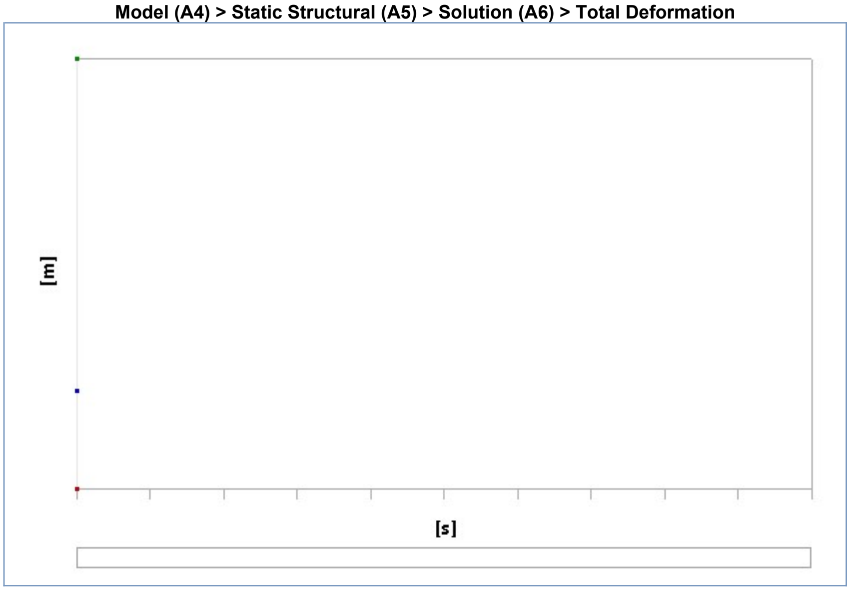

TABLE 51
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	0.	4.6528e-004	1.0544e-004

FIGURE 5
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

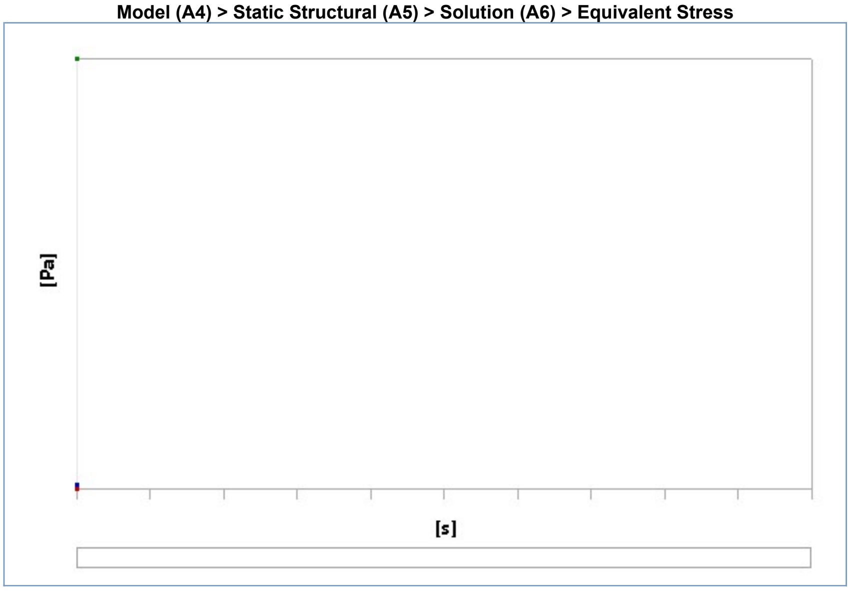

TABLE 52
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	95.637	1.3862e+008	1.1956e+006

FIGURE 6
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Deformation Rails

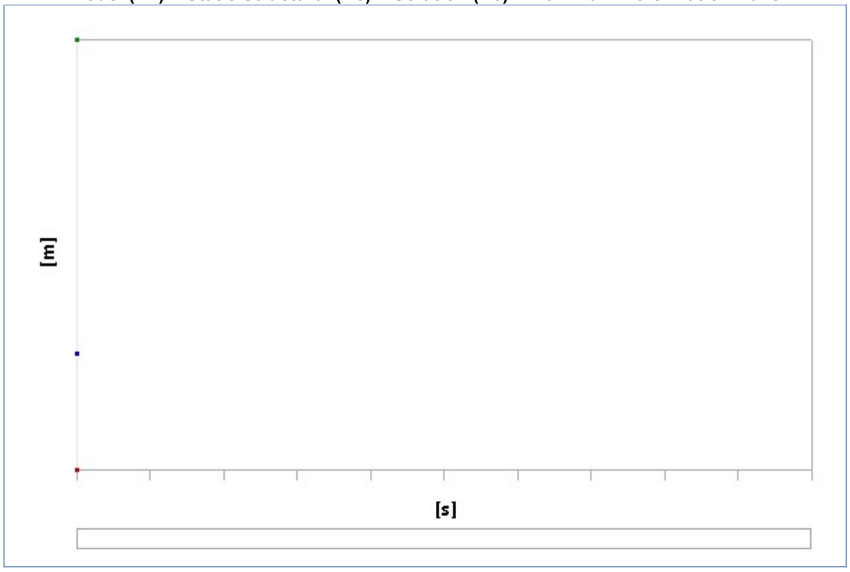

TABLE 53
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Deformation Rails

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	2.2649e-006	4.6528e-004	1.271e-004

FIGURE 7
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress Rails

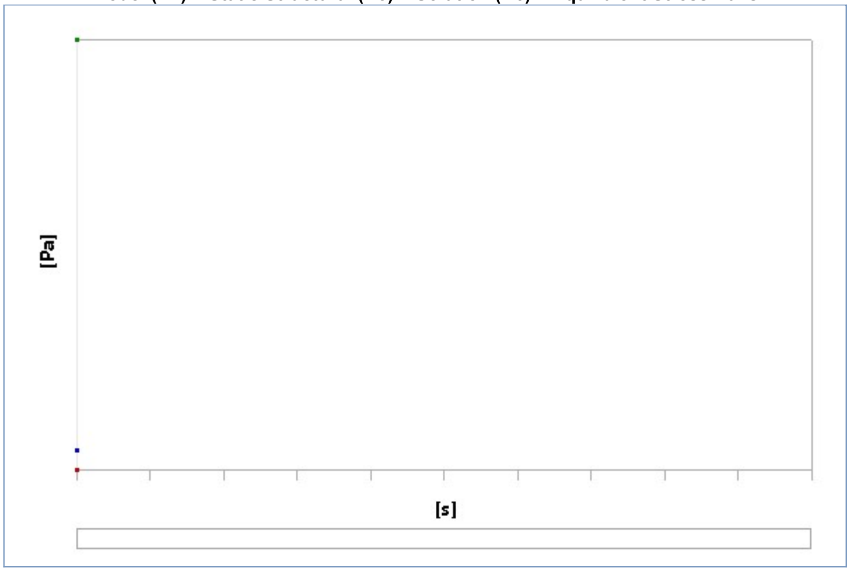

TABLE 54
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress Rails

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	4271.6	1.3862e+008	6.2811e+006

FIGURE 8
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Deformation Sleepers

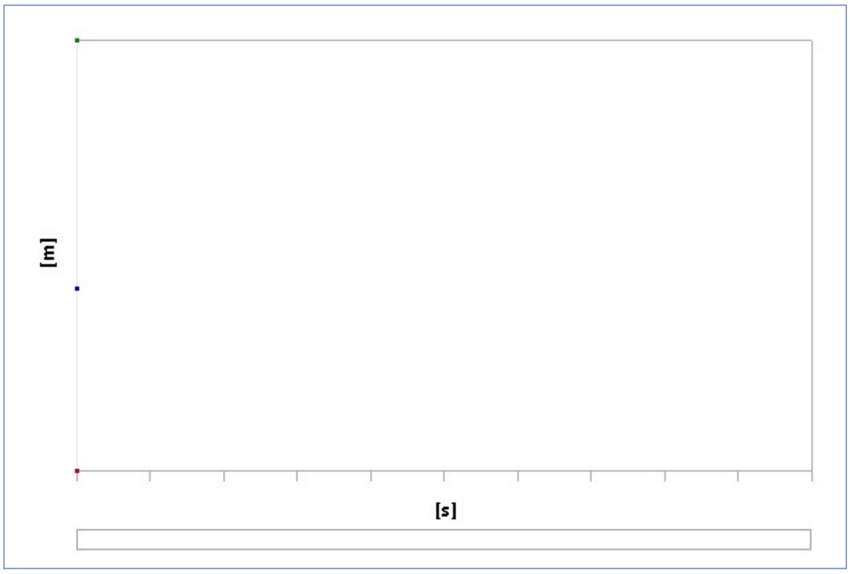

TABLE 55
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Deformation Sleepers

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	2.452e-005	2.2443e-004	1.0892e-004

FIGURE 9
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress Sleepers

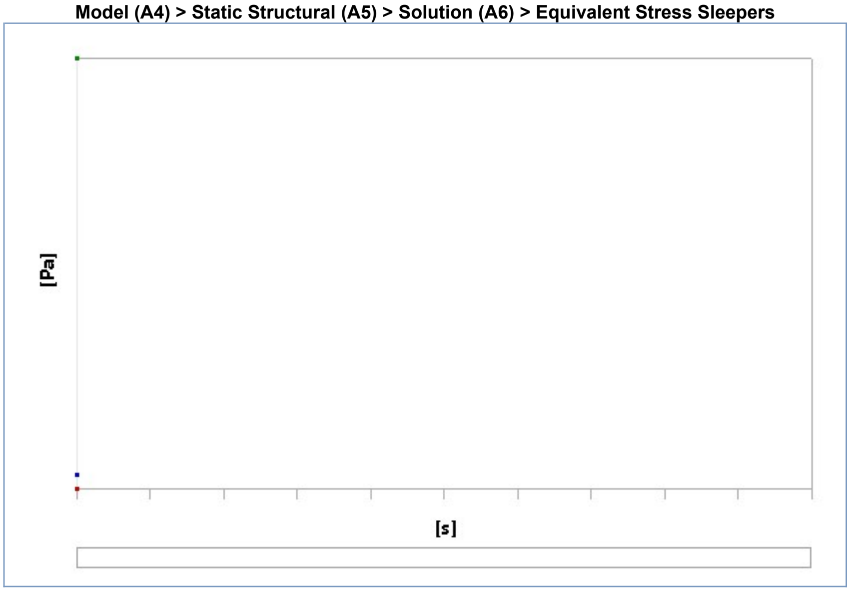

TABLE 56
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress Sleepers

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	4140.2	2.0876e+007	6.6663e+005

FIGURE 10
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Deformation Pads

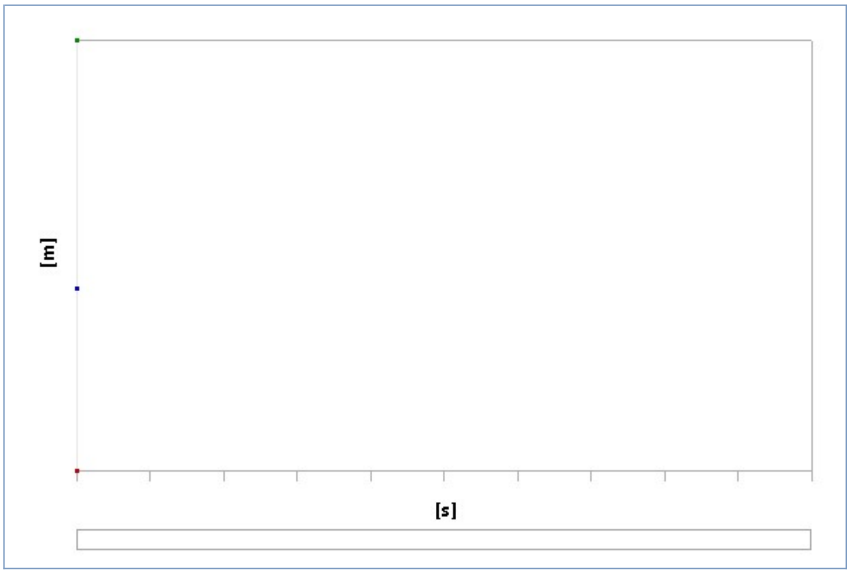

TABLE 57
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Deformation Pads

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	1.3341e-005	2.8192e-004	1.2669e-004

FIGURE 11
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress Pads

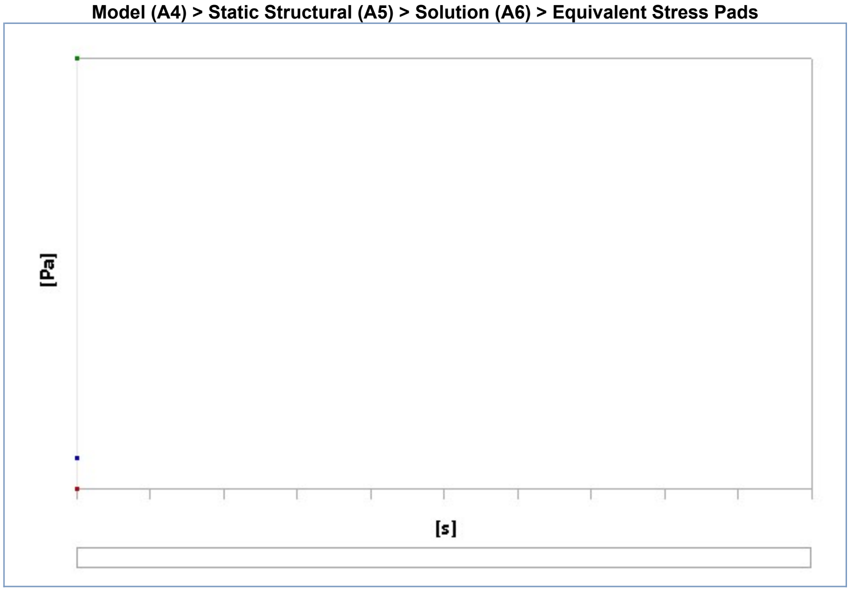

TABLE 58
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress Pads

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	1711.3	2.8138e+006	2.0202e+005

FIGURE 12
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Deformation Ballast

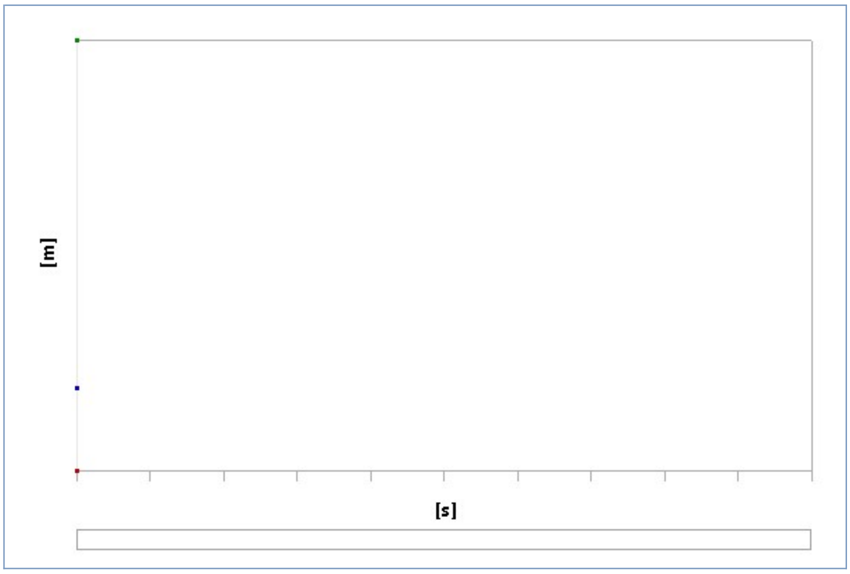

TABLE 59
Model (A4) > Static Structural (A5) > Solution (A6) > Maximum Deformation Ballast

Time [s]	Minimum [m]	Maximum [m]	Average [m]
1.	1.8493e-006	2.2179e-004	4.3881e-005

FIGURE 13
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress Ballast

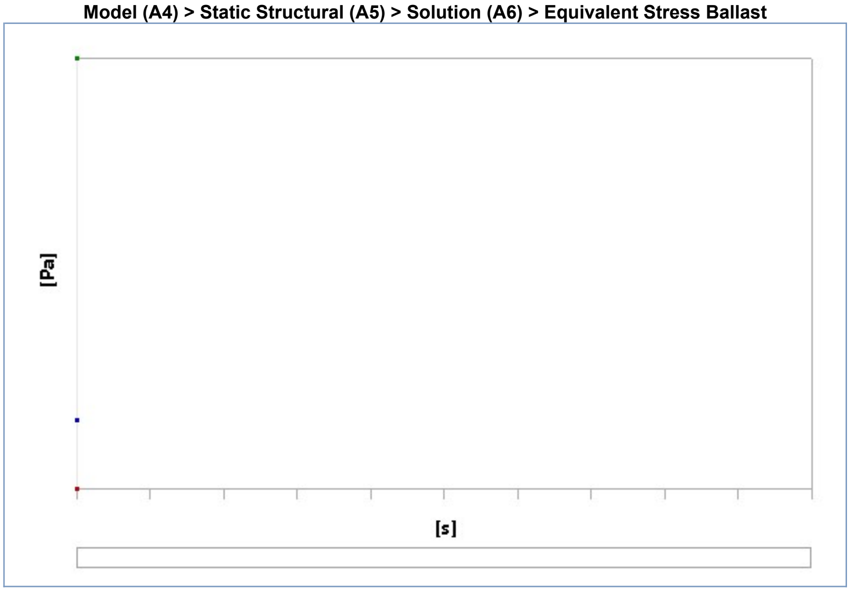

TABLE 60
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress Ballast

Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1.	181.79	1.1064e+005	17906

Material Data

Sub-Ballast

TABLE 61
Sub-Ballast > Constants

Density	1600 kg m^-3

TABLE 62
Sub-Ballast > Color

Red	Green	Blue
132	176	224

TABLE 63
Sub-Ballast > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
5.e+008	0.25	3.3333e+008	2.e+008	

Ballast

TABLE 64
Ballast > Constants

Density	1800 kg m^-3

TABLE 65
Ballast > Color

Red	Green	Blue
159	206	130

TABLE 66
Ballast > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
1.7e+008	0.3	1.4167e+008	6.5385e+007	

Rails and Tirafondos

TABLE 67
Rails and Tirafondos > Constants

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

TABLE 68
Rails and Tirafondos > Color

Red	Green	Blue
132	139	179

TABLE 69
Rails and Tirafondos > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
0

TABLE 70
Rails and Tirafondos > Compressive Yield Strength

Compressive Yield Strength Pa
2.5e+008

TABLE 71
Rails and Tirafondos > Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+008

TABLE 72
Rails and Tirafondos > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
4.6e+008

TABLE 73
Rails and Tirafondos > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 74
Rails and Tirafondos > S-N Curve

Alternating Stress Pa	Cycles	Mean Stress Pa
3.999e+009	10	0
2.827e+009	20	0
1.896e+009	50	0
1.413e+009	100	0
1.069e+009	200	0
4.41e+008	2000	0
2.62e+008	10000	0
2.14e+008	20000	0
1.38e+008	1.e+005	0
1.14e+008	2.e+005	0
8.62e+007	1.e+006	0

TABLE 75
Rails and Tirafondos > Strain-Life Parameters

Strength Coefficient Pa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient Pa	Cyclic Strain Hardening Exponent
9.2e+008	-0.106	0.213	-0.47	1.e+009	0.2

TABLE 76
Rails and Tirafondos > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
2.e+011	0.3	1.6667e+011	7.6923e+010	

TABLE 77
Rails and Tirafondos > Isotropic Relative Permeability

Relative Permeability

10000

Vainas

TABLE 78
Vainas > Constants

Density	950 kg m^-3
Coefficient of Thermal Expansion	2.3e-004 C^-1
Specific Heat	2300 J kg^-1 C^-1
Thermal Conductivity	0.28 W m^-1 C^-1

TABLE 79
Vainas > Color

Red	Green	Blue
130	154	176

TABLE 80
Vainas > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
0

TABLE 81
Vainas > Compressive Yield Strength

Compressive Yield Strength Pa
0

TABLE 82
Vainas > Tensile Yield Strength

Tensile Yield Strength Pa
2.5e+007

TABLE 83
Vainas > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
3.3e+007

TABLE 84
Vainas > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 85
Vainas > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
1.1e+009	0.42	2.2917e+009	3.8732e+008	

Clip

TABLE 86
Clip > Constants

Density	7800 kg m^-3

TABLE 87
Clip > Color

Red	Green	Blue
219	198	144

TABLE 88
Clip > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
1.8e+011	0.3	1.5e+011	6.9231e+010	

Codo-Pads

TABLE 89
Codo-Pads > Constants

Density	1360 kg m^-3

TABLE 90
Codo-Pads > Color

Red	Green	Blue
101	239	242

TABLE 91
Codo-Pads > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
5.2e+009	0.34	5.4167e+009	1.9403e+009	

Pads

TABLE 92
Pads > Constants

Density	850 kg m^-3

TABLE 93
Pads > Color

Red	Green	Blue
255	204	250

TABLE 94
Pads > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
1.e+008	0.49	1.6667e+009	3.3557e+007	

Sleepers

TABLE 95
Sleepers > Constants

Density	2300 kg m^-3
Coefficient of Thermal Expansion	1.4e-005 C^-1
Specific Heat	780 J kg^-1 C^-1
Thermal Conductivity	0.72 W m^-1 C^-1

TABLE 96
Sleepers > Color

Red	Green	Blue
180	173	167

TABLE 97
Sleepers > Compressive Ultimate Strength

Compressive Ultimate Strength Pa
4.1e+007

TABLE 98
Sleepers > Compressive Yield Strength

Compressive Yield Strength Pa
0

TABLE 99
Sleepers > Tensile Yield Strength

Tensile Yield Strength Pa
0

TABLE 100
Sleepers > Tensile Ultimate Strength

Tensile Ultimate Strength Pa
5.e+006

TABLE 101
Sleepers > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 102
Sleepers > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa	Temperature C
3.e+010	0.18	1.5625e+010	1.2712e+010	