STUDY ON STRESS ANALYSIS OF TWO DIFFERENT GAUGE OF RAILWAY TRACK UNDER HARMONIC LOADING

BEKHZAD YUSUPOV[1,2], YANJUN QIU[1,2]
[1]*School of Civil Engineering, Southwest Jiaotong University, Chengdu 610031, China*
[2]*Highway Engineering Key Laboratory of Sichuan Province, Southwest Jiaotong University, Chengdu 610031, China*
Corresponding author's email: publicqiu@vip.163.com

Abstract: *Developing a simulation model for railway subgrades is an important initial step forward towards to design a well-graded asphalt surfaces on top layer of railway subgrades. This paper presents a comparative simulation study on top of the subgrade surface of two different gauge by using finite element method. The simulation results show that when train is running at 400 km/h the maximum value of transverse tensile stress almost same for standard and broad railway track gauges, However, longitudinal stress of standard railway track gauge is greater than broad railway track gauge.*

Keywords: *Railway track gauge, asphalt concrete, finite element method, harmonic load.*

I. INTRODUCTION

Throughout the last decades, railway transport systems, in terms of high speed, comforts and intensity of today's railway traffic have become significantly advanced. However, there are still rooms for the improvements of the speed and comforts by optimizing motion dynamics, the quality of railway profile and the structural design of subgrade bases. Since the structural design of railway bases is highly nonlinear and complex, there is a need for research in order to improve reliability, safety and efficiency of track structure. Initial steps of analyses of stresses on the structural bases in terms of top layer of subgrades requires a simulation process of the structural bases of the railway and its parameters [1].

Track is the most fundamental component of the railway infrastructure. Therefore, the study of dynamic responses of the railway track system has been hot topic for engineers. In constructing those tracks, asphalt concrete has been widely used in high-speed railway due to its characteristics of reducing a high noises and vibrations, resistance to vertical deformations and durability on the subgrade [2, 3].

Establishing the dynamic stress on the subgrade surface demands not only fundamental design load but also many other factors influencing on the subgrade, such as train speed, track type and environmental factors. In addition, the dynamic response of subgrade system could also be effected by track gauge that is the nominal distance between the inner faces of the rails in [mm] [4-6].

In railway transportation system, track gauges are divided into many types like narrow or meter gauge where the distance between inner faces of rails ranges from 914 to1 067mm. This type of track gauges includes 16.6% of railways around the world. Another type, which is mostly common in use, is the standard gauge with the distance of 1435mm (consisting 60.2% of globe’s railway). Furthermore, there is a broad gauge type ranging from 1520 to 1676mm. This is the second common track gauges with 23.2% of existence.

As it is afore-mentioned, the standard gauge track is mostly used one and can be seen in the example of in China, USA, most of Europe countries, North Africa and many other countries. Broad gauge can be found in the railway systems in Uzbekistan, Finland, Mongolia, Spain, and Russia and many other countries called previously USSR. The track gauges throughout the world is shown in figure1 [7].

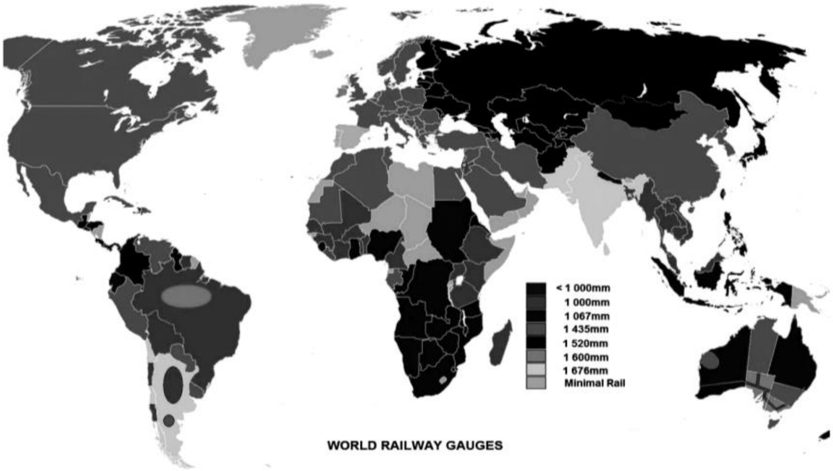

Figure 1. *Track gauges throughout the world*

With the aim of conducting a comparative analysis on two different gauge length under harmonic loading, the present paper focuses on checking the dynamic responses on the top of the subgrade layer of two different gauges that are distinguished as standard gauge (1435mm) and broad gauge (1520mm).

II. MATERIALS AND METHODS

2.1. Finite Element Analyses of Model

Generally, the ballastless track is composed by rail, slab track, CA mortar layer, PCC base, asphalt layer, upper subgrade, lower subgrade and a subgrade layer. The Finite Element Method (FEM) is the most common method for simulation and analysis of railway track. In this case, ABAQUS (Solution for realistic simulation from 3DS Academy) commercial software was employed to build three-dimensional model of track gauges and the ballastless track and to simulate the dynamic responses of the track gauges and subgrade layers.

These all layers in the subgrades could be modeled based on solid element with linear elastic behavior for simulation purposes. In the simulation model, the spring and dashpot elements were assumed to be in-between rails and slab layers. Each layer was designed with specific materials that the features of those materials were identified in Table 1. The asphalt layer was considered as elastic in the finite element model.

Table 1. *The parameters of railway track [8, 9]*

Parts	Geometry (m)	Materials	Elastic modulus (Pa)	Poisson ratio	Density (kg/m^3)	Damping ratio
Rail	UIC 60	Steel	2.06×10^{11}	0.030	7800	0.015
Concrete slab	Width: 2.4 Thickness: 0.19	Cement concrete, C50	3.5×10^{10}	0.167	2450	0.030
CA mortar layer	Width: 2.4 Thickness: 0.05	Cement, asphalt emulsion, sand	4×10^{8}	0.167	2050	0.035
PCC base	Width: 3 Thickness: 0.3	Cement concrete, C40	3.3×10^{10}	0.167	2300	0.030
Asphalt layer	Width: 13.5 Thickness: 0.15	Asphalt mixture	2×10^{8}	0.450	2360	0.055
Upper subgrade	Width: 15.6 Thickness: 0.7	Crushed stone	1.5×10^{8}	0.250	2200	0.045
Lower subgrade	Width: 22.5 Thickness: 2.3	A, B filler, improved soil	0.6×10^{8}	0.250	2000	0.039
Subgrade	Width: 26.5 Thickness: 5	A, B, C filler, improved soil	0.5×10^{8}	0.330	1800	0.035

The boundary conditions have an imperative role in predicting the response of the model, therefore, a fixed boundary conditions were applied on the bottom of subgrade layer. Tie constrains were used between two adjacent parts. Due to the importance of model meshing step in obtaining the most accurate results, many trials were carried out during simulation to define the best mesh size. The defined mesh step was used with integration unit of C3D8R as shown in Figure 2. The simulation deployed that higher accuracy with smaller computational cost can be obtained by setting correct mesh size and step [10].

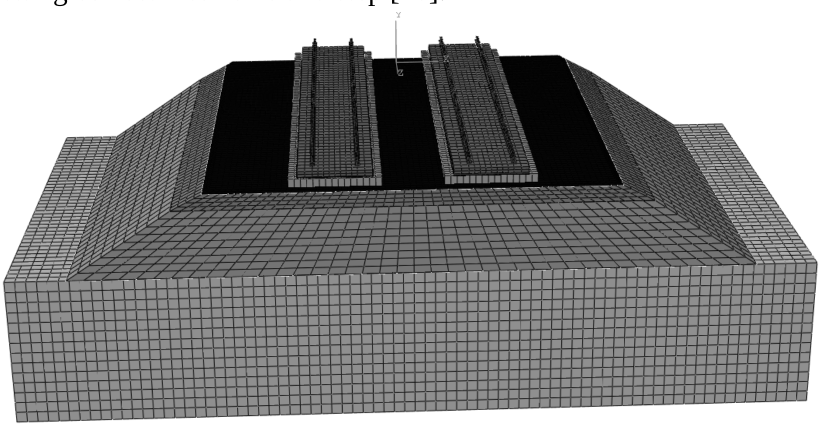

Figure 2*. Three-dimensional finite element model after meshing*

The dynamic behavior of the asphalt material is highly related to the changes in temperature. Considering those changes, the temperature was taken as 25^0 for our case of simulation. The Poisson's ratio and density were chosen as 0.35 and 2400 kg/m^3 and 4,000 MPa was adopted for elastic model of the asphalt material [9]. Full section was created with the length of 15 m along the longitudinal axes and 1:1.5 slope of embankment.

2.2. Determination of train loads

Modelling the dynamic effect of the railway track is the highly known technique in developing the design of the track structure and in increasing the speed of train. The trainload is the main dynamic effect on the railway track [11].

For simplifying the analysis in the ballastless track slab structure model, the train load geometry can be drawn by substituting the elliptical contact surface between wheel and rail for rectangular surface in the modeling [12] (can be seen in Figure 3).

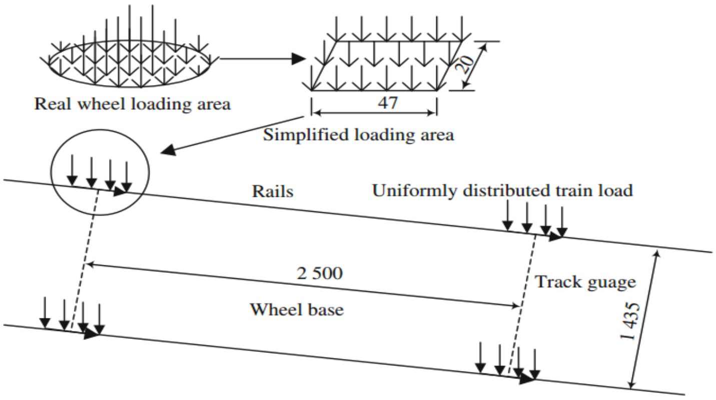

Figure 3. *Schematic view of the train load geometry*

There are several methods to determine the trainload, but some methods are infeasible to apply for the simulation models owing to its complexity. One of the common method that considers only structure weight in harmonic form was employed to define the train load [9]. By ignoring the additional load effects and simplifying the trigonometric complexity, the train load can be expressed as follows:

$$p(t) = \frac{p_o + p_1(\sin \omega t)}{A} \tag{1}$$

Where A is the loading area between wheel and rail contact, and it is equal to 940 mm^2 in our case that train speed is 400 [km/h]. P_0 is static rail load equal to 125 kN and P_1 is the amplitude of load with 36554 kN. ω is the circular frequency of the wheels with 349.06 Hz. [9]

III. RESULTS AND DISCUSSIONS

3.1. Transverse stress on the top of the subgrade layer

Figure 4 shows a transverse stress comparison between two different standard and broad gauge. there are not substantial differences in the shapes of the stress plots, transverse stresses were tensile for standard gauge and broad gauge on the top of the subgrade layer, the maximum stress was just about 6.68 kPa for both of them, however, the minimum transverse stress was reach at the standard gauge on the top of the subgrade layer.

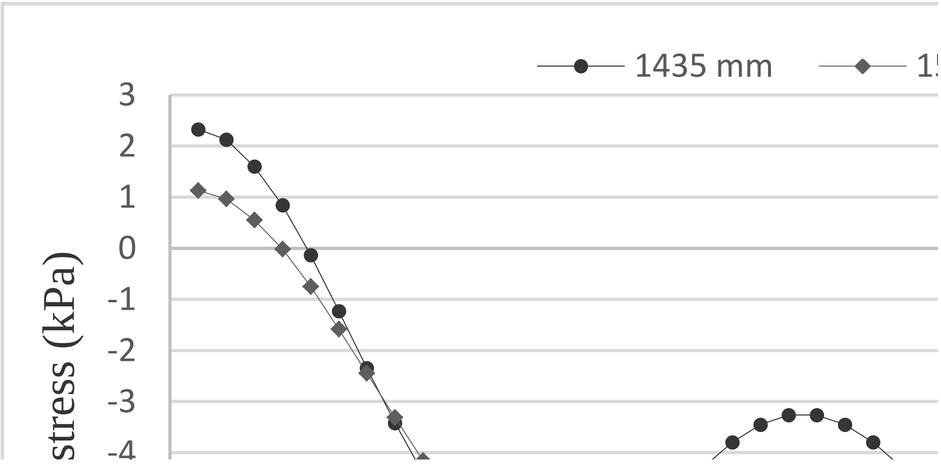

Figure 4. *The transverse stress on top of the subgrade layer*

3.2. Longitudinal stress on the top of the subgrade layer

The longitudinal dynamic stresses were computed along top of the subgrade, data curve is shown in Figure 5. The result shows that there are huge differences in the shapes of the longitudinal stress plots, longitudinal stresses were also tensile for standard gauge and broad gauge on the top of the subgrade layer, stress of standard gauge greater than broad gauge. The maximum stress was 9.41 kPa for standard gauge and the maximum stress value of broad gauge was about 7.2kPa

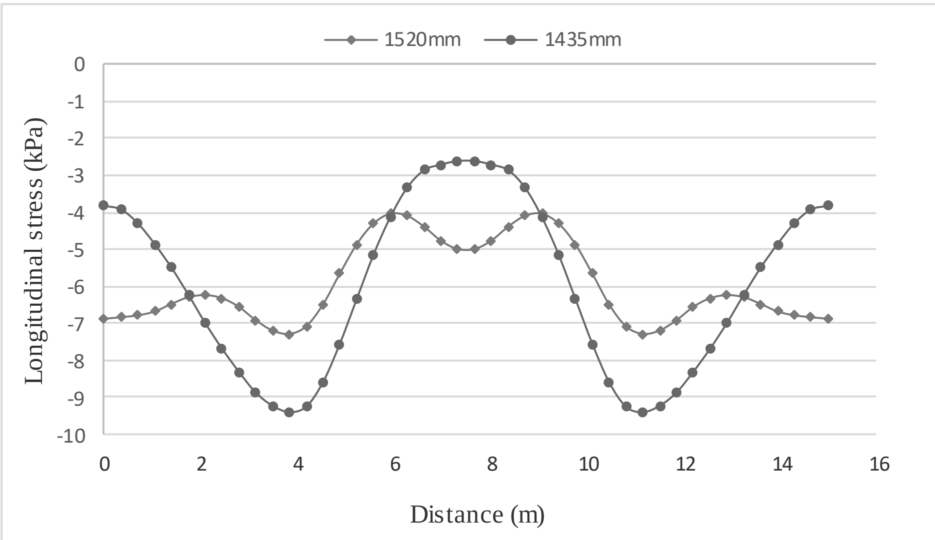

Figure 5. *The Longitudinal stress on top of the subgrade layer*

III. CONCLUSIONS

In this study, the comparison numerical analysis viewed horizontal stresses on the subgrade layer under the harmonic loading by using Abaqus commercial software. After analyzing and comparing the two different railway track gauge, the following was found

The maximum value of transverse tensile stress almost same for standard and broad railway track gauges, but longitudinal stress of standard railway track gauge is greater than broad railway track gauge.

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