DESIGNING AND CONSTRUCTION OF ROADS, SUBWAYS, AIRFIELDS, BRIDGES AND TRANSPORT TUNNELS

UDC 625.768.5

Voronezh State University of Architecture and Civil Engineering
Ph. D. in Engineering of Dept. of Design of Automobile Roads and Bridges
A. S. Gasparyan
D. Sc. in Engineering, Prof. of Dept. of Design of Automobile Roads and Bridges
T. V. Samodurova
Russia, Voronezh, tel.: (473)271-52-02; e-mail: tvs@vmail.ru

A. S. Gasparyan, T. V. Samodurova

TRAFFIC SAFETY ASSURANCE DURING WINTER MAINTENANCE OF HIGHWAYS

Statement of the problem. The problem of determining safe distances between snowplows during winter road maintenance has been discussed with consideration for safe overtaking.

Results and conclusions. Road, weather and technology factors influencing road safety were justified. The mathematical models for calculation are reported. The maximum permissible safe speeds for different road pavement conditions regarded as limiting conditions were computed. Calculations were performed for a wide range of road machine speeds and for various winter pavement conditions. The values obtained were compared with the values presented in standards.

Keywords: traffic safety, winter road maintenance technology, road pavement, overtaking.

Introduction

The Federal target program "Traffic Safety Improvement in 2006—2012" argues that the emergency risks posed by motor vehicles have been a particular concern over the last decade. The main reason for high emergency risks are the failure of the road infrastructure to keep up with the demand of society and state for the safe traffic, as well as poor traffic safety monitoring, outright ignorance and disregard of traffic participants.

Road conditions are usually direct and indirect cause of road traffic accidents. About 40 % of the RF road network tends to become slippery in winter thus causing excessive skidding. The analysis suggests that 12—15 % of the total road traffic accidents are caused by poor road conditions with 50 % occurring in the winter months due to a low road surface grip level. Therefore providing safe driving conditions during inclement weather is one of the major problems to be addressed by a road maintenance service.

In order to secure traffic safety during winter months, a road maintenance service undertakes maintenance works on road surfaces, artificial structures and betterment facilities. According to today's guidance documents there is a time limit for removing the effect of adverse weather conditions. However, during rainfalls and anti-skid works, there is an elevated risk of road traffic accidents owing to a decreasing grip level on an icy road surface, reduction in visibility during rainfalls, change in a traffic stream speed and overtaking during the operation of winter maintenance vehicles.

1. Road winter maintenance technologies and their effect on traffic safety

In the course of winter road maintenance winter maintenance vehicles cause a lot of travel disruption. There are the following factors to be identified that impact traffic safety:

- speed of travel of winter maintenance vehicles as they operate;
- large dimensions of rigging;
- winter maintenance vehicles positioned across the traffic lane;
- decreasing visibility of on-coming traffic during rainfalls;
- lower width of a traffic lane due to snow piling up as it is being removed.

At the core of the research lay the classification of technologies of winter road maintenance developed by the authors of the present paper and identified in Table 1 [1]. It was supplemented by a list of environmental and road parameters that impact traffic safety during winter road maintenance and anti-skid works.

Table 1

Factors affecting traffic safety during winter road maintenance works

Winter road maintenance technology	Factors affecting the traffic safety		
	Environmental	Road	Technology
Anti-skidding	Rainfalls (slushes, torrentials). Sleet. High air moisture	Lower grip coefficient	Speed of travel of winter maintenance fleet

End of Table 1

Winter road maintenance technology	Factors affecting the traffic safety		
	Environmental	Road	Technology
Preventive winter road maintenance	The same	-	The same
Removing loose snow off the surface	Precipitations (snow). Reduction in meteorological visibility	Decrease in the grip coefficient, evenness of the surface, width of a traffic lane, increase in rolling resistance	Speed of travel of the maintenance fleet, large dimensions of the maintenance vehicles, vehicles positioned across the traffic lane
Snow skid prevention	The same	The same	Speed of travel of the maintenance fleet
Friction material distribution	-	Decrease in the grip coefficient, flatness of the surface	The same

2. Calculating parameters of overtaking a maintenance fleet

The calculation of basic parameters of overtaking a maintenance fleet (overtaking sight distances and speeds) was performed with a view to find out whether this manoeuvre can be undertaken without disrupting the overall traffic safety.

V. F. Babkov [2] found out that the overtaking patterns are normally inconsistent with the currently agreed theoretical schemes. This is because the existing schemes make no consideration of peculiarities of the driver's judgment and response. A typical overtaking scheme is shown in Fig. 1.

During winter road maintenance overtakings have to be undertaken in adverse driving and weather conditions, in restricted visibility and low grip of the tires with the ground. The overtaken vehicle is a maintenance vehicle with dimensions of the rigging that large that it occupies the entire traffic lane.

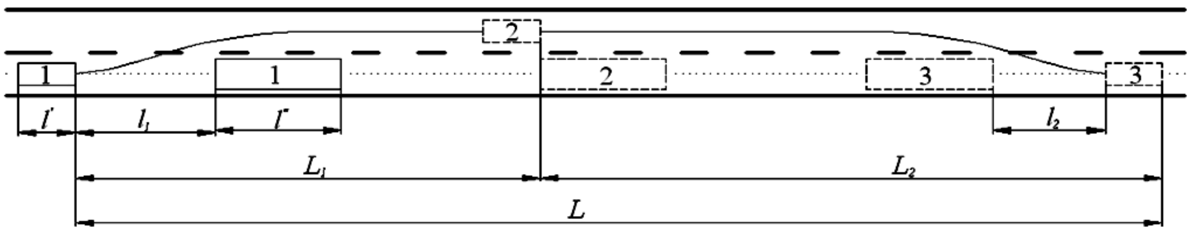

Fig. 1. Scheme of overtaking a vehicle:
1, 2, 3 — mutual positioning of the overtaken and overtaking vehicles at various overtaking points:
before overtaking (1), the overtaking vehicle catches up with the overtaken one (2), overtaking is completed (3);
L —overtaking path; l_1, l_2 — distances between the overtaking and overtaken vehicles at the moments overtaking is commenced (first safety margin) and completed (second safety margin);
l^I — length of the overtaking vehicle; l^{II} — length of the overtaking vehicle

The objective of the calculation was to determine the magnitude of a minimal technology gap L_P between the maintenance fleet that secures a safe overtaking. The design scheme of overtaking is presented in Fig. 2.

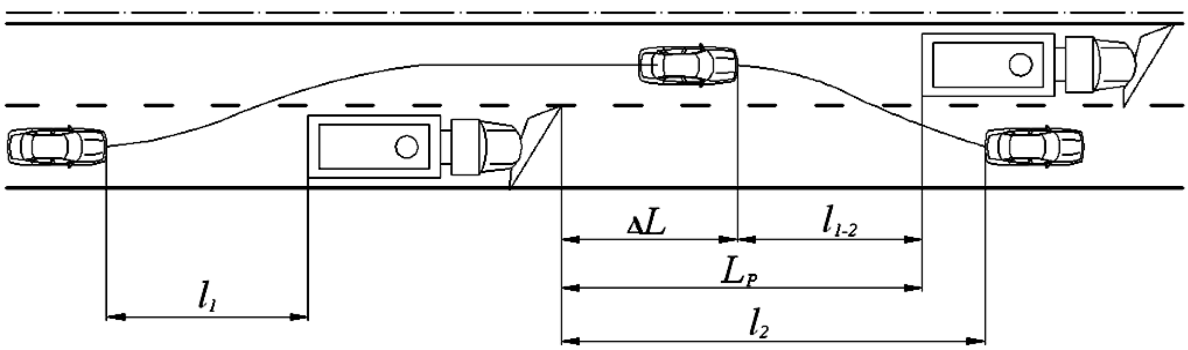

Fig. 2. Calculation scheme of overtaking during the operation of the maintenance fleet

The value L_P can be defined by the formula

$$L_P = \Delta L + l_{1\_2}, \qquad (1)$$

where ΔL is the distance between the road maintenance vehicle and overtaking vehicle at the moment it gets back onto its side of the road; l_{1_2} is the first safety margin in relation to the first vehicle in the maintenance fleet.

The overtaken car viewed in the rear of the overtaking car is necessary for the latter to get back onto its side of the road. The research by M. B. Afanasyev showed that the overtaking car gets back onto its side of the road halfway through the second safety margin l_2 [3], thus ΔL can be given by

$$\Delta L = +0.5 \cdot l_2 . \tag{2}$$

The known empirical formulas were used to calculate travel speeds of cars during overtaking [2]:

$$v_1 = v_0 + \Delta v_1 = v_0 + \frac{k_1(13 - k_2 v_0) + 15}{k k_2 l^{II}}, \tag{3}$$

$$v_2 = v_0 + \sqrt{2 l_1 a + \Delta v_1^2}, \tag{4}$$

$$v_3 = v_0 + k_3 \Delta v_2, \tag{5}$$

where v_0 is the average travel speed of the overtaken car during overtaking, m/sec; v_1, v_2, v_3 are speeds of the overtaking car, m/sec; Δv_1, Δv_2, Δv_3 are differences of speeds of the overtaken and overtaking cars at points 1, 2 and 3 respectively (see Fig. 1); a is the acceleration of the overtaking car

$$a = \frac{(D - \psi)}{\delta_{вр}} \cdot g, \tag{6}$$

where D is a dynamic factor; g is acceleration of gravity; ψ is the road resistance coefficient; $\delta_{вр}$ is the coefficient that allows for the effect of rolling masses.

The formulas [2] were used to calculate gaps during overtaking

$$l_1 = \frac{k_1 k_v k_{\Delta v} k_э^I v_1^2 - k_э^{II} v_0^2}{2g(\phi \pm i)} + 4, \tag{7}$$

$$l_2 = \frac{k_4 k_5 k_6 k_v k_{\Delta v} k_э^I v_3^2 - k_э^{II} v_0^2}{2g(\phi \pm i)} + 4, \tag{8}$$

$$L = l_1 + L_2 = l_1 \left(1 + \frac{2v_0}{\Delta v_1 + \Delta v_2}\right) + \left(l_1 + l^I + l^{II}\right) \cdot \left(1 + \frac{2v_0}{\Delta v_1 + \Delta v_2}\right), \tag{9}$$

$$l_{1\_2} = \frac{k_1 k_v k_{\Delta v} k_э^I v_2^2 - k_э^{II} v_0^2}{2g(\phi_1 \pm i)} + 4, \tag{10}$$

where k_i are empirical coefficients that allow for driving, environmental and technical factors; φ is the grip coefficient; i is a longitudinal gradient (in units of one).

The formulas (3)—(10) were selected for the calculation based on that the included parameters make maximum consideration of the effect basic road and transport parameters have in the course of an overtaking manoeuvre (namely, the width of a traffic lane, speed of travel, sight distance, longitudinal gradients of the road, grip and rolling resistance coefficients, dynamic characteristics of vehicles, dimensions of vehicles.

In the course of the calculation restrictions were made on maximum travel speeds of vehicles in adverse weather conditions with regard to the grip coefficient that relates to the road surface condition which is a likely one in the winter season. A maximum possible speed on a horizontal area and uphill given that it is necessary that the vehicle's wheel has a grip with the road surface with regard to the rolling resistance was defined using the formula set forth by A. P. Vasiliev [4]:

$$V_{\phi \max} = \frac{m \cdot \phi_{20} - f_{20} - i}{m \cdot \beta_{\phi} + k_f} + 20, \quad (11)$$

where m is coefficient of adhesion; β_φ is the coefficient that accounts for grip change in different types and states of road surfaces caused by speed; φ_{20} is the grip coefficient at the speed of 20 km/h; f_{20} is the coefficient of rolling resistance at the speed of 20 km/h; k_f is the coefficient of an increase in rolling resistance with speed.

The outcome of the calculation using the formula (11) was the magnitude of maximum acceptable travel speeds of vehicles for different states of road surfaces that contribute to the overall traffic safety. The design values of the speeds are given in Table 2.

The speed values obtained during further calculations are compared to maximum acceptable ones in certain states of road surface (Table 2) and are replaced by the latter in case they exceed.

The results of calculating an overtaking path depending on the speed of travel of the maintenance fleet and state of the road surface are identified in Fig. 3.

The calculations yielded graphs for determining a technology gap between vehicles in the fleets involved in winter road maintenance and ensuring a safe overtaking.

Table 2

Values of maximum acceptable speeds
of travel for different states of road surfaces

State of road surface	$V_{ф\ max}$, km/h
Loose snow of up to 10 mm in width	81.6
Loose snow of 10—20 mm in width	62.4
Skids	76
Glaze ice	45

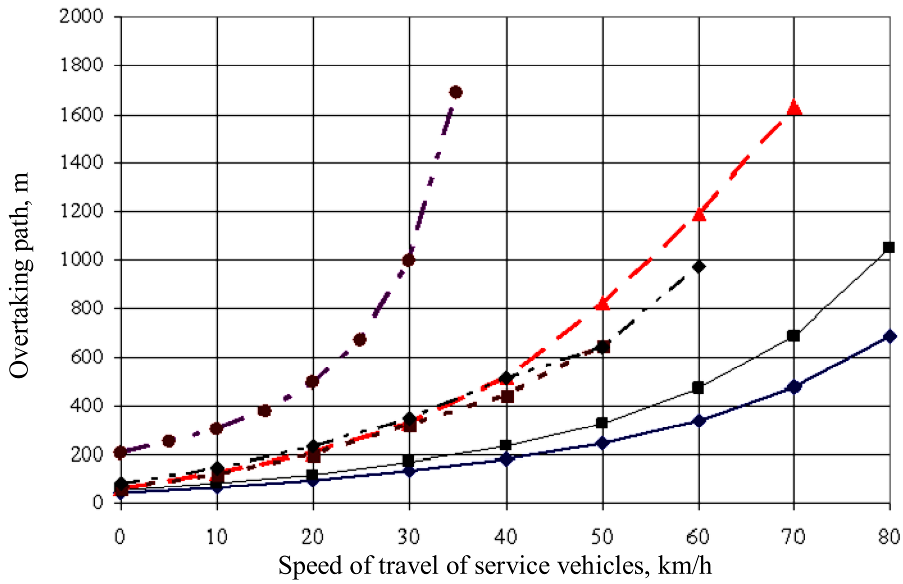

Fig. 3. Safe overtaking distance for different states of road surfaces:
dry; wet; loose snow on the surface of up to 10 mm in width;
loose snow on the surface of 10—20 mm in width;
skid; glaze ice

They are presented in Fig. 4 in conjunction with the values of a technology gap as set out in guidance documents.

The graph analysis showed that the state of the road surface contributes significantly to the magnitude of a technology gap. Table 3 provides a comparative characteristics of magnitudes of technology gaps as set out by the guidance documents and obtained experimentally.

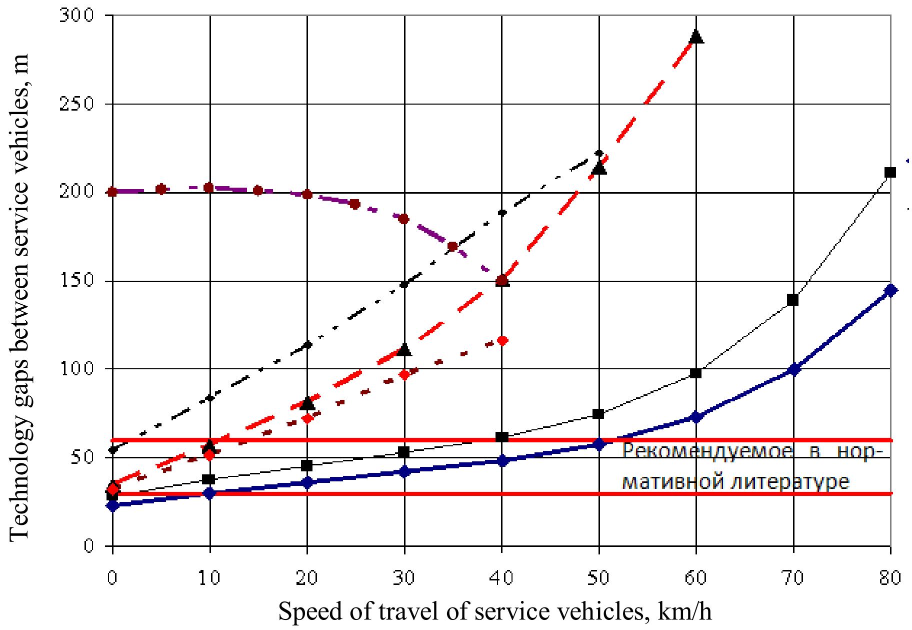

Fig. 4. Technology gaps between road service vehicles ensuring a safe overtaking:
рекомендуемое в нормативной литературе — as set out in the guidance literature;
dry; wet;
loose snow on the surface of up to 10 mm in width;
loose snow on the surface of 10—20 mm in width;
skid; glaze ice

Table 3

Technology gap between road service vehicles

Winter road maintenance method	Speed of travel of the maintenance fleet, km/h	Technology gap, m	
		Set out in the guidance	Calculated
Anti-skid works	30—40	30—60	150—200
Preventive winter road maintenance	30—40	Are not set out	50—100
Removing loose snow off the surface	30—40	30—60	100—150
	50—60	100—150	200—300

End of Table 3

Winter road maintenance method	Speed of travel of the mainten-ance fleet, km/h	Technology gap, m	
		Set out in the guidance	Calculated
Snow skid prevention	30—40	Are not set out	100—150
Friction material distribution	30—40	30—60	100—150

The outcome of the research can be made use of in the development of technology routing of a variety of road maintenance works.

Conclusions

1. A method of calculating magnitudes of technology gaps between road service vehicles involved in winter road maintenance which ensure traffic safety was suggested. For the first time ever the values of technology gaps for a wide range of travel speeds of road service vehicles with regard to the state of the road surface were obtained.
2. The outcome of the research allows for a more accurate technology routing of winter road maintenance with regard to the maintenance technology and the state of the road surface.
3. The results of the research need to be extended so that weather conditions (average rainfall during the maintenance period) could be given proper consideration.

References

1. T. V. Samodurova, *Operative Control of Winter Roads Maintenance. Scientific Foundations* (Voronezh, 2003) [in Russian].
2. V. F. Babkov, M. B. Afanasyev, A. P. Vasilyev, *Road and Traffic Conditions* (Moscow, 1967) [in Russian].
3. M. B. Afanasyev, G. I. Klinkovshtejn, V. A. Melky, *Highway Regulations and Traffic Safety for a Driver* (Moscow, 1998) [in Russian].
4. A. P. Vasilyev (ed.), *Encyclopaedia of a Road Builder. Vol. II. Repair and Road Maintenance* (Moscow, 2004) [in Russian].