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Study on Asphalt Pavement Temperature Field Distribution Law in Seasonally Frozen Regions

Rui Zhang [1,a] ,Yiqiu Tan [1, b] , Leyong Qu[2,c] ,Huining Xu[1,d]

[1] School of Transportation Science and Engineering, Harbin Institute of Technology, Harbin, Heilongjiang, 150090, China

[2]Beijing General Municipal Engineering Design &Research Institute, Beijing, 100082, China

[a] shanzhangrui@126.com, [b]yiqiutan@163.com,[c] 397978414@qq.com, [d]xhn1983@163.com

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Abstract. Based on the temperature field data collected from a self-developed pavement system, asphalt pavement temperature field distribution law in seasonally frozen regions was studied in detail. Test data illustrated that: The atmospheric and pavement temperature shows cycle sine rule; Minimum and maximum values of pavement temperature occur at surface, In winter, pavement temperature gradually increases with increasing depth, but has contrary result in summer; As the increase of depth, the fluctuation range of pavement temperature decreases gradually, which lead to the appearance of daily and annual constant temperature point; The max freezing depth appeared at 120cm and there will be freezing core in spring in seasonally frozen regions.

Introduction

Road structure is exposed to the natural environment, in addition to bear the vehicle load, but also affected by environmental factors such as temperature, radiation, wind, rain, snow and so on[1,2]. So the pavement structure must not only meet the load requirements, but also to adapt to their environment. Only thus can guarantee its long-term performance, otherwise, the road structure is bound to have early damage [3,4].

Among environment factors, temperature has the greatest impact on the road structure [5]. According to statistics, 53.5% of the area in china belongs to seasonal frozen region, where torridity summer, frigid winter, great annual temperature difference are obvious features. Bearing capacity and service performance of pavement are sensitive to the change of temperature [6]. Therefore, it is necessary to develop the study on temperature distribution characteristic of asphalt pavement in seasonally frozen regions.

Brief Introduction of Typical Pavement Structure Model System

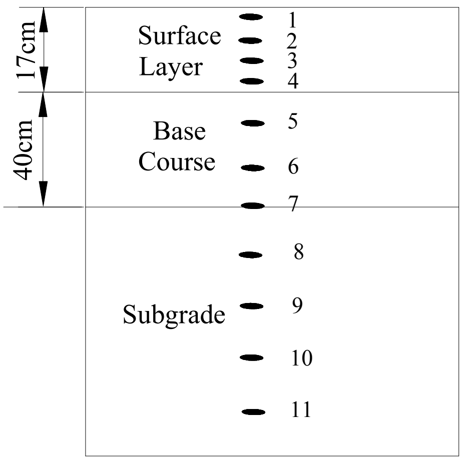
Currently,the experimental study on temperature field, mainly used building of typical test section in wild for long-term fixed point observation, and small indoor model test. The former need a long observation period, and consumes large amounts of human, material; the latter test could not impersonate the real working conditions of road structure because of small size, Therefore, this article adopts the common form road structure in China, builds outdoors test bench to simulate real-world conditions, and takes the study on variability and distribution of road structure temperature.

The seasonal frozen pavement structural model test bench has a total length of 5 meters, width of 2.1 meters, test-bed structure as shown in table 1:

Tab 1 Test-bed of Road Structures

structure layer	material	thickness /cm
surface layer	cmAC20+5cmAC20+7cmAC20	17
base	three-kinds ash	40
Subgrade	clay	—
Subgrade form	cutting	

The temperature sensors use semiconductor sensors of the WS-TS201, Measurement temperature range is -40~120℃, The measurement accuracy is ± 0.5℃. Sensor buried schematic as shown in Fig.1:



Sensor 1- depth 2cm Sensor 2- depth 5cm Sensor 3- depth 10cm Sensor 4- depth 17cm
Sensor 5- depth 30cm Sensor 6- depth 43cm Sensor 7- depth 57cm Sensor 8- depth 90cm
Sensor 9- depth 130cm Sensor 10- depth 170cm Sensor 11- depth 210cm

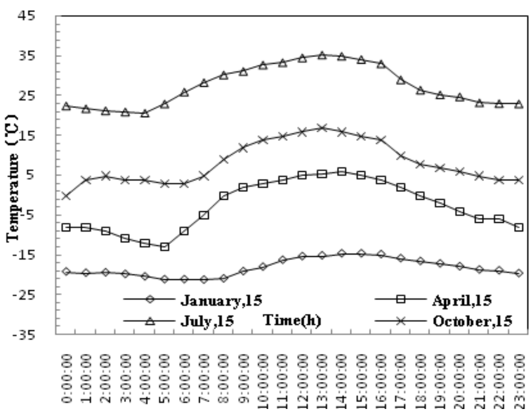
Fig.1: Sensor buried schematic

Daily Variation Law of Atmospheric Temperature

From the figure 2, we can know the daily variation law of atmospheric temperature:

The atmospheric temperature shows cycle sine rule. Heat up time is much shorter than the time to cool, so heating rate is greater than the cooling rate.

Minimum temperature occurred in 4:00-6:00 am, maximum temperature occurred in 14:00-15:00 pm.



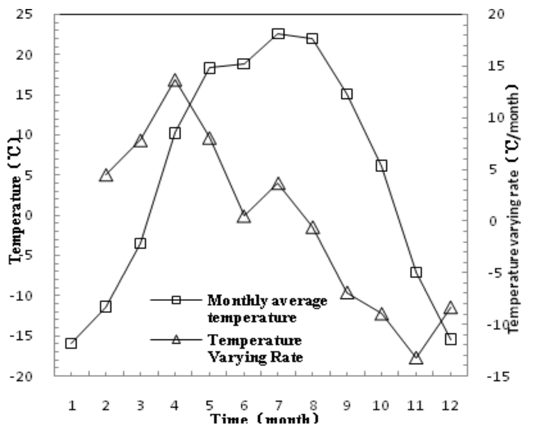


Fig.2: Daily atmospheric temperature in Harbin Fig. 3: Annual atmospheric temperature in Harbin

Annual Variation Law of Atmospheric Temperature

As known in Figure 3, the minimum average temperature occurred in January with -15℃, maximum average temperature occurred in July with 25℃.

Longer winter and summer, shorter spring and autumn, greater annual range of temperature are major features in Harbin.

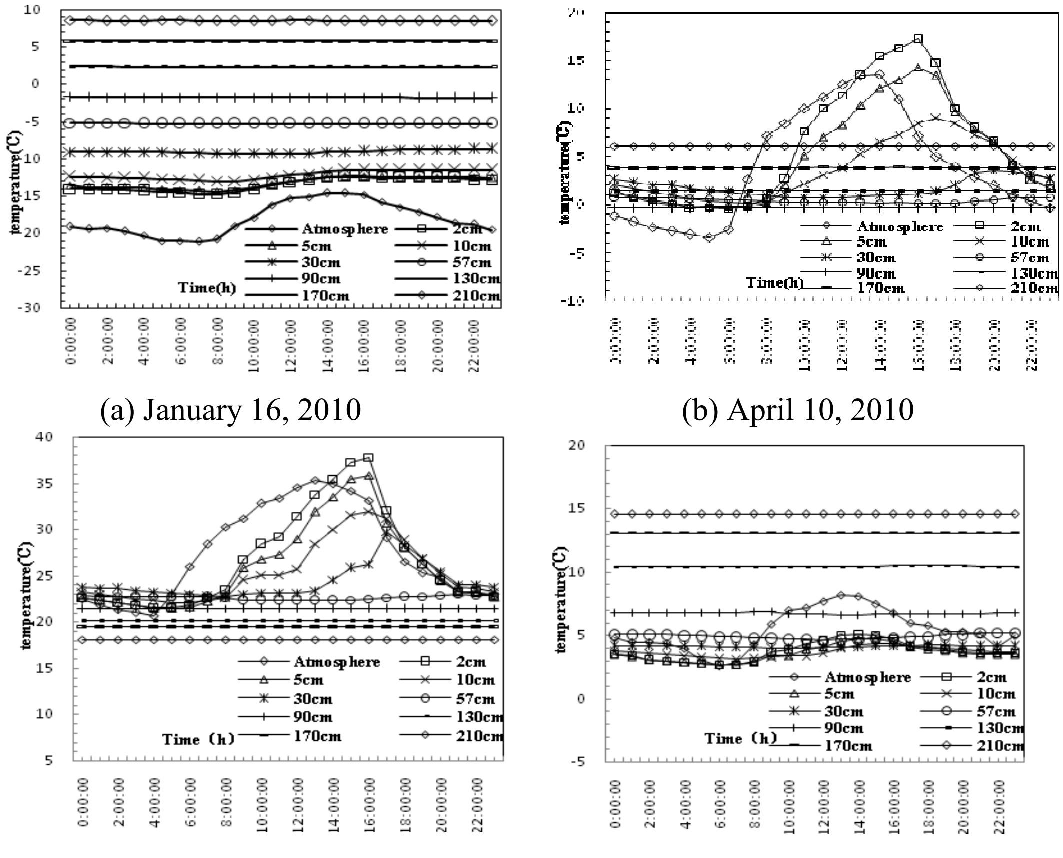
Daily Variation Law of Pavement Temperature

The Figure 4 demonstrates the law as follows:

Pavement temperature has the similar variation law to atmospheric temperature, but lagging behind atmospheric, Minimum temperature occurred in 6:00-7:00 am, maximum temperature occurred in 14:00-15:00 pm.

Hysteretic nature gradually increases with increasing depth.

As increasing depth, the fluctuation range of pavement temperature decreases gradually, and tends to 0℃ at a certain depth, which can be called daily constant temperature point. Below daily constant temperature point, temperature a day can be represented by the temperature at any time, a daily cycle of temperature change can be instead by the annual cycle.



(a) January 16, 2010 (b) April 10, 2010

(c) July 27, 2010 (d) November5, 2010

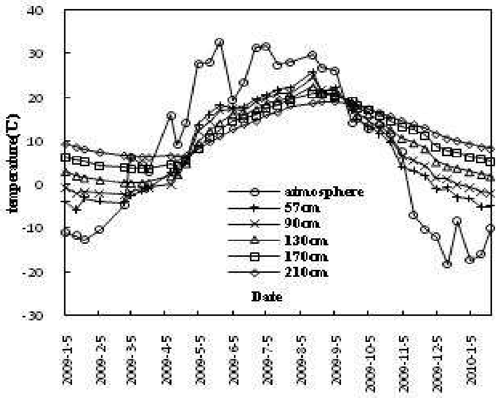
Fig.4: Daily variation law of pavement temperature in Harbin

Annual Variation Law of Pavement Temperature

Figure 5 and Figure 6 illustrated that, the pavement temperature shows cycle sine rule with the period of a year, but has different extremum and phase.

In winter, pavement temperature gradually increases with increasing depth, but has contrary result in summer.

With the depth increasing, Hysteretic nature gradually increased and annual range of temperature difference gradually decreased. At a certain depth, the difference will tend to 0℃, where we can call the depth annual constant temperature point. Below the point, the structure will be constant temperature layer.



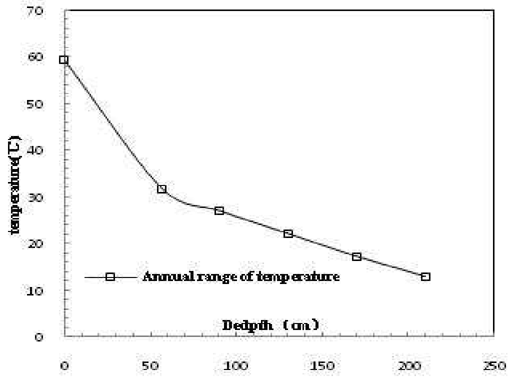


Fig.5: Annual variation law Fig.6: Annual range of temperature difference

Annual Change of Daily Constant Temperature Point

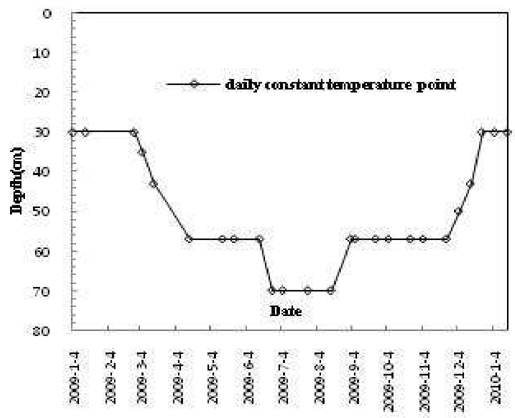


Fig.7: Daily constant temperature point

Figure7 shows the annual change of daily constant temperature point:
The curve is approximately symmetric. In winter, the daily constant temperature point has the minimum at 30 centimeter. And in summer, it has corresponding maximum at 70 centimeter. Moreover, there is sharply change in spring and autumn.

Freezing Depth Line

Figure 8 and Figure 9 shows that, the freezing depth line start in mid-November and reach maximum in late February with 120 cm. Subsequently, upper layer and lower layer start to melt synchronously in spring, which result in the appearance of freezing core. The freezing core is unique freezing phenomenon in seasonally frozen regions.

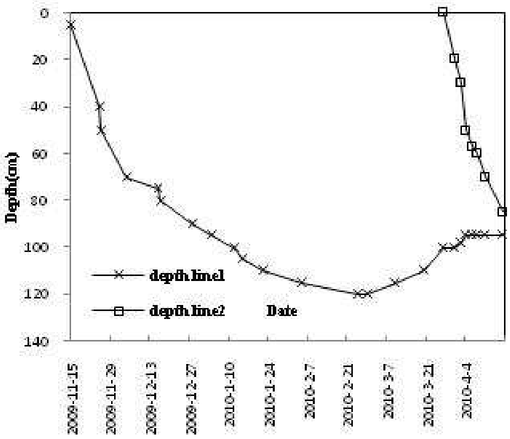


Fig.8: Freezing depth line in 2009~2010

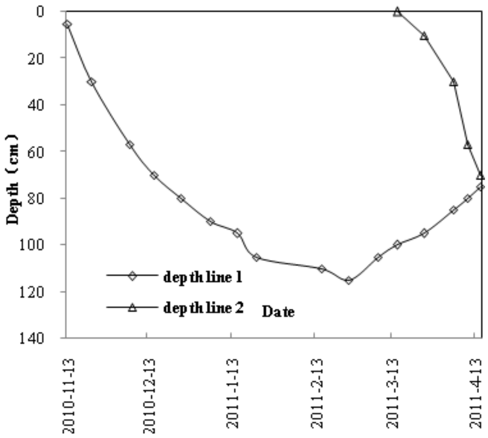


Fig.9: Freezing depth line in 2010~2011

Conclusions

The atmospheric and pavement temperature shows cycle sine rule. Heat up time is much shorter than the time to cool, so heating rate is greater than the cooling rate. As increasing depth, the fluctuation range of pavement temperature decreases gradually, which lead to the appearance of daily and annual constant temperature point. The max freezing depth appeared at 120 cm and there will be freezing core in spring in seasonally frozen regions.

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