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Research and verification of transfer model for roughness conditions of pavement construction

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Abstract

In order to study the transfer law of roughness during asphalt pavement construction, a mathematical model concerning the effect of sublayer, paving layer, random factors and paving materials compactness on final surface layer roughness was established through theoretical deduction and data statistical analysis. The critical conditions of sublayer roughness transfer to final surface layer were determined through the application of the Error Propagation Theory, allowing to further establish, the transfer model for roughness conditions in asphalt pavement construction, internal relationships among paving roughness, initial compactness and final surface layer roughness were also clarified. Moreover, the best initial compactness under different paving smoothness was determined and the transfer model was verified using typical engineering test data.

Keywords: Pavement engineering; Roughness; Transfer characteristic; Critical condition; Mathematical model; Experimental verification

1. Introduction

Good roughness is one of the essential purposes of asphalt pavement. It not only directly affects the driving quality and the riding comfort, but also the service life and the maintenance cost of pavement [1]. Ghosh's research showed that pavement roughness conditions affect energy consumption throughout the use phase [2]. Janoff's research indicated that good roughness of the pavement has fewer cracks and lower maintenance costs within 10 years [3]. In America, the roughness index in 15 states is set at a maximum gap between the pavement surface and a 3 m straight ruler, while in seven states it is set for 5 mm [4]. The standard in China requires the roughness of the upper layer to decrease from 1.8 mm to 1.2 mm [5]. Moreover, some equipment manufacturers have tried to improve paving roughness through improving the structure of pavers and the performance of leveling systems [6]; the constructors have improved pavement roughness through the improvement of construction technology [7]. Based on the previous studies, this paper established a transfer law for roughness and critical conditions in construction through further theoretical analysis and experimental research, and then built a transfer model for roughness conditions of asphalt pavement construction. The model was verified using a full-scale experiment.

2. The major factors of roughness in asphalt pavement construction

There are many factors that affect pavement roughness, which can be divided into two stages, namely the construction stage and the operation stage. The roughness transfer model of the construction is mainly studied in this paper.

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During the process of construction, the major factors that affect roughness in asphalt pavement are related to the sublayer roughness, the paving operation and the rolling operation.

2.1. The influence of sublayer roughness

The influence of sublayer roughness refers to the reflex action, resulting from layer thickness of uneven sublayer pavement to final surface layer roughness. When the roughness of the sublayer was unsatisfactory, a smooth loose layer can be made by pavers through an automatic leveling system. However, the different loose layer thicknesses caused a compression difference during the rolling process. The poor sublayer roughness was reflected through the rolling to the final surface layer.

2.2. The influence of paving operation

The influence of paving operations refers to the reflex action of the change of layer roughness to final surface layer roughness. The change of layer roughness mainly results from an automatic leveling system, a leveling benchmark, paver operational parameters, working parameters, etc.

The paver is composed of traction engine and working device. The traction engine provides power and the working device realizes the functions of feeding automatic control and layer's automatic leveling control. The floating screed is the working device of paver, and its working principle is shown in Fig. 1. Due to the self-weight, tension of towing point and the synthetic action of supporting force, friction and pile resistance in front of the screed steady layer is spread out when the force is in balance.

The working principle of floating screed is to regulate the height of towing point of big arm to change the included angle between screed floor and paving layer to destroy the balance of existing power, which makes the screed rise or fall to adjust to a new location. Based on a reference datum (e.g. a tie wire), the height of towing point can be regulated by electronic leveling system equipped in the paver.

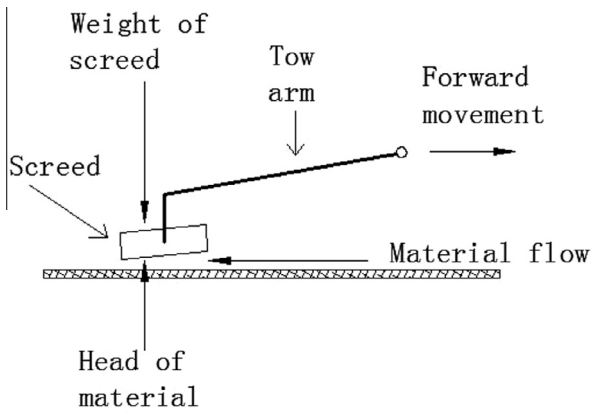

Fig. 1. The working principle of floating screed of a paver.

From the perspective of force balance of screed, factors which break the force balance affect paving roughness during the working process of paver, and they can change the push resistance of material piles in front of screed, paving resistance, towing point, etc.

2.3. The influence of rolling operation

The influences of a rolling process on pavement roughness are: the impact of the tangential thrust generated by a steel wheel on mixture during compaction, the mixture density of the loose layer and the non-homogeneity of mechanical property on roughness. When the roller changes its rolling direction, the brake is implemented, thus producing an inertial force. This force leads to a change in the tangential thrusts the starting, oscillation starting and oscillation stopping of a vibratory roller causes bulge and indentations on the final surface layer. Furthermore, the non-homogeneity of mixture layer material and temperature results in the inconsistent compaction power toward material resistance. These factors affect pavement roughness in direct or indirect ways.

3. The transfer characteristic of roughness in asphalt pavement construction

The influential of roughness in asphalt pavement construction can be divided into certainties and uncertainties. The sublayer roughness and paving operation, which can follow some rules, belong to certainties while the influence of rolling operation on pavement roughness is random and uncertain. However, a large amount of experimental data should be obtained for the statistical analysis.

3.1. The influence of certain factors on the roughness in pavement construction

The influence of an uneven sublayer on the final roughness of the surface layer is analyzed in the following section. By taking out a unit cell from the layers found below the roller steel wheel, the force state can be shown, such as in Fig. 2. As shown, σ_1 is the vertical compacting

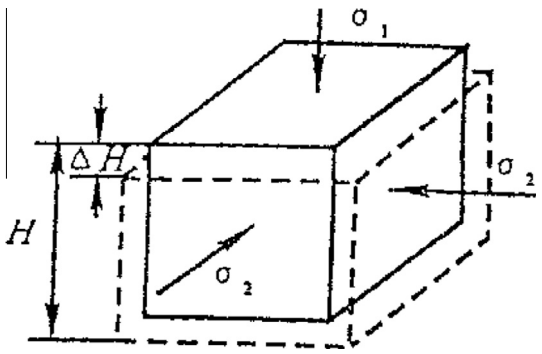

Fig. 2. Unit force diagram.