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The Research on Equipment for Detecting Strength of Shallow Asphalt Pavement under Ice Frozen

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Keywords: Asphalt pavement; Penetrating Strength Detector of Shallow Pavement; Falling distance; Penetrator Probe

Abstract: Aiming at detection of strength of shallow asphalt pavement under ice frozen, this thesis has developed the Penetrating Strength Detector of Shallow Pavement through finite element numerical simulation, whose theory is based on evaluating strength of asphalt pavement by penetrating depth of the penetrator impacting into asphalt pavement.

Introduction

The ice frozen phenomenon has generally occurred to the pavements in the moist plateau district of southwest China, which has tended to get worse in recent years. The freeze-thawing effect due to ice frozen phenomenon has led to weakness and destruction of the shallow asphalt pavement, and then diseases such as cataclasm, stripping, pit slot, loosening etc. turn up. How to evaluate ice frozen effect to the strength of asphalt pavement accurately is of great actual significance for establishment of deuteric maintenance and repair plan.

Nowadays, relevant non-destructive inspection methods to evaluate strength of asphalt pavement on spot conclude Benkelman Beam, Falling Weight Deflectometer(FWD), Rolling Dynamic Deflectometer(RDD), Traffic Speed Deflectometer(TSD) etc, which own a common feature that the measurement index is deflection, while deflection is defined as reflection of the combined strength of pavement structure layers under loading points, and the strength value of asphalt shallow pavement remains unavailable[1-4].

The thesis has developed the Penetrating Strength Detector of Shallow Pavement through finite element numerical simulation, whose theory is based on evaluating strength of asphalt pavement by penetration depth of the penetrator impacting into asphalt pavement. This new-style instrument is able to evaluate strength of shallow asphalt pavement quickly, possessing extensive applicability and wide prospect.

Design principle of Penetrating Strength Detector of Shallow Pavement

The thesis draws lessons from the operating principle of Dynamic Cone Penetrator (DCP)[5]. Falling hammers of certain sizes will be designed and made to fall free from a certain height, generating impact force that can inject the penetrator into pavement with a certain depth. The whole working process will be simulated by finite element method to confirm the specification of the detector.

Selection of instrumental components based on finite element analysis

Three types of falling hammers are drafted initially for the instrument, according to hammering energy, divided as 5kg, 10kg, and 15 kg. Falling distance of hammers sets as 0.5-0.8m; there're also 4 types of penetrators with the height of 120mm, according to diameter, divided as 12mm, 10mm, 8mm and 6mm.

The thesis has simplified the impacting and penetrating simulation and only established a penetrator-pavement model instead, while function from falling hammer to penetrator is simply to impacting load upon the penetrator. Considering the size of penetrator is relatively small to pavement structure and the detection aim is strength of pavement surface layer, a pavement model by length*width*height=1.0m*1.0m*0.15m is sufficient for accuracy requirement. The penetrating depth is setting as about 10cm.

Considering the process of penetrator impacting into pavement has a significant effect only to a small region around the penetrator and the actual situation of the chosen pavement model, boundaries and underside of the model are totally fixed， that is U1=U2=U3=UR1=UR2=UR3=0; and symmetry planes adopt symmetrical boundary condition, that is U3=UR1=UR2=0 and U1=UR2=UR3=0; top surface remains free. The boundary condition is shown in Figure 1[6].

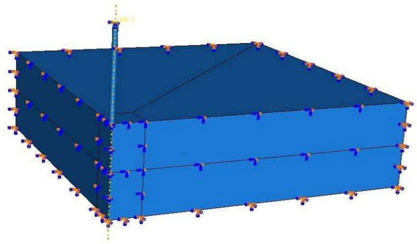

Figure 1. Boundary condition of finite element model

The thesis has conducted grids division to the asphalt pavement model in numerical simulation. We choose 8-node solid element C3D8R of reduced integration as pavement element and explicit linear three dimensional stress elements C3D4 as penetrator model [7]. In order to improve the accuracy of simulation and calculation, the region of pavement structure affected by penetrator has been divided to grids as shown in Figure 2.

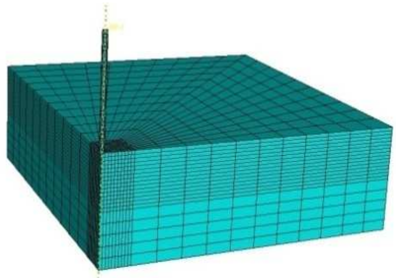

Figure 2. Grids division of finite element model

Considering the force applied to asphalt pavement is instantaneous impact load, we can ignore the viscous effect to material and assume that asphalt concrete only presents elastoplasticity, therefore the D-P Model is chosen to simulate asphalt concrete. The material parameters of finite model are shown as Table 1, 2 and 3.

Table 1. Material parameters of pavement model

Elastic modulus (MPa)	Poisson's ratio	Density (kg/cm^3)	Damping
13400	0.25	2.4	0.9

Table 2. Parameters of D-P model

Angle of friction	Flow stress ratio	Dilation angle
30°	1	30°

Table 3. Material parameters of penetrator model

Elastic modulus (MPa)	Poisson's ratio	Density (kg/cm3)
210000	0.3	7.85

The instantaneous impacting force of penetrator F varying with time t is a half-sine relationship: $F=F_0\sin wt$. According to momentum theorem, the impacting load from falling hammer to penetrator can be calculated by $\int_0^{0.0004} F_0 \sin \omega t dt = \Delta mv$ as Table 4 shows. Falling distance chooses 0.5m.

Table 4. Impact load

Hammer weight(kg)	5kg	10kg	15kg
Impacting load(N)	6146.7	12293.4	18440.1

We can get 4 series of relationship as follows by software calculating:

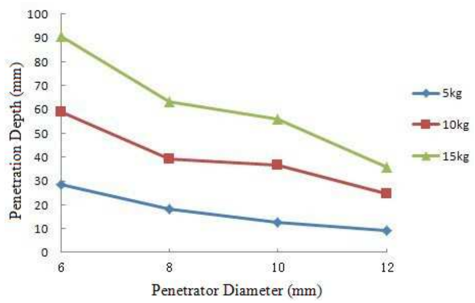

Figure 3. Relationship between penetration depth and penetrator diameter

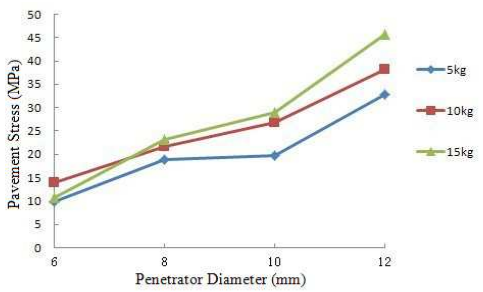

Figure 4. Relationship between pavement stress and penetrator diameter

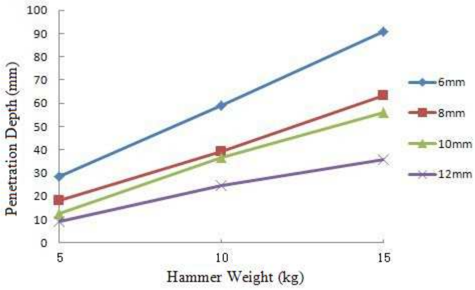

Figure 5. Relationship between penetration depth and hammer weight

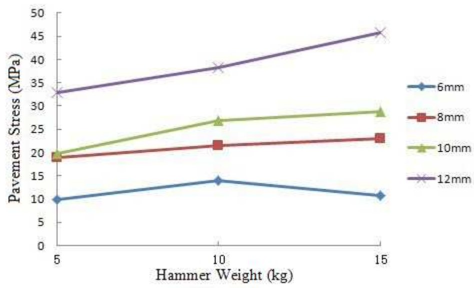

Figure 6. Relationship between pavement stresses and hammer weight

Analyzing the data from 4 pairs of relationship above, the penetrator with diameter of 12mm and the falling hammer weighing 15kg will generate oversized stress to pavement and result in destruction; while stress and penetration depth of the 6mm-diameter penetrator and the falling hammer weighing 5kg will make the reference standard lose the relevant part of high pavement strength in follow-up research, which is uncompleted.

In summary, the penetrators with diameter of 8mm and 10mm as well as hammer weighing 10kg are determined to be the main instrumental components.

Design of the Penetrating Strength Detector of Shallow Pavement

The Penetrating Strength Detector of Shallow Pavement is mainly consisted of 4 parts as whole supporting structure, guide bar, falling hammer and penetrator, shown in Figure 7.

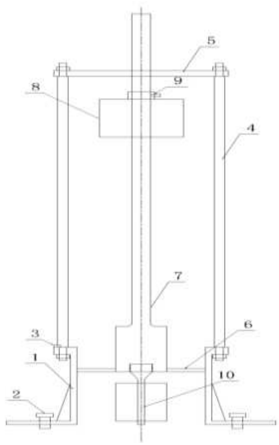

Figure 7. Design chart of Penetrating Strength Detector of Shallow Pavement

1.Bottom fixed barrel; 2.Leveling bolt; 3.Leveling bubble; 4.Fixed bar; 5.Top guide disc;

6. Bottom guide disc; 7.Guide bar; 8.Falling hammer; 9.Block button; 10. Penetrator probe.

The entitative structure of the Penetrating Strength Detector of Shallow Pavement is shown in Figure 8.

Figure 8. Penetrating Strength Detector of Shallow Pavement

After the establishment of reference standard through comparison with other indoor experiment results, this detector can conduct impacting penetration experiments to evaluate strength of pavement indirectly after suffering ice frozen damage, which is characterized by simple operation, convenient application, clarity and accuracy of data collecting, etc.

Conclusion

According to analyzing and calculating results, conclusions can be figured out as follows:

The design range of falling hammers of the Penetrating Strength Detector of Shallow Pavement is 5kg, 10kg and 15kg, and the hammer weighing 10kg is chosen as main instrumental component.

The design range of falling distance of the Penetrating Strength Detector of Shallow Pavement is 0.5-0.8m.

The penetrator height of the Penetrating Strength Detector of Shallow Pavement is 120mm. There're 4 types of penetrators classified by diameter as 12mm, 10mm, 8mm and 6mm. The depth of measurement can reach 100mm.

The thesis has developed the entitative structure of the Penetrating Strength Detector of Shallow Pavement.

The determination of corresponding reference standard between falling distances, diameter of penetrator, penetration depth and pavement strength about the Penetrating Strength Detector of Shallow Pavement will get further demonstration in other thesis.

Summary

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