Proceedings IRF2018: 6th International Conference Integrity-Reliability-Failure
Lisbon/Portugal 22-26 July 2018. Editors J.F. Silva Gomes and S.A. Meguid
Publ. INEGI/FEUP (2018); ISBN: 978-989-20-8313-1

PAPER REF: 7165

RESILIENCY OF SLAB TRACK SYSTEMS SUBJECTED TO LONG-TERM DETERIORATION: NUMERICAL MODELLING WITH SUBSTRUCTURING TECHNIQUES

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ABSTRACT

This paper presents a dynamic three-dimensional finite element model developed and built in ANSYS/APDL specifically to investigate the long-term performance of slab track systems. The long-term effect in slab tracks is achieved in the model through iterative simulations, emulating several years of track lifetime and in each cycle, soil settlement is updated. The used methodology considers a thermo-hydro-mechanical model of the soil A case study, that includes examples of commercially existing ballastless systems, is assessed to evaluate the performance of such systems to millions of train circulations over the serviceability life of the track. In addition, also this paper explores the challenge of understanding and managing the risks of extreme weather conditions. An example to be presented is testing track resiliency and fast recovery when subjected to heavy rainfalls and heat waves.

Keywords: slab track, railway track modelling, substructuring, dynamic analysis, long-term behavior, concrete fatigue, extreme weather scenarios, track resiliency.

INTRODUCTION

The current growing trend in commercial speeds and daily services results in an extra need for maintenance in the traditional ballasted track, which exhibits an early and pronounced degradation. In this context, several ballastless systems arise, promising high structural stability and reduced maintenance requirements. Despite being less frequent, these systems still require an assured level of maintenance, and in certain cases, it is complex and requires a considerable amount of time and resources. Hence, due to the lack of worldwide examples of historical maintenance records, track resiliency and recovery from foreseeable and unforeseeable events should receive further attention in the upcoming years.

This paper considers the prediction the long-term behavior of ballastless tracks over their serviceability life. To accomplish such goal, a dynamic three-dimensional finite element model is developed and built specifically in the commercial finite element software ANSYS/ APDL. Since it is expected the slab track behavior during lifetime, over millions of cycles, an efficient model is envisaged to allow further analyses in time and space domain. Numerical reduction techniques are applied and precisely matrix reduction through the generation of superelements (track “slices”) that are periodically repeated over the track length. This model in time domain has a dynamic vehicle interaction that is able to reproduce train circulations even at high-speeds and a variety of slab tracks systems used around the globe. In each train running simulation (one iteration), the model can deliver track deformations, stresses and accelerations at several sensors previously defined.

RESULTS AND CONCLUSIONS

Achieving a service-life level simulation is a vital part of the developed model that shall be carefully included and updated in each iteration. Soil settlement and concrete fatigue are two major issues for slab track deterioration and the way they are taken in the model is going to be presented. Permanent deformation of the soil is updated in each iteration, by using a thermo-hydro-mechanical soil model already developed in a previous research work. This model takes the track response and atmospheric properties as a calculation input and predicts soil settlement accordingly, by using an incremental evolution. Such model allows the emulation of extreme weather scenarios, such as floods and droughts, hence evaluating the resiliency performance of slab tracks. Also, the cyclic nature of a railway track brings the relevance of concrete deterioration that is taken into account through a mechanistic approach.

Special attention is focused on testing a few examples of existing slab track systems subjected to an initial soil settlement. The results to be presented take into account the settlement evolution under train circulations and seasonal rainfall in several climates. Slab performance is evaluated through the level of cumulated damage at the end of the simulation. In addition, some practical aspects regarding track vulnerability were outlined so that the risk of failure is minimized.

Resilient, fast recovery and low maintenance solutions are key requirements for future railway infrastructure. Hence the importance of efficient long-term numerical models as a tool to support the decision making in track design that significantly improves maintenance and renewal operations.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding by Ministério da Ciência, Tecnologia e Ensino Superior, FCT, Portugal, under grant PD/BS/113751/2015.

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