Research on Pavement Temperature Prediction Based on Neural Network

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Abstract. Through data of pavement temperature, air temperature, humidity, wind speed and rainfall in the Dianjiang-Wanzhou section of G42 Shanghai-Chengdu Expressway from 2014 to 2016, it is found from the change law of the pavement temperature of this expressway section that the annual average values of pavement temperature of most monitoring stations gradually lower, but extent is not quite big; the lowest pavement temperature is between -3.2°C and 1.4°C, the highest pavement temperature is 57.9°C to 76.5°C; no matter which season, the pavement temperature and air temperature are characterized by rapid temperature rise after sunrise and significant temperature drop after sunset; the correlation between pavement temperature and air temperature is the best, the correlation coefficient reaches 0.986, and then its correlation with humidity, wind speed and rainfall decrease progressively, and they are -0.467, 0.189, 0.034, respectively. It can be found from the prediction results of pavement temperature in Chongqing Dianjiang-Wanzhou Expressway section based on neural network that the summer error is the largest, the spring is second, the autumn error is less, and the winter error is the smallest; from the angle of fitting degree of time series, the autumn fitting is optimal, the spring and winter is second, the summer effect is not good enough; the correlation coefficient between the model prediction sequence and the live sequence of the four seasons is greater than 0.89, and the overall effect is ideal. Through the research on pavement temperature, the cooperation between meteorological department and transportation departments can be strengthened, accident losses can be reduced, and the maximum benefit of road transportation can be brought into playr.

Keywords: Expressway, pavement temperature, meteorological service.

1. Introduction

The communications and transportation are the foundation of the development of the national economy, and are prerequisite for the normal operation and coordination of social production, circulation, distribution and consumption and so on. By the end of 2017, the traffic mileage of Chongqing expressway had exceeded 3,000 kilometers. Chongqing has special topography and is characterized by fog, heat and changeable weather; etc., therefore, road transportation safety is often affected by meteorological disasters such as dense fog, rainfall, thunderstorms, strong wind, snowfall, low temperature freezing, high temperature and the secondary disasters caused by the above meteorological disasters. Especially in the summer season of Chongqing, the average temperature is high, the high
temperature time is long, and the continuous high temperature causes the pavement temperature to be too high, the driving is prone to tire burst, which causes a series of traffic safety accidents. Safeguarding the safety of national life and property, avoiding and reducing traffic accident losses have become the consensus of governments at all levels and the public, therefore, it is particularly important to carry out industrial meteorological services for communications and transportation, especially related services in hot weather are particularly important [1-4]. However, the current road weather service only includes regular weather, temperature, rainfall and other forecast products, and there is no pavement temperature forecast of expressway. In order to strengthen the cooperation between meteorological department and transportation department, reduce accident losses, and maximize the benefits of road transportation, this paper takes the Dianjiang-Wanzhou section of the G42 Shanghai-Chengdu Expressway in Chongqing as an example and carries out the research on expressway pavement temperature.

2. Research on the Distribution Law of Pavement Temperature of Dianjiang-Wanzhou Expressway

2.1. Year Change
It can be found from the monitoring data of Dianjiang-Wanzhou section of G42 Shanghai-Chengdu Expressway from 2014 to 2016 that the annual average value of the pavement temperature of most monitoring stations gradually decreased, but the extent was not too big. The lowest pavement temperature was between -3.2°C and 1.4°C, it appeared in December or January, and the highest pavement temperature is 57.9°C to 76.5 °C, all appeared in July.

2.2. Month Change
Analysis of the month change of pavement temperature found that all stations in 2014 showed obvious single peak characteristics: the pavement temperature reached the maximum in July, and the pavement temperature in winter was lower, among them, Mawangcao and Jinzhulin station reached minimum value in December and the rest of 10 stations reached minimum value in January. The temperature rise was obvious in June and July, the largest was Xiaoyakou Station (differ by 12.7°C), and the smallest was Liangping Station (differ by 6.6 °C).

In 2015, all stations showed obvious single peak characteristics: the pavement temperature reached maximum value in July, and the winter pavement temperature was lower, among them, Liangping toll station, Longbao, Tiancheng and Dianjiang station reached minimum value in January, and the rest of 8 stations reached minimum value in December. The extent of monthly temperature rise was the largest in March and April in 2015; it is between 4.5 and 8.0°C. Compared with 2014, the temperature rose slightly in June and July, the largest was Mawangcao station (differ by 7.4°C), and the smallest is Liangping station (differ by 4.1°C).

The differences between 2016 and the last two years are reflected in: the pavement temperature in July and August was relatively close, and they together formed the peak value of the whole year, in addition, the lowest value of pavement temperature of these 12 stations in this year all appeared in January. Because pavement temperature was generally high in August, the temperature dropped largest in August and September, it was between 6.7°C (Dajiang toll station) and 9.3°C (Longbao station).

2.3. Day Change
The pavement temperature and air temperature two factors from January 2014 to December 2016 in Xiaoyakou station were recorded monthly, and the winter, spring, summer and autumn were represented by January, April, July and October, respectively, the results showed that the day change of pavement temperature in different seasons had different characteristics.

No matter which season, the pavement temperature and air temperature two factors are characterized by rapid temperature rise after sunrise and significant temperature drop after sunset. From the temperature rise/drop extent, the pavement temperature and air temperature were different: the
maximum daily range of pavement temperature occurred in summer, reached 21.1 °C, and the maximum daily range occurred in autumn, and it was significantly smaller than daily range of pavement temperature, it was only 8.2°C. For the occurrence time of the daily highest temperature, the pavement temperature was basically 13-14 hours, and the temperature was lagging behind, when it was 15-16 hours. Compared with the daily temperature changes in different seasons, it was found that the temperature before the sunrise and after sunset in winter was higher than 0.3-0.8°C the pavement temperature, the temperature before sunrise and after sunset in spring and autumn was slightly lower than the pavement temperature or basically similar, the pavement temperature of these two periods in summer was significantly higher than air temperature.

The pavement temperature and air temperature of Mawangcao station from January 2014 to December 2016 were counted hour by hour in accordance with weather, no matter what kind of weather, the road temperature and air temperature two factors were reflected in rapid temperature rise after sunrise and significant temperature drop after sunset. The highest temperature of the pavement during one day was significantly higher than the highest air temperature, and the time was basically 13-14 hours, the occurrence time of highest temperature slightly differ with the weather conditions (17 o'clock on sunny days, 16 o'clock on cloudy days, and 15 o'clock on rainy days).). Among the four kinds of weathers, the difference between the highest pavement temperature and the highest air temperature day was sunny>cloudy>overcast>rainy, the difference between the two is 28.3°C in sunny day, and the rainy day is 7.9 °C. Maybe the reason is that the cloud amount in the sky increases; it reduces the heating effect of short-wave radiation on the ground. On sunny days, cloudy days, and rainy days, the pavement temperature is higher than air temperature at all times in one day, the temperature before sunrise and after sunset in cloudy weather is slightly higher than the pavement temperature, or the two are close.

### 2.4. Correlation Analysis

The correlation between pavement temperature and other meteorological elements (Table 1) found that pavement temperature had the best correlation with air temperature, the correlation coefficient reached 0.986, and passed the 0.01 significance test. The correlation with rainfall is not obvious, and the correlation coefficient is 0.034. The related system of wind speed was 0.189, and passed the 0.01 significance test. The related system of humidity was -0.467 and passed the 0.01 significance test.

| correlation coefficient | pavement temperature | air temperature | rainfall | wind speed | humidity |
|-------------------------|-----------------------|-----------------|----------|------------|----------|
| pavement temperature    | 1.000                 | 0.986**         | 0.034    | 0.189**    | -0.467*  |
| air temperature         | 0.986**               | 1.000           | 0.077**  | 0.186**    | -0.409** |
| rainfall                | 0.034                 | 0.077**         | 1.000    | 0.214**    | 0.326**  |
| wind speed              | 0.189**               | 0.186**         | 0.214**  | 1.000      | 0.072*   |
| humidity                | -0.467**              | -0.409**        | 0.326**  | 0.072*     | 1.000    |

**. When the confidence (double test) is 0.01, the correlation is significant.
*. When the confidence (double test) is 0.05, the correlation is significant.

### 3. Pavement Temperature Prediction of Dianjiang-Wanzhou Section of Shanghai-Chengdu Expressway Based on Neural Network

Neural network is actually a data processing system which can automatically realize the non-linear mapping relationship between two groups of variables. The essence of the algorithm is gradient descent method in optimization calculation. Using the first derivative information of the error for the weight and the threshold, and applying the principle of error back propagation constantly adjust the network weights and thresholds to make the error between the network output value and the expected value squared, and reach the minimum or less than the set accuracy. Neural network model is generally composed of input
layer, hidden layer and output layer. The elements used in the pavement temperature prediction of Dianjiang-Wanzhou section of Shanghai-Chengdu Expressway based the neural network include pavement temperature, wind direction, wind speed, rainfall, temperature and humidity. Sample duration: hourly data in 2014-2016. Sample selection principle: considering that the validity requirements of modeling for record. Removing the record of wind direction as PPC, namely the sample is selected when the wind is not static. The records without testing values in the element are removed. Modeling method: the model information uses neural network, which is divided into winter, spring, summer and autumn for modeling; 12 stations are separately modeled; samples of each station for each season is randomly partitioned with 9:1 ratio, 90% of the samples are used to train neural network models, and 10% of the samples are used to test the effects of the models built.

Table.2 Analysis and Evaluation Table of Training Samples of Neural Network Model

|      | maximum error | mean error | mean absolute error | standard deviation | linear correlation |
|------|---------------|------------|---------------------|--------------------|-------------------|
| winter | 15.86         | 0.01       | 1.63                | 2.57               | 0.92              |
| spring | 23.87         | -0.01      | 2.60                | 4.20               | 0.93              |
| summer | 47.84         | -0.01      | 3.62                | 6.11               | 0.89              |
| autumn | 21.45         | 0.02       | 1.63                | 2.93               | 0.95              |

Table.3 Analysis and Evaluation Table of Testing Samples of Neural Network Model

|      | maximum error | mean error | mean absolute error | standard deviation | linear correlation |
|------|---------------|------------|---------------------|--------------------|-------------------|
| winter | 10.00         | -0.08      | 1.48                | 2.30               | 0.92              |
| spring | 18.19         | -0.15      | 2.40                | 3.88               | 0.93              |
| summer | 44.31         | -0.22      | 3.92                | 6.56               | 0.87              |
| autumn | 16.41         | 0.04       | 1.50                | 2.73               | 0.95              |

Taking Hexing station as an example, the prediction and analysis of neural network were carried out. Table 2 represents the result evaluation of model training samples, from the angle of error, the error in summer is the largest, the spring is second, and the error in autumn is small, and the error in winter is the smallest. From the angle of fitting degree of time series, the fitting in autumn is the best, the second are spring and winter, and the effect is not good enough in summer, the correlation coefficients between the prediction sequence and the actual sequence of the four seasons are all greater than 0.89, and the effect is relatively ideal. Table 3 reflects the effect evaluation of model test samples; it can be found that the performance is roughly the same as that in table 2, there is a slight decrease in summer. As can be seen from the time series diagram in Figure.1, we can see that the extreme value forecasting ability is slightly worse in summer, and other seasons are good, which is consistent with the conclusion in the table.
4. Conclusion

Through data of pavement temperature, air temperature, humidity, wind speed and rainfall in the 8 traffic weather stations of Dianjiang-Wanzhou section of G42 Shanghai-Chengdu Expressway from 2014 to 2016, by analyzing the change law of pavement temperature in this expressway section, it is found that the annual average value of pavement temperature of most monitoring stations decreases gradually, but the extent is not large. The minimum pavement temperature was between -3.2°C and 1.4°C, appeared in December or January, and the highest road temperature was 57.9°C to 76.5°C, all appeared in July. No matter which season, the pavement temperature and air temperature two factors are characterized by rapid temperature rise after sunrise and significant temperature drop after sunset. The highest temperature of pavement during one day is significantly higher than the highest temperature, and the occurrence time is basically 13-14, the highest temperature occurs slightly with the weather conditions. It is sunny at 17 o'clock, cloudy at 16 o'clock, and rainy at 15 o'clock. The pavement temperature had the best correlation with temperature, the correlation coefficient reached 0.986, and the correlation coefficient with humidity was -0.467. The pavement temperature forecast analysis of the Dianjiang-Wanzhou section of Chongqing based on the neural network shows that the summer error is the largest, the spring is second, the autumn error is small, and the winter error is the smallest. From the angel of time series fitting, the autumn fitting is optimal, the spring and winter are second, and the summer effect is not good enough. The correlation coefficient between the model prediction sequence and the live sequence of the four seasons is greater than 0.89, and the effect is ideal.
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