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Sleepers spacing. Introduction to Odstrack project.

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Abstract

The sleepers and fastenings are the most numerous elements of the superstructure of the track. The cost per km is directly proportional to the number of them along the track, so one of the simplest ways to reduce construction costs is to reduce some of these elements. The objective of the ODSTRACK project is to establish an optimal separation of sleepers to optimize the initial construction costs.

The project has several steps. First it is necessary a revision of the state of the art to go beyond. After that a theoretical modelling (trough finite element software) of the separation of sleepers in the rail track is proposed, which can help us to study this separation and the consequences in the operation of the track superstructure. Preliminary dynamic analyses have been carried out with finite element software. These initial approaches have shown that the distance between sleepers can be increased and, therefore, it is possible to reduce the construction costs of the railway superstructure. This also involves a reduction of environmental cost (by carbon footprint reduction).

In order to achieve this preliminary numerical study, it is necessary to carry out laboratory tests (static, dynamic, and fatigue tests). These tests will help to correlate the previous models. Thank to this, several study cases will be analysed in order to shed light about track performance under different sleepers spacing (more than the current 0.6 m). Economic and environmental costs will be calculated for the optimal distance.

Keywords: railway track, track design, sleeper spacing, numerical analysis.

1 Introduction

Railway's administrations use a fixed separation of sleepers on the track. The sleepers and the fastenings are the most numerous elements of the superstructure of the track, and their cost represent a very significant part of the total construction cost of a new railway line. The cost per km is therefore strongly determined by the sleeper's spacing. So, one of the simplest ways to reduce construction costs is to increase the sleeper's spacing. In line with this reasoning, the objective of ODSTRACK project is to establish an optimal sleeper spacing to optimize the initial construction costs. There is a lack of studies concerning this aspect. This study will also focus on the effects of changing this value and what effects can be observed on the track.

ODSTRACK project follows several steps. Initially, an exhaustive state of the art revision will be carried out then a theoretical modelling of the separation of sleepers in the rail track is proposed, which can help us to study this separation and the consequences in the operation of the track superstructure. To carry out this study, on the one hand, the analysis of a long and straight finite track section will be performed first, with finite element software. The realization of dynamic and static theoretical analysis is proposed. The numerical analyses will be carried out with 2D and 3D finite elements software. All this numerical study will be supported by laboratory tests (static, dynamic, and fatigue tests). This practical analysis will help in the correlation of the previous numerical models and help researchers to have a more realistic approach to the problem of increasing this distance.

In the concerned field, there is a lack of studies on the optimal separation of sleepers. The railway infrastructure managers use a fixed separation of sleepers with limited scientific support for this choice. Therefore, it is necessary and worth conducting the study, to investigate if the historical distance between the elements of the track superstructure, such as sleepers, can be modified.

Preliminary dynamic analyses have been carried out with finite element software. Initial results have shown that the distance between sleepers can be increased and, therefore, it is possible to reduce the construction costs of the railway superstructure.

The objective of this research is to increase and find an optimal separation of sleepers to optimize not only the initial manufacturing, construction, and environmental cost.

Next step will be to carry out the solution to a real track in order to see the track response under real conditions.

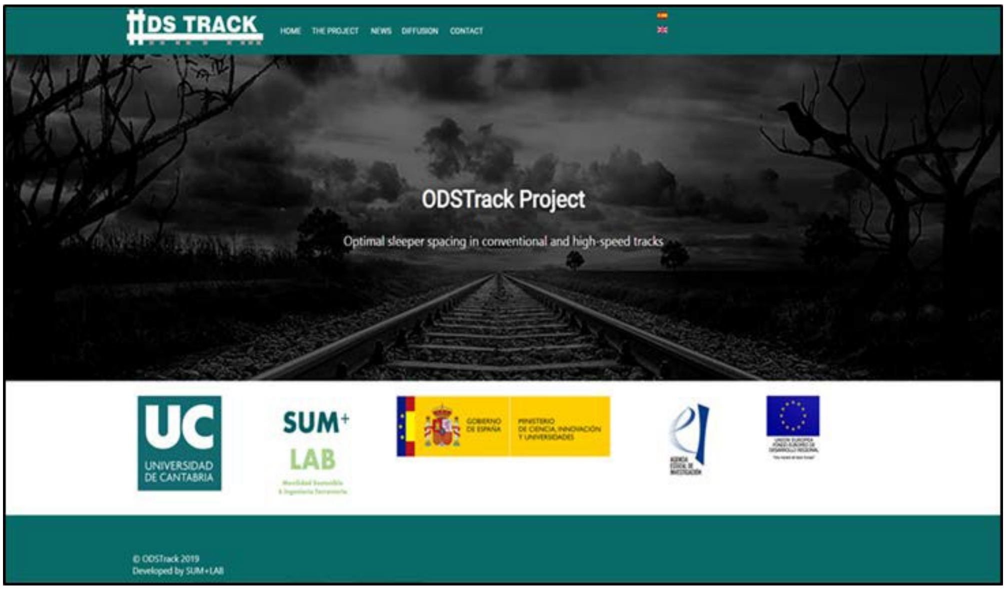

Figure 1: The ODSTRACK Project Web Page [1].

2 Methodology

The project pursues to study and analyse the behaviour of all the elements of the railway superstructure, with non-conventional spacing between rail supports of ballasted tracks. The methodology is defined to study how this affects the rail track performance. In addition, wants to prove if it is feasible and applicable to existent and new tracks. The methodology proposed for this theoretical-practical study is described here. After studying in the bibliography for existing cases or similar experiences and grouping their conclusions, next step is to design by finite elements of a section of track in two and three dimensions.

A tensional (stresses) and deformational (Vertical displacements) study will be carried out on all the elements forming the railway superstructure. It will be performed based on the distance between supports (sleepers). Thank to this, it will be possible to see the influence of the distance between sleepers on the different elements of the railway superstructure. Both dynamic and static study of the phenomenon will be carried out. Although the starting point will be a base case and a pilot test (in the lab) with all the configuration of the track, then several case studies will be analysed. (i.e. the increase of the bearing surface of the sleeper (sleeper size), the use of heavy rails, different materials on the sleepers, different fastening configuration, etc.).

The project proposes a new simple methodology as it can be seen in figure 2.

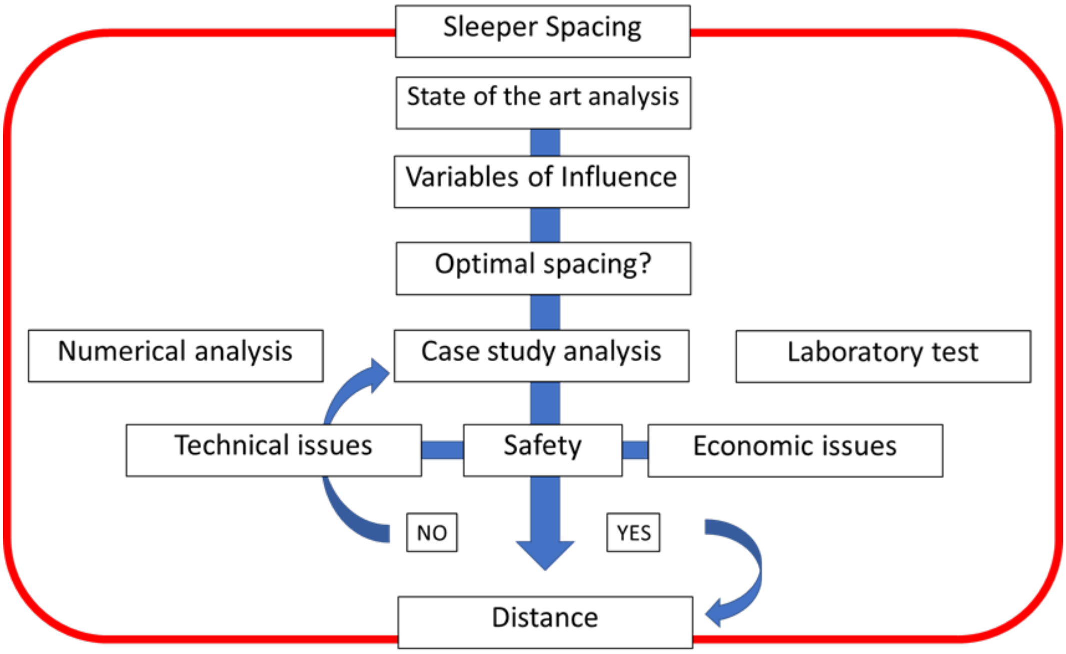

Figure 2: Proposed methodology for the development of the project

Under the technical and economic feasibility, the main basic pillars on which the proposed project is based are below:

1) Analysis of the state of the art and analysis and compilation of previous documentation.
2) Design and numerical modelling of the track. Behaviour model Analysis of case studies. Optimal solutions (figure 3).
3) Proposition of several case studies to optimise sleepers' distance.
4) Laboratory tests of the theoretical model and case studies. Evolution of the track resistance (figure 4).
5) Correlation between computational models and laboratory test results.
6) Analysis elements of track and maintenance. Technical feasibility.

It is necessary to study the behaviour and the whole track performance during construction and operation. Economic feasibility and environmental savings will be also analysed. Project now is under phase 4 and 5.

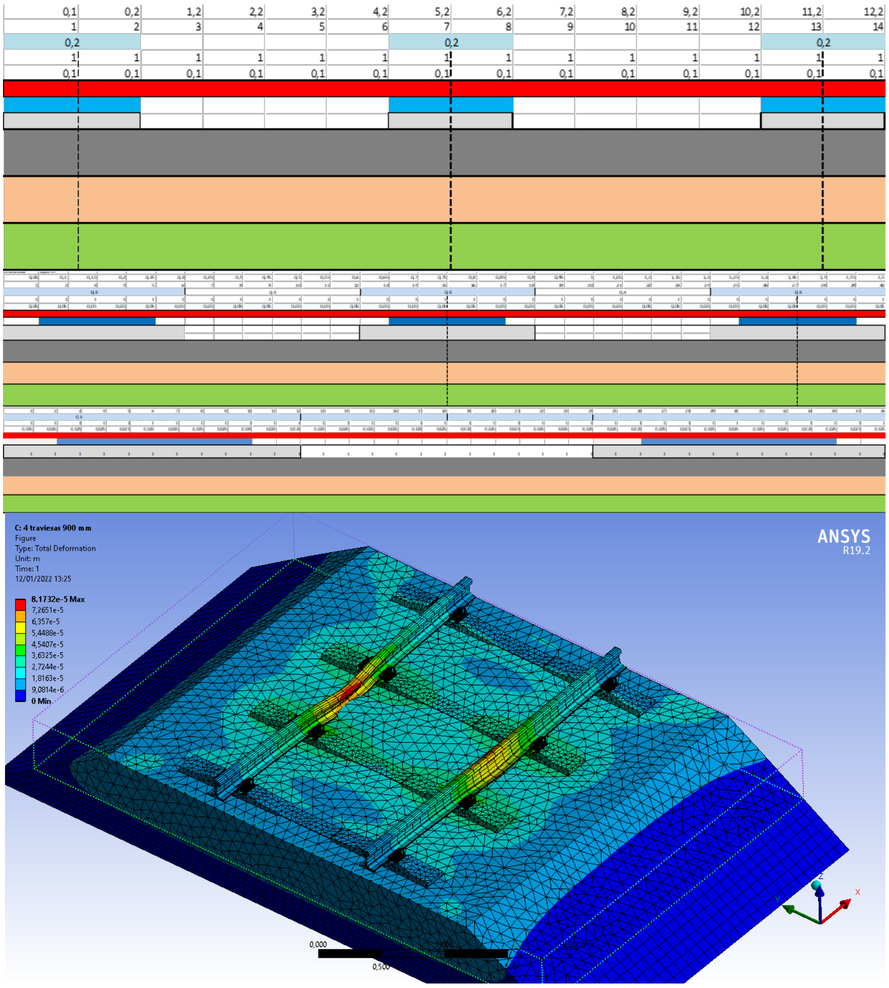

Figure 3: Numerical track models. Scheme of 2D track model. Simplified model (up) and 3D track model for different sleepers spacing (down).

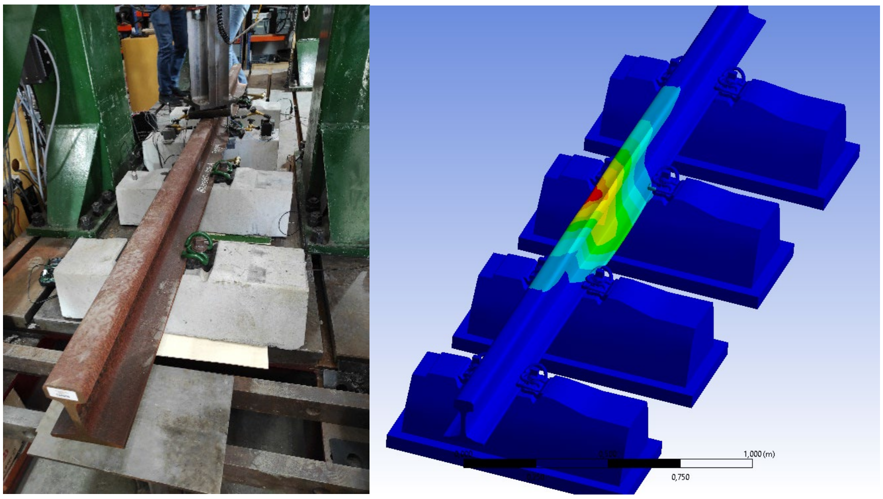

Figure 4: Laboratory test (left). 3D track model to calibrate (right).

3 Initial Results

Literature review has shown a scientific shortage in relation to sleeper spacing. Most of references give values to sleeper spacing in relation to track load, sleeper material, and the distance from the joint rail depending on the track gauge [2,3]. Some values are adopted depending if rail is LWR or SWR [2].
EEUU use spacings between 0,5 m and 0,6 m [4]. Guidelines in Europe use small values 0,57 m in the surroundings of structures such as track transitions, bridges, [5-7] also depending on the type of soils [8]. ORE report D-117 [9] showed that lateral track resistance has a lineal decreased when sleepers spacing increase.

Up until ORE track experiments, literature review showed a lack of scientific support to justify sleepers spacing. After that nothing more has been done to study this sleeper spacing and try to increase it. From this literature review a complete analysis must contain track behaviour with sleeper spacing, vertical stress on sleepers, pads, ballast, the influence in rails (specially welded rails), its influence in lateral and longitudinal track resistance. The influence with maintenance operations, tamping grinding, etc. The influence with train speed, track vibration and material wear.

Literature review from project results [10] showed that it is possible to increase initial distance from 0.6 m. It is necessary to find a gap between structural safety and economic feasibility.

Some preliminary studies have been used [11-13] and one international conference [14]. These initial results (2D analysis) showed that the maximum values followed a linear trend for all the variables considered in the study. The initial data analysed has shown that when the distance between axis of sleepers is high enough, the stresses increase linearly when the distance increases. One of the most restrictive variables which was found in 2D analysis was vertical displacements in rails and stresses under sleepers (over ballast). Some authors recommend that the maximum values be less than 500 KN/m^2 or even 300 KN/m^2 [15,16]. An increase in spacing has negative consequences in those variables.

After these preliminary results a 3D static analysis have been performed with punctual load between and over sleepers. These 3D models will be calibrated with laboratory tests. This 3D analysis will serve to see the performance of all track elements, rails, fastenings, sleepers, ballast and under ballast layers to have a general idea of the track behaviour. Next step, once the model is calibrated will be to run several case studies and obtain a real approximation to the track performance under different sleeper spacing. Last year (2021) several authors have studied lateral track stability under different sleeper spacing by using laboratory test [17] and develop a methodology to calculate transversal track stability and others in [18] develop numerical models concluding that the influence of sleeper spacing on the behaviour of railway tracks is only tangible on the distribution of the vertical wheel load. A theoretical analysis of track stability can be found in [10].

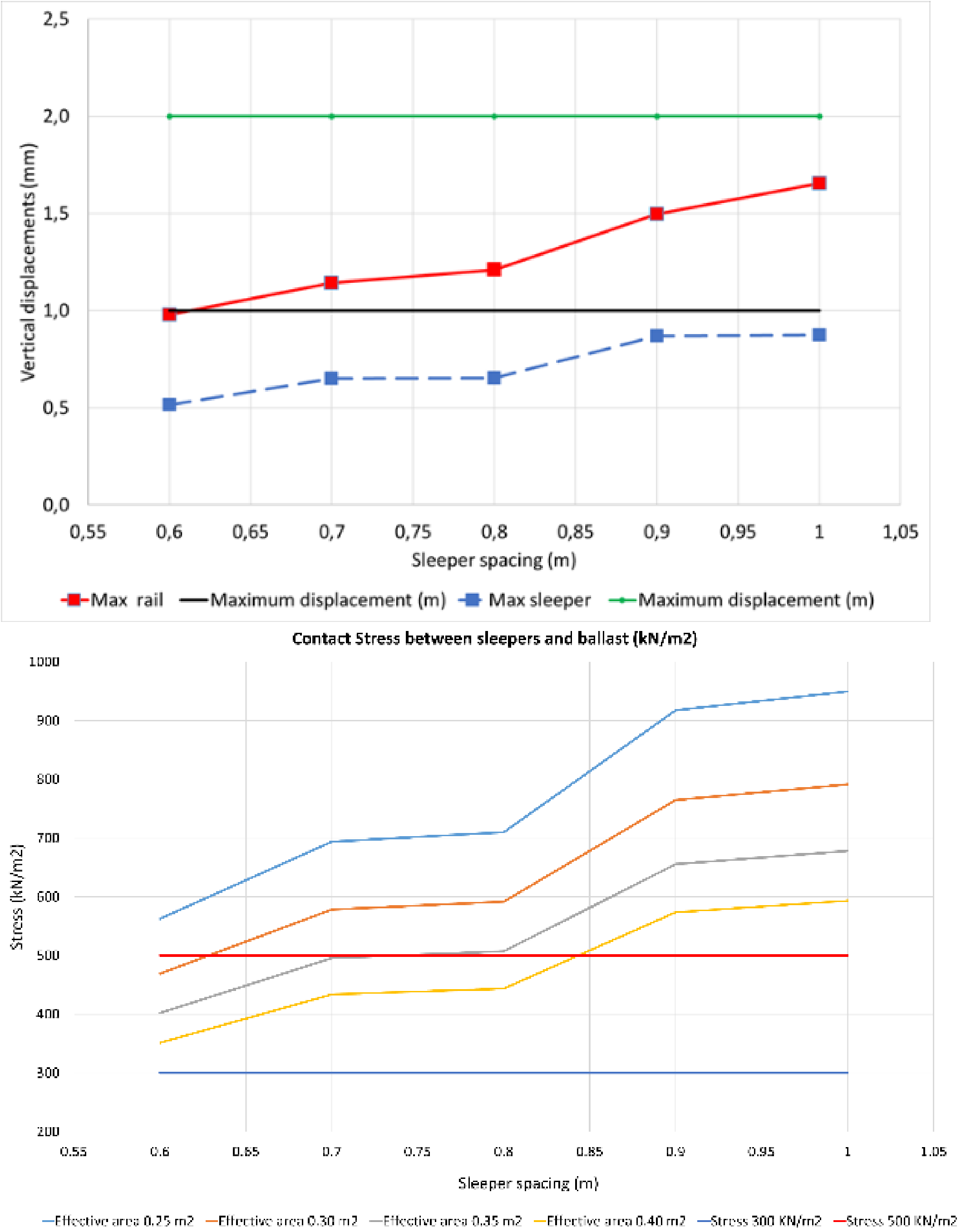

Figure 5: Vertical displacements in rails (up). Vertical stress under sleepers (down)

4 Conclusions and Contributions

The ODSTRACK project main aim is to find an optimal sleeper distance in the railways track. Thanks to previous experience in relation with track superstructure, finite element modelling of the track structure, laboratory test and numerical analysis of track structure elements such as rails, fastening systems, sleepers and the effect of sleeper separation in the track performance [11, 13], allowed authors to propose a deeper analysis of sleepers' separation in a railway track.

Initial state of the art analysis revealed a lack of studies in relation to sleepers spacing. The project has proposed two different approximations, technical and economical.

Preliminary results (2D analysis) have shown that maximum most values followed a linear trend for all variables considered. The most restrictive variable seemed to be vertical displacements in rails and vertical stresses under sleepers.
On the other hand, smaller separation increases the stiffness of the track, but this also means an increase in the track construction cost and difficulties to maintain the track (tamping limits) under optimum conditions.

Although the initial simulations have a good correlation between numerical results and regression models, the research is ongoing, and it is necessary to go further. To go beyond what has been done so far, it will be also necessary to carry out laboratory tests to calibrate the numerical models to have a more realistic result. This task is being done and will help us to understand the track performance.

The next step within ODSTRACK project is to calibrate the numerical models with laboratory results and propose some different study cases to see the track performance for different spacing between sleepers. Next steps can be found in the project web page [1].

Beside this, a vibration analysis and long-term analysis (fatigue analysis) is also necessary to have a general idea of how this spacing between sleepers can influence the performance of the of the vehicle- track system and its maintenance. It will be interesting to analyse the possibility of increasing this separation of the sleeper by increasing the contact area of the sleeper on the ballast. The wear of the elements (fastenings, sleepers, ballast between others) and their integrity should also be studied to know their behaviour in this situation.

Initial results demonstrate that the distance can be increased. It must comply with technical, safety and economic conditions to involve a complete and a definitive solution to justify the increasing of sleeper spacing.

Acknowledgements

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