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Determination of the steady deceleration for vehicles category M_1 depending on the type of tires

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Abstract. Tests of vehicles of category M_1 were carried out when using the BRAKE TESTER descener model LWS models - 2 / MC on: dry asphalt concrete coating T = (0 ± 0.5)°C; dry asphalt concrete coating T = (+17 ± 0.5)°C; Rocherated snow coating T = (-15 ± 0.5)°C; The calculation method is considered, the results obtained are analyzed.

1 Introduction

Weather-climatic conditions make significant changes in the trajectory of vehicle movement. The definition of the brake path is not always possible, especially for modern vehicles [1], improving together with technological progress.

Thirty-six modern vehicles were involved to determine the braking path and testing. Measurements were carried out using the BRAKE TESTER model LWS models - 2 / MC.

To determine the deceleration of vehicles, a desperometer was used, having an error of measurements of the steady deceleration of no more than 4%. The deceleration sensor of the instrument was fixed on the windshield inside the car and it was calibrated before each measurement. Measures of the brake path and deceleration were made on the summer and winter studded and non-studded rubber with different tread pattern height. The depth of the tread pattern was determined using the caliper. The mass of the vehicle was determined as the oven mass and a mass of one passenger [2].

Measurements of the deceleration of vehicles of category M1 were carried out on: dry asphalt concrete coating at positive temperatures [1, 6]; on a wet asphalt concrete coating at zero temperatures [3,5]; On the rolled snow coating at negative temperatures [4].

An experimental study was carried out on an even portion of the road surface (with a thicker of the rolled snow more than three centimeters).

The slowdown of the TC was fixed from the mark of 40 km / h. It was made by one driver and with one passenger at a given values of factors that have a significant impact on the deceleration of the car [7]. In the experimental study, 36 modern vehicles category M1 were involved. The slowdown of each of them was fixed by a deceterometer from 5 to 10 times in order to prevent the introduction of false data [8, 9].

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2 Experimental studies

The sensor that registers the slowdown of vehicles, was attached to the windshield glass of the vehicle, and its calibration was performed at each measurement (due to the possibility of changing its position as a result of emergency braking) [10]. On the granted drawings, the lines describing the process of slowing the machines are visible: red - slowing down; Green - speed, yellow - distance traveled.

2.1 Study of deceleration in the summer

As a result of experimental studies to establish a slowdown in the vehicles of category M_1 when using summer tires on a dry asphalt concrete coating and the ambient temperature of +17 ± 0.5 ° C obtained data slowdowns of vehicles and reflected in Table 1. An example of the data obtained is shown in Fig. 1 and Fig. 2.

From these graphs it can be seen that:

- measurements were performed on a dry asphalt concrete coating [11];
- peak deceleration value was achieved at the beginning of braking [12];
- Emergency braking system was used;
- Braking was carried out with an active anti-lock system [13].

Table 1. Slowing of vehicles of category M_1 when using summer tires on dry asphalt concrete coating and ambient temperature +17 ± 0.5ºC

Brand	Model	Year	Weight, kg	Protector, mm	JTC max, m/s2	Jтс, m/s2	φ
Audi	A8	2016	2035	3,81	11,01	9,5	0,98
BMW	750D	2017	2095	6,26	11,05	9,55	0,99
Mersedes-Benz	S-klasse	2016	2150	4,27	11,07	9,57	0,99
Audi	A6	2018	1884	5,13	10,99	9,49	0,98
BMW	5	2016	1845	3,93	11,06	9,56	0,99
Mersedes-Benz	E-klasse	2017	1815	2,88	11,12	9,62	1
Volvo	S80	2011	1866	4,85	11,05	9,55	0,99
Toyota	Camry	2017	1695	3,14	11,18	9,88	1,03
Lexus	IS	2013	1635	4,28	11,26	9,86	1,03
Mersedes-Benz	C-klasse	2015	1475	4,8	11,08	9,68	1,01
Audi	A4	2016	1485	3,28	10,92	9,81	1,02
BMW	3	2013	1485	3,77	10,63	9,29	0,97
Audi	A3	2008	1625	2,37	10,2	9,41	0,98
Mazda	CX-5	2015	1635	4,64	10,96	9,86	1,02
Toyota	LC 150	2019	2310	3,23	11	9,5	0,98

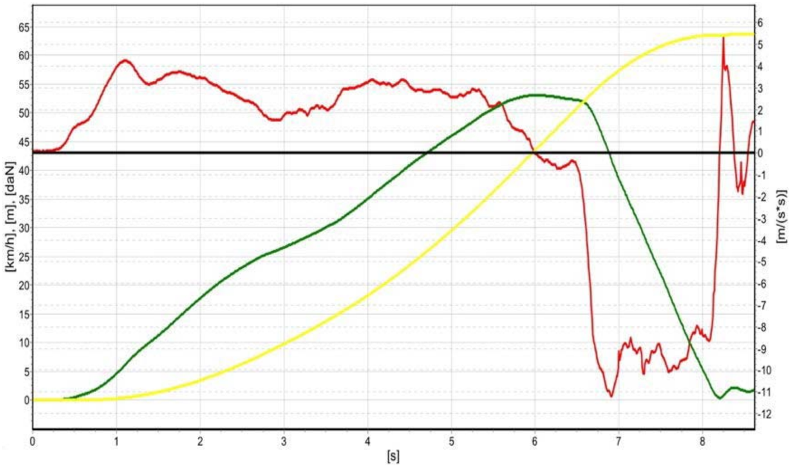

Fig.1 The result of measuring the deceleration of the Audi A3.

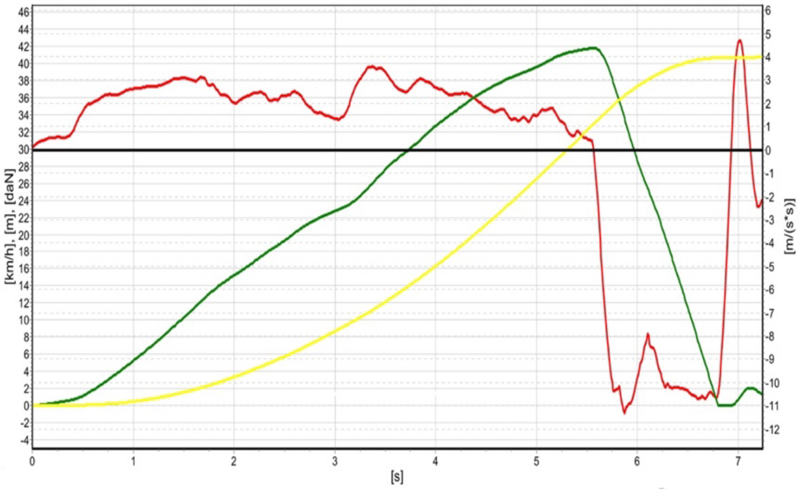

Fig. 2 The result of measuring the deceleration of the Audi A6.

2.2 Study of deceleration in the autumn-spring period

As a result of experimental studies to establish a slowdown of vehicles of category M_1 when using winter rubber on a dry asphalt concrete coating $T = (0 \pm 0.5)^{\circ}$ C obtained data slowdowns. An example of data obtained is displayed on Fig. 3 and Fig. 4.

From the data schedule it is clear that:

- In both cases, an emergency braking system was used.
- Braking was carried out with an active anti-lock system.

With a detailed consideration of the deceleration line, it is clear that a more smooth deceleration was carried out on the Audi AU6 vehicle, while on the BMW 750D vehicle, the active response of the anti-lock system was explicitly expressed [14]. Table 2 presents data obtained during testing.

Table 2. Slowing of vehicles of category M1 when using winter rubber on a dry asphalt concrete coating and ambient temperature 0 ± 0.5 °C

Brand	Model	Year	Weight, kg	Thorns	Protector, mm	$J_{TC\ max}$, m/s^2	J_{TC}, m/s^2
Audi	A8	2016	2035	Yes	6,31	8,01	7,07
BMW	750D	2017	2095	Yes	8,82	7,99	7,1
Mersedes-Benz	S-klasse	2016	2150	No	7,43	7,99	6,97
Audi	A6	2018	1884	Yes	8,03	7,96	7,38
BMW	5	2016	1845	No	6,39	7,98	7,38
Mersedes-Benz	E-klasse	2017	1815	No	5,66	8,04	7,39
Volvo	S80	2011	1866	Yes	7,04	7,97	7,34
Toyota	Camry	2017	1695	Yes	5,84	8,1	7,3
Lexus	IS	2013	1635	Yes	6,64	8,18	7,28
Mersedes-Benz	C-klasse	2015	1475	No	7	7,8	7,18
Audi	A4	2016	1485	Yes	5,94	7,84	7,23
BMW	3	2013	1485	Yes	5,58	7,81	7,17
Audi	A3	2008	1625	No	5,3	8,25	7,34
Mazda	CX-5	2015	1635	Yes	6,89	7,88	7,28
Toyota	LC 150	2019	2310	Yes	10	7,92	7,29

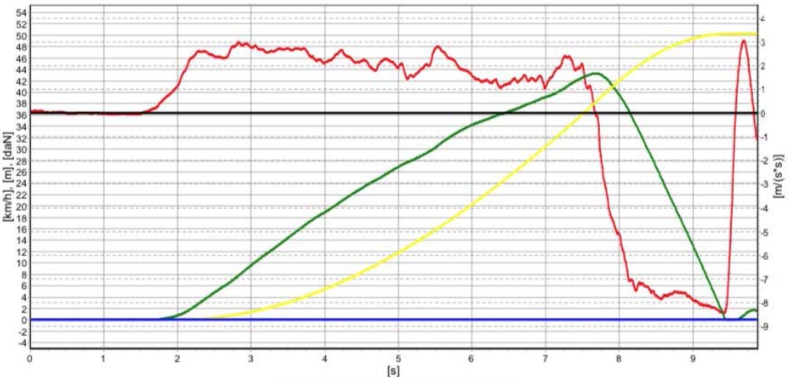

Fig. 3 The result of measuring the deceleration of the Audi A6.

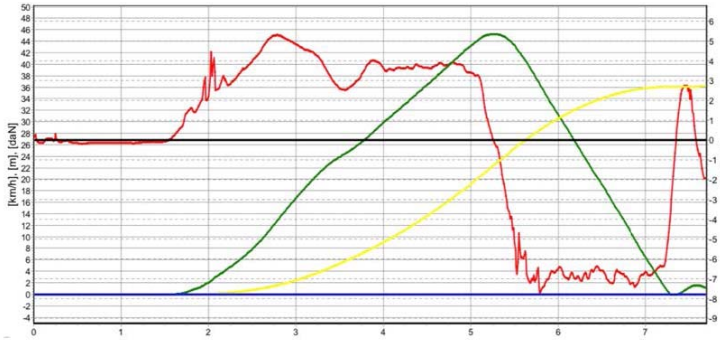

Fig. 4 The result of measuring the deceleration of the BMW 750D.

2.3 Study of deceleration in winter

As a result of experimental studies to establish a slowdown in the vehicles of category M_1 when using winter tires on a rolled snow coating and the ambient temperature -15 ± 0.5ºC, data deceleration data were obtained. An example of the data obtained is shown in Fig. 5 and Fig. 6.

From the graphs it is clear that:

- measurements were performed on a rolled snow coating;
- Peak deceleration values were achieved during the entire braking due to the response of anti-slip systems.

Table 3. Slowing of vehicles Category M1 when using winter tires on a rolled snow coating and ambient temperature -15 ± 0.5 ºC

Brand	Model	Year	Weight, kg	Tire, mm	$J_{TC\ max}$, m/s^2	J_{TC}, m/s^2	φ
Audi	A8	2016	2035	6,31	4,46	3,5	0,36
BMW	750D	2017	2095	8,82	4,44	3,48	0,36
Mersedes	S-klasse	2016	2150	7,43	3,67	2,81	0,29
Audi	A6	2018	1884	8,03	4,4	3,44	0,35
BMW	5	2016	1845	6,39	3,98	2,79	0,29
Mersedes	E-klasse	2017	1815	5,66	3,85	2,89	0,3
Volvo	S80	2011	1866	7,04	4,4	3,44	0,35
Toyota	Camry	2017	1695	5,84	4,33	3,37	0,35
Lexus	IS	2013	1635	6,64	4,32	3,36	0,35
Mersedes	C-klasse	2015	1475	7	3,89	2,93	0,3
Audi	A4	2016	1485	5,94	4,31	3,35	0,35
BMW	3	2013	1485	5,58	4,34	3,38	0,35
Audi	A3	2008	1625	5,3	3,78	2,77	0,28
Mazda	CX-5	2015	1635	6,89	4,27	3,31	0,34
Toyota	LC 150	2019	2310	9	4,24	3,28	0,33

From the listed cars, sniffing tires were not equipped with - Mercedes S-Class, BMW 5, Mercedes E-Class and Audi A3, the rest of the cars listed in this table were equipped with studded tires.

From the table, it can be seen that the values of the deceleration indicate the differences between the studded tires.

Analyzing Figure 5 and Figure 6, you can see the difference between the deceleration lines (red lines). A more active triggering of the anti-lock system is visible in Fig. 2. Both vehicles are equipped with winter unwanted tires. If on the chart of slowing the car 2008, the deceleration line is lowered not so fast, then on the 2015 car slowing schedule [15] The deceleration line has a more vertical direction and a more stable slowdown after the growth of the brake effort.

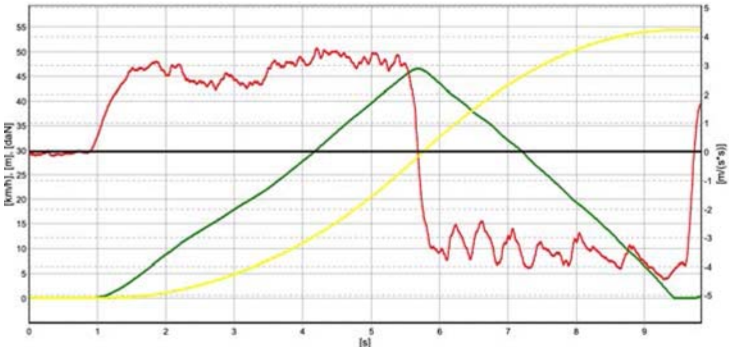

Fig. 5 The result of measuring the deceleration of the Mersedes-Benz C-class.

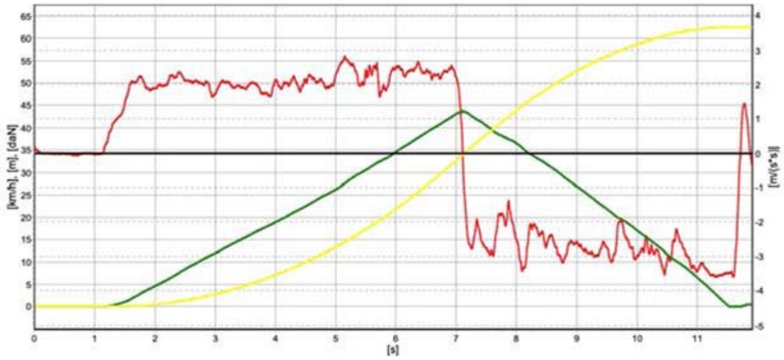

Fig. 6 The result of measuring the deceleration of the Audi A3.

3 Model of calculating deceleration value

Determining the total inhibitory strength, as the sum of the forces acting on the vehicle, you can add the power of the spike hooking, which is interacting with the surface of the road coating, depending on the strength he entered in formula (1) and described in (4).

$$J_{зам} = \frac{g(m_{тор}\cos\alpha\varphi_n + m_a g\sin\alpha) + P_{в} + P_{зац}}{m_a \delta K_э}, \tag{1}$$

where $K_э$ is the braking efficiency coefficient; G - acceleration of free fall; $m_{тор}$ - Mass included on the inhibited wheels; α - the angle of the longitudinal tilt of the road; φ - wheel clutch coefficient with expensive; m_a - the actual mass of the vehicle; $P_{зац}$ - the power of the thoroughbreaker.

The accounting coefficient of rotating masses is considered by the formula:

$$\delta = 1 + \left(\frac{z_k J_k}{m_a r_k^2}\right), \tag{2}$$

where Z_k - the number of rotating wheels; J_k - the moment of inertia wheels; r_k-static radius of the wheels.

Air resistance strength is considered by the formula

$$P_{в} = \frac{C_x \rho F_A V^2}{2}, \tag{3}$$

where C_x is the windshield coefficient; ρ - air density; F_A - frontal square.

$$P_{зац} = 0{,}1\, z\, \sigma_p\, F_{ВШ}, \tag{4}$$

where σ_p is the product of the dynamic tensile strength; $F_{ВШ}$ - the area of the longitudinal cross section of the insertion of the spike; z - the number of spikes on the wheel, and the multiplier 0.1 indicates a contact with the support surface of only 10% - 15% spikes from the total.

4 Conclusion

The value of the established deceleration for vehicles of category M_1 obtained during experimental activity exceeds table values for coating data. From the data obtained during conducting experimental studies, it can be concluded that: the presence of spikes on the tires significantly affects the slowdown of the passenger vehicle on the rolled snow coating; The presence of spikes on tires does not affect the slowdown on the opelated asphalt concrete coating; The maximum value of the deceleration is diverged in the summer; The influence of the release of the vehicle and the configuration code significantly affects the value of the slowdown.

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