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Study on the Influence of Ice and Snow on Pavement Evaluation

Ou Zhilin*,Bai Bin**,Lv Yongheng**
(Department of Road and Railway Engineering,Chongqing Jiaotong University, Chongqing 400074, China)

Abstract
The study analyzed mountainous highway operation safety factors from the road environment, traffic environment and climate factors. Utilizing the indoor test to measure the friction coefficient of ice and snow road, summarize the changing trends of friction coefficient which was compared with accident rates, and then establish the model of friction coefficient and accident rate. A model of the vehicle under snow environment was put forward. The study deeply analyzed the influence of snow and ice weather on the roadpavement;it can provide technical support for highway of seasonal frozen area dealing with ice and snow weather.
***Keywords*:**Snowstorm,Pavement,Impact evaluation,Security measures

I. Introduction

In recent years, extreme weather occurs frequently, in connection with the impact of ice and snow weather on pavement performance, domestic and foreign experts and scholars conducted a series of studies in terms of pavement performance evaluation, new materials development and security technology in seasonal frozen area and achieved a series of results [1-5].

However, the research to make the appropriate security measures is not perfect. This study based on the impact evaluation of ice and snow on the mountainous highway pavement, analyzed of Coupling Relationship between road and vehicle, proposed road safety measures to provide technical support for the highway safety operations in ice and snow.

II. Operational safety analysis of highway in ice and snow

II.1. Road environment

Road conditions including road linear, geometric layout of section and pavement conditions have impact on highway safety operations. The highway is a linear structure, in the mountains, its linear is winding and longitudinal slope changes frequently, especially the mountain curved bridge road in the high elevations, tunnels import and export located in the back side of mountain and big longitudinal slope sections are dangerous places in ice and snow weather.

Concave vertical curve is easy to water and freeze at low temperatures, and the size of the vertical curve radius has great impact on driving line of sight. Accidents occur easily under the joint action of two adverse factors.

II.2. Traffic environment

About traffic factors in ice and snow weather,we mainly consider the following: operating problems, such as slow moving and traffic jams; time affect, such as peak time and congestion time and the effectiveness of timely processing the ice and snow. The motor vehicles impact the pavement under snow and ice in the following aspects: the tires rolling, scratching, removing and dispersing ice and snow from the road; Motor vehicle engine generates heat to increase the road temperature; The driving vehicle takes away deicing salt on the road spreading before snow, reducing snowmelt quality.

II.3. Climate factors

Climate is an important factor affecting the safe operation of road in ice and snow weather. Meteorological elements can describe the weather, such as the type of precipitation and rainfall, visibility, wind speed and direction, temperature and relative humidity, etc. Precipitation type is undoubtedly the most important meteorological condition, it is essential to master and identify its precipitation type and accumulation of data in the planning stage of dealing with ice and snow in winter. Other important factors affecting pavement condition in winter are cloud cover conditions, air temperature, pavement temperature change trend within a certain range, freezing temperature, condensation point, pavement temperature, relative humidity, wind speed and wind direction, etc.

III. Antiskid characteristics impact evaluation of pavement in ice and snow

The impact of snow and ice on the pavement antiskid characteristics is to cover the road, so that the pavement temperature decreases and the friction coefficient becomes smaller. This study conducted field test on the correlation between pavement static friction coefficient and the temperature and the correlation between pavement dynamic friction coefficient and speed, then established the relationship models between pavement temperature and dynamic friction coefficient with different speeds.

III.1. Test on the change of pavement dynamic friction coefficient in ice and snow

When the vehicle is moving, the friction force is sliding friction but not static friction, so it is necessary to test the change of dynamic friction coefficient when measure the vehicle friction force in the process of moving.

The basic principle of the test [6]: Experiments based on the Coulomb law of friction, under different circumstances, by measuring the frictional resistance (F) and contact surfaces pressure (N), to study the nature of the sliding friction coefficient(μ).

During the experiment, put the car on the snow surface, the car will get a acceleration (a) due to the frictional resistance, for the measurement of acceleration, assuming t_1,t_2,t_3 is the time a thin rod used to via the three photoelectric doors respectively, f is the distance between the two photoelectric doors, d is the diameter of the light shielding thin rod, g is the acceleration of gravity. Assuming v_1 is the average velocity within the t_1 time, v_2 is the instantaneous velocity of a thin rod through the intermediate position of photoelectric door, according to the basic laws of the uniformly accelerating linear motion, the equation between v_1 and v_2 is $v_2^{\,2} = v_1^{\,2} + a^2 t_1^{\,2}/4$, becauseof $a^2 t_1^{\,2}/(4v_1^{\,2}) \le 1$, $v_2 \approx v_1 \approx d/t_1$. Likewise, the speed of thin rod through the middle positions of the two remaining photoelectric door is $v_2' \approx d/t_2, v_1'' \approx d/t_3$, according to Newton's theorem, $a = (v_2^{\,2} - v_1^{\,2})/2l$. According to Newton's second law $F = ma$,and $a = \mu \cdot N, N = mg$, μ=a/g can be obtained.

III.2. Analysis of test results

Figure 1 shows the specific relationship between the temperature, speed and the sliding friction coefficient.

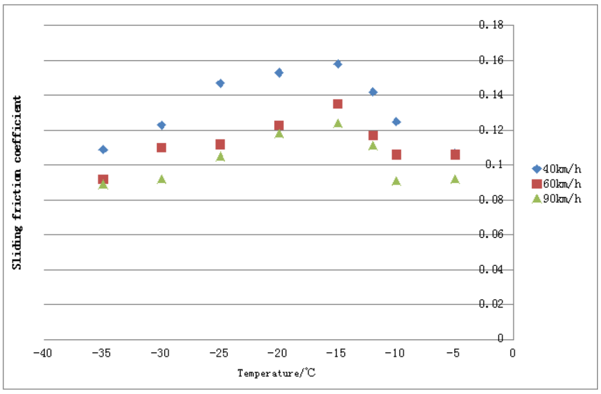

Fig. 1 Changes of sliding friction coefficient trend with different temperature of three speed conditions

(i) Regression analysis of the temperature and sliding friction coefficient with different speeds. When the speed is 40km / h, the relationship model between surface temperature andfrictioncoefficient:

$$\mu = -0.0002t^2 - 0.0085t + 0.0694, R^2 = 0.909$$

When the speed is 60km / h, the relationship model between surface temperature and friction coefficient:

$$\mu = -0.0001t^2 - 0.0042t + 0.0851, R^2 = 0.7285$$

When the speed is 90km / h, the relationship model between surface temperature and friction coefficient:

$$\mu = -0.0001t^2 - 0.0047t + 0.0695, R^2 = 0.6536$$

It is obvious that when the speed increases, the effect of temperature on the correlation coefficient of sliding friction reduces.

(ii) With the increase of sliding speed, the friction coefficient decreases, then stabilizes gradually, which is consistent with many of the results of academic research.

(iii) Friction coefficient of snow is relatively complex as the temperature changes. With the decrease of the snow temperature, the friction coefficient increases and then decreases, reaches maximum between -15℃ and -20℃.

III.3. The relationship between the friction coefficient and the accident rate

This study reached the accident rate situation under different friction coefficient intervals, the results are shown in Table 1 and Figure 2.

Table1 Accident rate under different friction coefficient intervals

Friction coefficient intervals	Accident rate (Millions of vehicles/ km)
<0.15	0.80
0.15～0.24	0.55
0.25～0.34	0.25
0.35～0.44	0.20

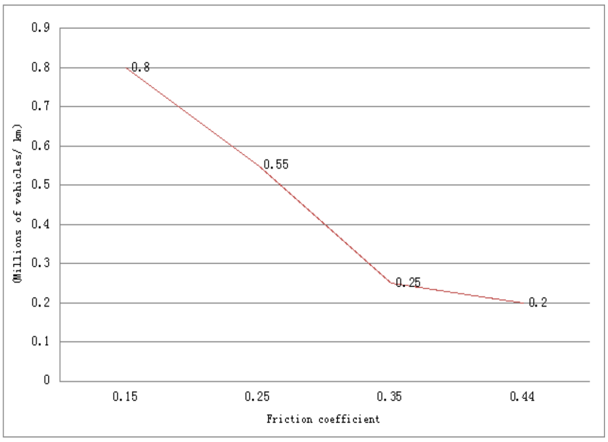

Fig. 2 Relationship between friction coefficient and the accident rate

As shown in Table 1, when the friction coefficient reduces to 0.15, accident rate increases significantly, this time the frictional resistance between the vehicle and the road surface reduces severely, which greatly affected the safety driving of motor vehicles.

The following regression model can be obtained by the accident rate and the friction coefficient data:

$$D = 0.21\mu + 0.975,\quad R^2 = 0.9383$$

Where D is the accident rate (millions of vehicles/ km), μ is the friction coefficient.

It can be obtained that the accident rate and friction coefficient have significant negative correlation, the greater the friction coefficient, the accident rate is smaller relatively, and the correlation is very high.

IV. Mechanical model of vehicle driving in and snow

IV.1. Rigid body model

The vehicle motion is assumed to be rigid motion, the basic principles of the ion dynamics is available for the driving vehicle. If the longitudinal acceleration of the vehicle is a, the gravitational acceleration is g, the frictional force of the vehicle can be expressed as the Equation (1).

$$f_1 = a / g \qquad (1)$$

Generally, the speed is easy to measure than acceleration, when the longitudinal velocity is v, the friction that the vehicle suffered can be expressed as the Equation (2).

$$f_2 = (\frac{dv}{dt}) / g \qquad (2)$$

If the initial speed, stopping speed and driving distance of the vehicle is known, the friction that the vehicle suffered can be expressed as the Equation (3).

$$f_3 = (v_1^2 - v_2^2) \big/ 2gS \qquad (3)$$

It can be obtained from Equation (3) that when the driving speed is certain, the vehicle braking distance becomes larger due to the road friction reduction, which can cause rear-end collision easily and effect traffic security seriously.

IV.2. The interaction model of tire and road

Tire and road contact region consists of attachment region and sliding region, the frictional force induces a longitudinal displacement in the attachment region, in sliding region, the displacement is generated by the sliding force. The length of the attachment region interaction between tire and road surface can be derived by the following equation [7].

$$\frac{n+1}{n}\frac{2^n F_Z \mu_S}{l^{n+1} w}\left[(\frac{l}{2})^n - (l_n - \frac{l}{2})^n \right] = sC_x l \quad (4)$$

Where s is the sliding ratio, n is order points along the contact surface, l is contact length, w is contact width, μ_s is standard friction coefficient, C_x is the elasticity coefficient of tires, F_Z is vertical load.

In Equation (4), the sliding ratio s mainly refers to the ratio of the difference between vehicle and wheel speed and the vehicle speed.

When the vehicle is decelerating,

$$S_d = \frac{V_{bdy} - V_{whl}}{V_{vhl}} \qquad \left(S_d > 0\right) (5)$$

When the vehicle is accelerating,

$$S_a = \frac{V_{bdy} - V_{whl}}{V_{vhl}} \qquad \left(S_a < 0\right) \quad (6)$$

Where V_{vbd} is the vehicle speed, V_{whl} is the wheel speed, the value intervalof S_d is (0,1), the value interval of Sa is (-1,0).

Anti-skid Braking System, referred to ABS, is a automotive safety control system with non-slip, anti-lock and other advantages. Emergency braking or braking on low adhesion coefficient road such as ice and snow road, because the braking force exceeds the maximum adhesion force that road surface can provide, the rolling wheels and road surface tend to slip and the wheels tend to lock. The locking wheels will lose the lateral adhesive ability, can't withstand lateral forces, front wheels locking generally causes the car to lose steering capability, rear wheels locking can cause the car drift and instability. The sliding ratio of ABS is 0.15 to 0.20, under such conditions the tire contact length is 20% to 40% of the entire contact surface. After the contact length is determined, the longitudinal force acting on the entire tire contact surface is the sum of adhesion in attachment region and sliding force in sliding region [8].

$$F_x = sC_x w \frac{l_h^2}{2} + \frac{n+1}{n}\frac{2^n F_z \mu_d}{l^{n+1}}\left[\left(\frac{l}{2}\right)^n (l - l_h) - \frac{1}{n+1}\left\{ \left(\frac{l}{2}\right)^{n+1} - (l_h - \frac{l}{2})^{n+1} \right\} \right] \qquad (7)$$

It can be obtained from Equation (7) that the adhesion force depends on the length of the attachment region. In ice and snow, due to the increases of the road surface unevenness, the length of the tire and the road surface attachment region changes, the vehicle prone to skidding.

V. Conclusions

By analyzing the impact of ice and snow on the traffic,the study conducted tests on the road surface friction coefficient at different temperatures and at different speeds, analyzed the relationship between the changes of friction coefficient and accidents, established the regression model of friction coefficient with the accident rate. It obtained that accident rate and friction coefficient has significant negative correlation, the greater the friction coefficient, the accident rate is relatively smaller, and the correlation is very high.

In addition, we analyzed the mechanical model of vehicle driving in ice and snow, proposed interaction model of tire and road surface, further analyzed the effects of ice and snow on the road and the vehicle, and then provide technical support to cope with winter weather for seasonal frozen areas.

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