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Modelling, Simulation and Experimental Investigation of a Vibratory Roller Concrete Compaction

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Abstract: Concrete compaction by vibration is a complex process. The interaction between properties of concrete and the dynamic parameters of the vibration roller creates a nonlinear dynamic system. The prediction about the dynamic behaviors of the roller drum influencing on the concrete layers is essential. It can be used to optimize the parameters of the roller drum. In this paper, a viscoelastic-plastic (VEP) model is used to simulate the response of vibratory rollers during the compaction of concrete surface. The VEP model takes into account the most important factors affecting the dynamic characteristics of the system. The comparisons of the simulation results with those collected during the construction of concrete pavement indicate that this model can serve as a theoretical basis for the implementation of effective concrete pavement compaction. The results also help in determining velocity, acceleration of the vibratory roller, as well as the relationship between the acting force and the displacement.

Keywords: *Concrete Compaction, Vibratory Roller, Viscoelastic, Roller drum, Parameters of Vibration Roller*

Introduction:

The basic characteristics of the quality of road are durability, covering density, surface evenness, ability to adhere to car wheels. To provide the required parameters is possible only if the technology of the compaction work is strictly observed, the choice of the components of road concrete mix is correct and there is a selection of the necessary compaction equipment [1]. These are traditional static and vibration road rollers with smooth drums, road rollers with pneumatic tires, combined road rollers, rammers etc [2]. The most progressive vibration road rollers do not fully correspond to the requirements of the road practice. But they have potential possibilities and ways for functional and technological improvement due to of the intellectual regulation of sealing force effects and the creation of more universal models [3].

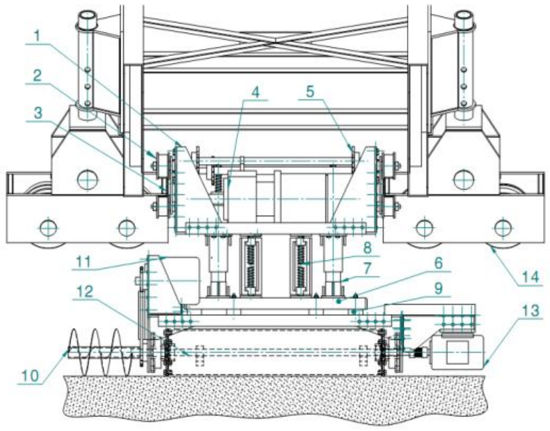
In this paper, a mathematical model describing the interaction between the vibration roller and the concrete pavement layer is presented. The vibration roller is modelled as a second-order system comprising of mass, spring, and damper elements. The concrete pavement is modelled as a viscoelastic-plastic (VEP). The dynamical equations for the coupled system are shown to be computationally tractable and suitable for numerical simulation. It is also shown that the parameters in these equations are dependent on the roller and the properties of concrete mix. Further, it is shown that these parameters can be obtained from experimental results in a straightforward manner. The simulation results show that the model accurately predicts the compaction of the fresh concrete mix in field. The comparisons of the simulation results with those collected during the construction of concrete pavement indicate that this model can serve as a theoretical basis for the implementation of effective concrete pavement compaction.

The rest of the paper is organized as follows. First, the modelling of the vibratory roller and concrete pavement is presented. Then, the parameters in the dynamical model from experimental data are determined. Simulation results for different compaction scenarios and their comparisons with field compaction data are presented and discussed. Finally, conclusions are drawn from the current study and the direction of future research is provided.

Materials and Methods:

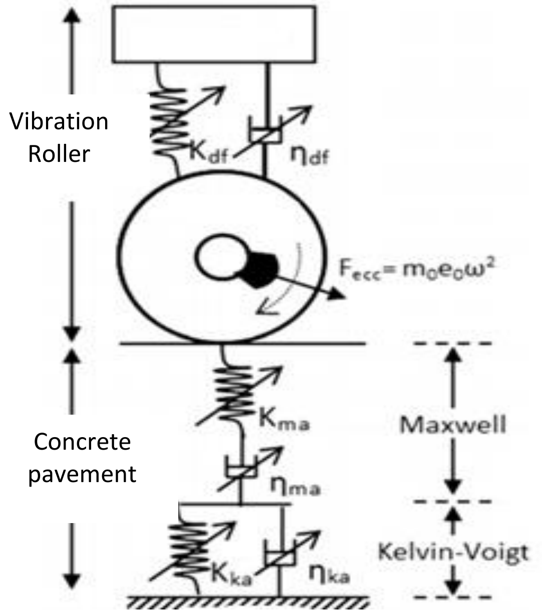
Model of vibratory roller

Figure 1: Structural of vibratory roller



The working of vibratory roller consist of many elements [6]: (1) car structure; (2) car wheels; (3) Rails;(4) &(13) motor; (5)Traction chain; (6) vibration table; (7) guide tube for vibration table; (8) adjusted crew; (9) damp rubber; (10) conveying crew; (11) roller drum; (12) eccentric shaft.

Model Description:



Fugure 2: Parameters model of the interaction of vibratory roller and concrete pavement

During field compaction, the vibratory roller and the underlying concrete pavement layers form a coupled system. Thus, any changes in the stiffness of the concrete mix would affect the vibratory response of the roller. The proposed model can be split into two parts: The first part representing the dynamical characteristics of the vibratory roller and the second part representing the dynamical characteristics of the concrete pavement [4,5].

Fecc: Centrifugal force
k_{df}: Drum-frame stiffness
η_{df}: Drum-frame damping
k_{ma}: Maxwell spring stiffness
η_{ma}: Maxwell dashpot damping
k_{ka}: Kelvin spring stiffness
η_{ka}: Kelvin-Voigt dashpot damping

Table1. Dynamic parameters of vibration roller

Symbol	Discription	Unit	Value
C_{df}	Drum/frame damping coefficient	N.s/m	0.05
k_{df}	Drum/frame Stiffness coefficient	N/m	39951
m_f	Frame mass	kg	310
m_d	Drum mass	kg	570
m_0e_0	Eccentric moment	kg.m	0.4-0.9
ω	Eccentric rotational frequency	rad/s	40-60
W	Drum width	m	1.2
A	Drum contact area	m^2	0.05

Using MATLAB Simulink to simulate, we can obtain the working parameters of vibratory roller.

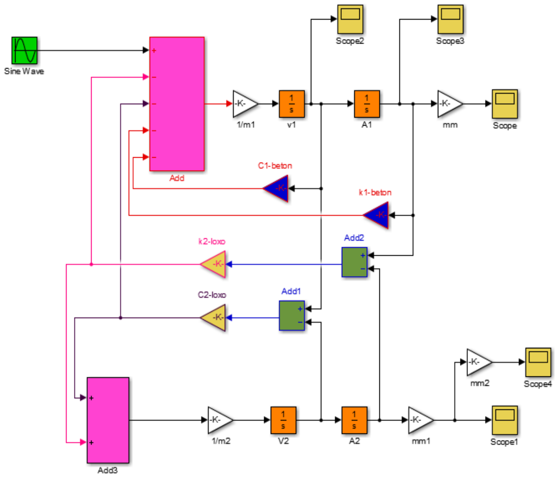
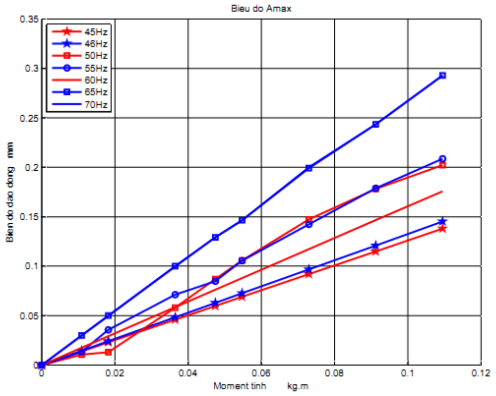


Figure 3: Simulation program to define the working parameters of vibratory roller



Results and Discussion:

The results of simulation are shown in following charts:

Figure 4: Vibration amplitude and eccentric moment

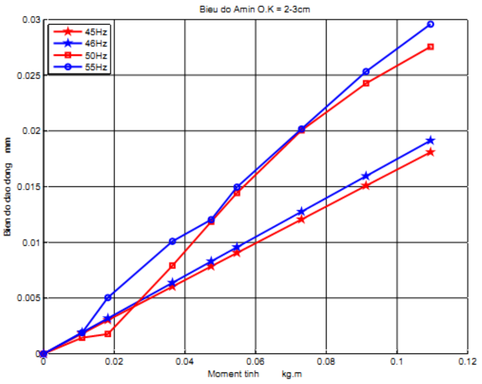


Figure 5: Vibration amplitude at the concrete surface

The results of experiment are shown in following charts:

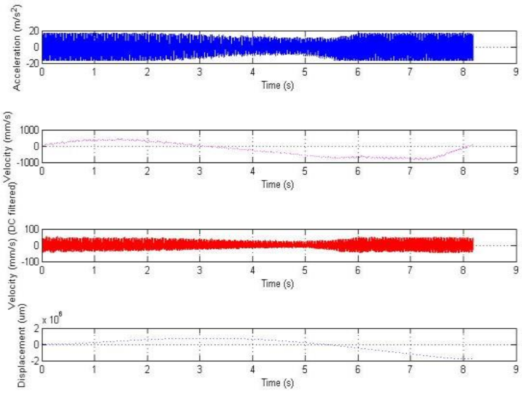


Figure 6: Displacement, velocity and acceleration of drum at concrete surface

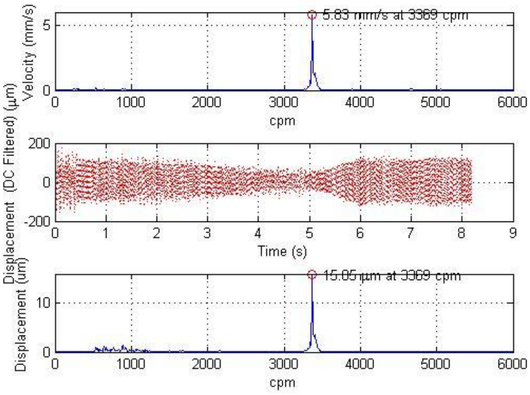


Figure 7: Vibration amplitude and velocity of roller drum in 50Hz

Base on the results (figure 4, 5, 6, 7), we can choose the appropriate working parameters of vibratory roller to compact the concrete surface with mark 200, layer thickness 200cm, slump cone 5cm. The working parameters are as follows:

-Eccentric static moment: 6kg.cm

-Vibration frequency: ω= 50H_z

-Vibration amplitude of roller drum at the concrete surface: A_{max}=0.15mm

-Vibration amplitude of concrete layer at the depth 200mm: A_{min}=0.03mm

-Acting force on the concrete layer: F=3500kG

Conclusion:

In this paper, a mathematical model was developed with an aim to understand the interaction between a concrete mix layer and a vibratory roller during the construction of concrete pavement. The model take into accounts for the viscoelastic-plastic properties of concrete mix and the dynamics of the roller drum to predict the effect of compaction on the vibration of the roller drum. Further, the parameters of the model are shown to be easily derived from the roller specifications and from the material properties of the concrete mix.

References:

[1]. Sergey Maksimovich Ugay, Uri Uakovlevich Kovalenko and Natalya Sargeevna Pogotovkina-Statistical research of vibration road rollers and perforated operating devices, World Applied Sciences Journal 25, 2013
[2]. Malutin-Roll to the fullest. Road Rollers, 2013.
[3]. Kostelyov, M.P.-The compaction of asphalt requires the renewed generation of rollers, Road equipment, 2003.
[4]. Fares Beainy, Sesh Commuri, Musharaf Zaman, Imran Syed –Viscoelastic-Plastic model of asphalt-roller interaction, International journal of Geomechanics-ASCE, American, 2013.
[5]. Fares Beainy, Sesh Commuri, Musharaf Zaman – Dynamical response of vibratory rollers during the compaction of asphalt pavements, International journal of Geomechanics-ASCE, American, 2014.
[6]. Nguyễn Hồng Ngân, Huỳnh Công Lớn,Đặng Sỉ Lể- Nghiên cứu hợp lý hóa các thông số làm việc của máy san đầm trục lăn trong quá trình đầm bê tông, Hội nghị khoa học và công nghệ toàn quốc về cơ khí lần thứ III, 2013.
[7]. Trần Văn Tuấn- Cơ sở kỹ thuật rung trong trong xây dựng và sản xuất vật liệu XD, NXB Xây dựng Hà Nội, 2005.
[8]. Burger- Considerations-model systems-phenomenological theories of relaxation and of viscosity, mechanical, Viscosity and Plasticity, Nordemann Publishing, New York, 1935
[9]. Ralph O.Lane- Behavior of fresh concrete during vibration, reported by ACI Committee 309. USA, 1998.