The method of accident reconstruction according to the parameters of the braking process of M₁ category vehicle under the conditions of the North-West region

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Abstract. The article analyzes the number of accidents and measures that implement the reduction of mortality on the roads. The authors proposed a set of factors that must be taken into account when reconstructing an accident according to the parameters of the braking process of M₁ category vehicles, such as: the actual load of the vehicle, modern complexes of car active safety systems (ABS, EBD, ASR, BAS), a trailer of up to 750 kg, the condition of the road surface coverage and seasonality of tires in the conditions of the North-West region. The results of experimental studies of the actual values of the steady-state deceleration and its rise time are presented, confirming the regularity of the influence of the studied factors. Coefficients have been developed that correct the recommended normative values of steady-state deceleration and rise time. The method of accident reconstruction according to the parameters of the braking process of M₁ category vehicles is proposed, which allows more objective and reliable expert research and provides the ability to establish real cause-effect relationships for the occurrence of accident.

1. Introduction
Traffic accidents are an integral part of road transport operation. Traffic accidents are one of the world’s death threats. Over the past 10 years, more than 2 million traffic accidents occurred in the Russian Federation, more than 270 thousand people died, and 2.5 million people were injured. Accident statistics, according to the traffic police of the Russian Federation, are presented in figure 1 [1].

To save the lives of citizens from the consequences of road accidents, the Federal Targeted Program “Improving Road Safety in 2013-2020” and the Road Safety Strategy for 2018-2024, leading to a reduction in road deaths, are being implemented [2]. New rules and requirements for the design of the car are also presented, focusing on active, passive and post-accident safety, which affects the reduction in the likelihood of accidents and the severity of the consequences [3].

One of the measures to ensure road safety is to study the cause-effect relationships of accidents. The technical aspect of an accident is examined by competent specialists - experts in the field of automotive technical expertise, where they establish signs and circumstances of a road traffic situation (RTS).
In current expert practice, determining the vehicle’s speed and the technical ability of the driver to prevent accidents is most often established by the parameters of the vehicle’s braking process. As a rule, the values of the steady-state deceleration and its rise time are important initial data in traditional calculation methods [4, 5].

The use of certain recommended normative values of the steady-state vehicle deceleration and its rise time is especially relevant in modern science. Currently, experts mainly use the values recommended by RFCSE and TR 018/2011, as well as by other scientific and methodological support of modern scientists [4, 5, 6, 7, 1, 2 and others]. However, the braking process parameters proposed for use by vehicles of M1 category do not always take into account the whole spectrum of influencing factors, for example, such as a change in the design of the brake control of modern cars and the operating conditions of vehicles depending on the region, which does not fully allow an objective and reliable research of accident reconstruction.

Thus, in connection with the foregoing, the aim of the study is to develop a method for the reconstruction of accidents by the parameters of the braking process of vehicles of M1 category under the conditions of the North-West region [9, 10].

To achieve this goal, the following tasks were completed:

- factors were identified by a priori ranking method;
- full-scale experiments were conducted on the territory of St. Petersburg with the help of the “Effect-02” measuring instrument by measuring the parameters of the braking process in order to determine the actual values of the steady-state deceleration (jssd) and its rise time (tt) taking into account the factors under study, such as: actual vehicle load, the presence of a modern complex of active safety systems for cars (ABS, EBD, ASR, BAS), a trailer up to 750 kg, the surface condition of the road surface and seasonality of tires under weather and climate conditions of North-West region;
- to clarify the calculated dependencies of traditional methods, by introducing correction factors (Kjssd) and (Ktt) [11].

2. Experiment results and discussion
The results of a full-scale experiment are presented in figure 2, in the form of a comparative analysis of experimental actual values and recommended normative values [2].
The analysis shows that the difference in values is on average more than 30%, therefore, the difference in expert conclusions, for example, in calculating the vehicle speed, may differ in the same range. This gives reason to assume that the true values of the calculations are deliberately underestimated or overestimated, which leads to the unreliability of the investigated case of an accident and the establishment of a real causal relationship of an accident.

Figure 2. Comparative analysis of experimental and normative (averaged) values of steady-state deceleration at \( \varphi \approx 0.45 \) and the presence of a modern complex of auxiliary emergency braking systems (ABS, BAS).

Thus, when choosing the values of the steady-state deceleration and the time of its rise, the authors propose using the coefficients \( (K_{jssd}) \) and \( (K_{tt}) \), which correct the magnitude of the steady-state deceleration and the time of its rise taking into account the studied factors [2].

Examples of averaged correction factors for steady-state deceleration \( K_{jssd} \) and its rise time \( K_{tt} \) for vehicles of M1 category are presented in table 1.

| Seasonality type of tires | Steady-state correction factor \( K_{jssd} \) | Steady-state correction factor \( K_{tt} \) |
|---------------------------|---------------------------------------------|---------------------------------------------|
|                           | dry asphalt / 0.75 | wet asphalt / 0.45 | snow covered asphalt / 0.25 | icy asphalt / 0.15 |
| Summer                    | 1.21                           | 1.15                           | -                            | -                     |
| All-season                | 0.98                           | 1.21                           | 0.74                         | 1.98                  |
| Frictional                | 0.94                           | 1.38                           | 1.14                         | 2.74                  |
| Studded                   | 0.89                           | 1.65                           | 1.99                         | 2.61                  |

Then, the calculated dependences for the accident reconstruction method according to the parameters of the braking process of vehicles of M1 category under the conditions of the North-West region, which allows us to investigate the issue of vehicle speed and technical ability to prevent accident from taking into account the above factors, will take the form:

- vehicle speed of M1 category before braking, km/h:
  \[
  V_a = 1.8 \cdot j_{norm} \cdot K_{jssd} \cdot t_j \cdot K_{tt} + \sqrt{26 \cdot S_s \cdot j_{ssd} \cdot K_{jssd}},
  \]

\[(1)\]
• the maximum permissible speed of a vehicle of M1 category, taking into account the visibility conditions, km/h:

\[ V_{\text{max}} = 3.6 \cdot j_{\text{ssd}} \cdot K_{f_{\text{ssd}}} \cdot T \cdot \left[ \frac{2.5g}{j_{\text{ssd}}K_{f_{\text{ssd}}}T^2} + 1 - 1 \right], \]  

(2)

• vehicle stopping path of M1 category in the absence of braking traces, m:

\[ S_o = (t_1 + t_2 + 0.5 \cdot t_3 \cdot K_{ct}) \frac{V_a}{3.6} + \frac{V^2_a}{26j_{\text{ssd}}K_{f_{\text{ssd}}}}, \]  

(3)

• stopping path of a vehicle of M1 category in the presence of braking traces, m:

\[ S_o = (t_1 + t_2 + t_3 \cdot K_{ct}) \frac{V_a}{3.6} + S_e, \]  

(4)

• vehicle stopping path of M1 category at the maximum permissible vehicle speed, m:

\[ S_o = \frac{(t_1 + t_2 + 0.5 + t_3 + K_{ct})V_{\text{max}}}{3.6} + \frac{V^2_{\text{max}}}{26j_{\text{ssd}}K_{f_{\text{ssd}}}}, \]  

(5)

• the distance of removal of a vehicle of M1 category from the place of collision with a pedestrian at the time when making emergency braking, m:

\[ S_y = (t_1 + t_2 + t_3 \cdot K_{\text{ep}}) \frac{V_a}{3.6} + S_e - B_{\text{mc}} - L_{\text{n.c.}}. \]  

(6)

• stopping time of a vehicle of M1 category by emergency braking, s:

\[ T_o = \frac{(t_1 + t_2 + 0.5 \cdot t_3 \cdot K_{f_{\text{ssd}}}) V_a}{3.6j_{\text{ssd}}K_{f_{\text{ssd}}}}, \]  

(7)

where \( t_1 \) is driver reaction time, s; \( t_2 \) is the operating delay time of the working brake system, s (for passenger vehicles \( t_2 = 0.1 \)); \( t_3 \) is the rise time of the vehicle deceleration; \( j_{\text{ssd}} \) - steady-state vehicle deceleration, m/s\(^2\); \( S_s \) is the length of the tracks of the brake skid, m, (from the accident diagram); \( V_a \) - vehicle speed (in the absence of traces of the brake skid, \( V_a \) is set according to the driver's words), km/h; 1.8; 26 are constant coefficients (conversion); 3.6; 26 - conversion factors from km/h to m/s; \( S_e \) - the distance traveled by the vehicle from the beginning of the formation of traces of braking to the place of collision with a pedestrian recorded in the accident diagram, m; \( B_{\text{mc}} \) - vehicle base, m; \( L_{\text{n.c.}} \) - the length of the front overhang of the vehicle, m; \( V_{\text{max}} \) - maximum permissible speed in accordance with clause 10.2 of the SDA (in the settlement \( V_s = 60 \) km/h, outside the settlement \( V_s = 90 \) km/h); \( K_{f_{\text{ssd}}} \) - coefficient correcting the value of the steady-state deceleration of vehicles of M1 category, m/s\(^2\); \( K_{ct} \) is a coefficient that corrects the value of the rise time of the steady-state deceleration of the vehicle of M1 category, m/s\(^2\).

The method allows to obtain an effective calculation in the study of accident reconstruction during the operation of M1 category vehicles in the North-West region, as well as to make a more objective and reliable expert study.

3. Conclusion

Thus, the studies made it possible to prove the complex effect of factors affecting the parameters of the braking process of vehicles of category M1 under the operating conditions of the North-West Region experimentally, to determine the coefficients that correct the steady-state deceleration and its rise time, refined calculation methods that allow more objective and reliable expert research during the reconstruction of an accident and makes it possible to establish real causal relationships of the occurrence of an accident.

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