stopping distance, deceleration, VBOX 3I GPS Data Logger

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RESEARCH OF THE STOPPING DISTANCE FOR DIFFERENT ROAD CONDITIONS

Summary. In this paper a modern method for determination of stopping distance is represented. Application of the non-contact VBOX 3i 100Hz GPS Data Logger speed and distance measurement system is represented. A description of the total stopping distance of vehicle main components - driver reaction time, vehicle reaction time and vehicle braking capability has been made. Research of the total stopping distance of a vehicle for different road conditions has been made. The results for the stopping distance can be very useful in the expert practice.

ИССЛЕДОВАНИЕ ПУТИ ТОРМОЖЕНИЯ В РАЗНЫХ ДОРОЖНЫХ УСЛОВИЯХ

Аннотация. В работе представлены современные методы определения пути торможения при экстренном торможении в разных дорожных условиях. Представлены времена характеризующие путь торможения – время реакции водителя, время запаздывания срабатывания тормозного привода и время нарастания замедления. Экспериментальные исследования проводились при помощи записывающего оборудования VBOX 3i 100Hz GPS Data Logger. Был определен путь торможения для разных дорожных условий. Результаты этого исследования могут быть полезны в практике экспертиз.

1. INTRODUCTION

The number of people killed in road accidents in Bulgaria in 2010 is 775 [9]. Although they are less compared with the previous year, their number is much higher in comparison with developed European countries. In urban areas about half of car accidents with killed people are pedestrian hit. The problems related to traffic safety are particularly important. Road accidents are associated with major socio-economic losses and lasting psychological hurt for people.

In expert practice, particularly important stage in accident investigation is determination of the vehicle stopping distance. In many cases, depending on the value of the estimated stopping distance is determined the possibility of drivers to prevent accident by braking.

The aim of this work is to present a modern method for determination of the vehicle stopping distance and researching of the stopping distance for different road conditions.

2. PREREQUISITES AND SOLUTION OF THE PROBLEM

The process of stopping be a movement of the vehicle with deceleration in which its velocity decreases. Emergency braking is a process in which the driver takes braking by activating the braking system with a maximum press of the brake pedal [2, 3].

In accident investigation the cases where it is not required to determine if the stopping distance is much. Total stopping distance can be calculated by the following equation:

$$S_d = (t_{drt} + t_{vrt} + 0{,}5t_{inc})V + V^2 C_{eff} / 2j_{br}, \quad (1)$$

where:
t_{drt} – is the driver reaction time, *s*;
t_{vrt} – the vehicle reaction time, *s*;
t_{inc} – the time for increase the braking deceleration, *s*;
V – the speed of the vehicle, *m/s*;
J_{br} – the braking deceleration, *m/s,*
C_{eff} – coefficient of efficiency.

The times and distances defining the stopping distance are shown in fig. 1.

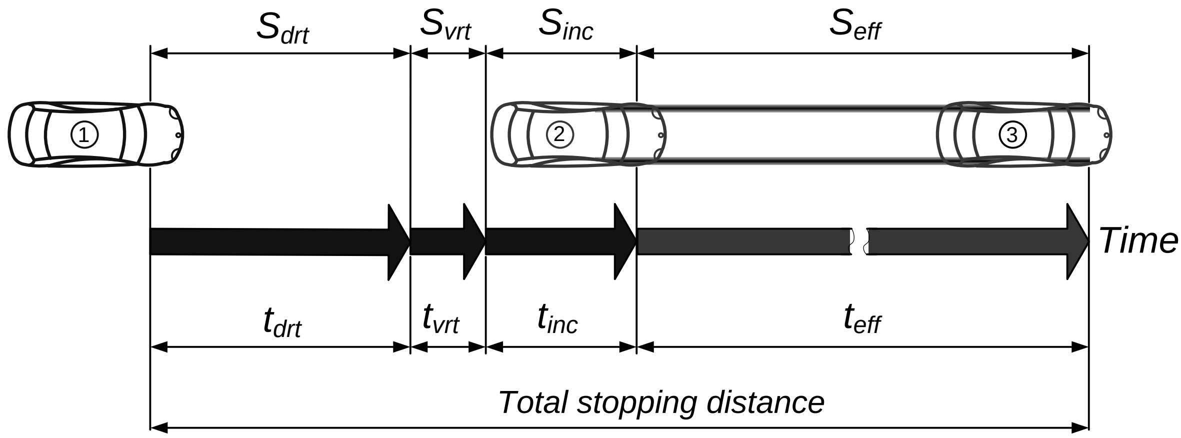

Fig. 1. The total stopping distance times and distances: t_{drt} – the driver reaction time; t_{vrt} – the vehicle reaction time; t_{inc} – the time for increase the braking deceleration t_{eff} - the time for effective braking distance; s_{drt} – the distance travelled for a driver reaction time; s_{vrt} – the distance travelled for a vehicle reaction time; s_{act} – the distance travelled for a time of increasing the braking deceleration; s_{eff} – the effective braking distance

Рис. 1. Времена и расстояния характеризующие путь торможения: t_{drt} – время реакции водителя; t_{vrt} – время запаздывания срабатывания тормозного привода; t_{inc} – время нарастания замедления; t_{eff} – время эффективное торможение; S_{drt} – расстояние для время реакции водителя; S_{vrt} – расстояние для время запаздывания срабатывания тормозного привода; S_{act} – расстояние для время нараста-ния замедления; S_{eff} – расстояние для эффективное торможение

The total stopping distance of a vehicle is made up of three main components: driver reaction time, vehicle reaction time and vehicle braking capability.

The driver reaction time is made up of human perception time - how long the driver takes to see the hazard, and the brain realize it is a hazard requiring an immediate reaction and the human reaction time - how long the body takes to move the foot from accelerator to brake pedal. The human perception time can be as long as 0.25 - 0.50 seconds. The human reaction time can vary from 0.25 – 0.75 seconds [8].

Once the brake pedal is applied there is the vehicles reaction time which depends on the brake pedal free-play, hydraulic properties of the brake fluid and working order of the braking system.

The last main factor than determines the total stopping distance is the cars braking capability which depends on factors such as the type of braking system, brake pad material, brake alignment, tyre pressures, tyre tread and grip, vehicle weight, suspension system, the co-efficient of friction of the road surface, slope of road, surface smoothness, the braking technique applied by the driver, etc.

Very often in expert practice in determining stopping distance the experts using data for the driver reaction time, the vehicle reaction time, the time to increase the braking deceleration and the braking deceleration from reference books.

In many of these reference books the data refer to the old vehicle models, the dynamic characteristics that differ from those of modern vehicles. Furthermore, the data do not relate exactly to the technical condition of the particular vehicle type and condition of the road at the place of the accident. Using reference books all these factors, including cars braking capability can lead to considerable inaccuracies in determining the stopping distance.

There are a number of different methods for measuring braking deceleration and braking distance [2, 7]: Fifth wheels were the original way of measuring braking distance, but these are difficult to fit, easy to damage and suffer from a number of mechanical limitations which affects accuracy, such as skipping and bouncing; Radar is used by law enforcement agencies because it is very accurate, but you can only measure the speed from a stationary point directly in front of the target vehicle; Microwave sensors use a similar method, but are used on the vehicle. These suffer from quite a high measurement noise, and are very sensitive to the height they are mounted above the road. Surface water and snow also affect the readings; Optical sensors have proved a popular replacement to the fifth wheel in the past due to their size and accuracy but they take a long time to fit to the vehicle, struggle to work consistently in wet or snowy conditions, and can be easily knocked off during testing.

Than those disadvantages of these methods we should pay attention to the fact that the most crucial part of determination of the vehicle stopping distance is measuring the exact point at which the brake pedal is pressed, and starting the distance measurement from this point.

Therefore it is necessary the use of modern precise recording equipment for determining the stopping distance. Precise recording equipment leads to a more accurate, and more correct conclusion in accident investigation.

GPS has now become the most popular way of measuring braking distances due to the very high accuracy, size and ease of fitting, flexibility to carry out many different tests, and ruggedness.

Fig. 2 shows a photo of precise recording equipment VBOX 3i GPS Data Logger of the company Racelogic Ltd - UK [7]. VBOX is a powerful instrument used for non-contact 100Hz measuring the speed and position of a moving vehicle. It is based on a new generation of high performance satellite receivers, and will measure speed, distance, acceleration, lap times, position and much more. A very powerful processor ensures low latency with updates of speed, position and acceleration, 100 times a second. The logged data is stored directly onto a compact flash card for easy transfer to a PC. The equipment VBOX 3i is suitable to study of different vehicle movement parameters [1, 4-6].

Measuring stopping distance using a brake trigger (Fig. 2) allows us to measuring the exact point at which the brake pedal is pressed and starting the distance measurement from this point.

Carry of equipment is done very easily and convenient because it is small and located in the carry case (Fig. 2), in addition to mobility it should be noted that for the installation of equipment to each mobile object are necessary about 10 minutes.

In this work the stopping distance is determinate for the road surface covered with different percentage leaves - road covered with up to 50% and over 50%, using Volkswagen Passat test car (Fig. 3) and VBOX 3i GPS Data Logger equipment. The selected road is straight and horizontal.

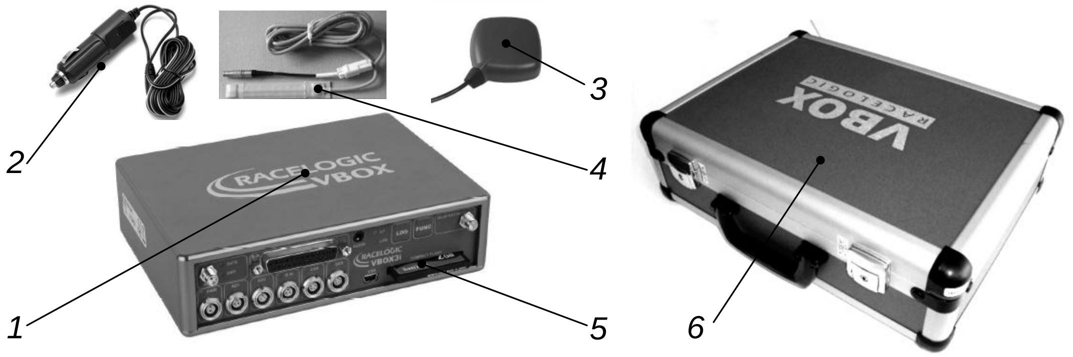

Fig. 2. Recording equipment VIBOX 3i: 1 – VBOX Data Logger; 2 – Power connector; 3 – GPS antenna; 4 – Brake trigger; 5 - SD card; 6 - Carry case

Рис. 2. Записывающее оборудование VIBOX 3i: 1 – VBOX Data Logger; 2 – контакт; 3 – GPS антенна; 4 – датчик торможения; 5 – SD карта; 6 – чемодан

Fig. 3. Test car Volkswagen Passat with equipment VBOX 3i GPS Data Logger

Рис. 3. Автомобиль -лаборатория Фольксваген Пассат с оборудованием VIBOX 3i

A brake trigger is added either to the face of the brake pedal (fig. 4). This is to detect when the brake pedal has been pressed and signals the start of the test.

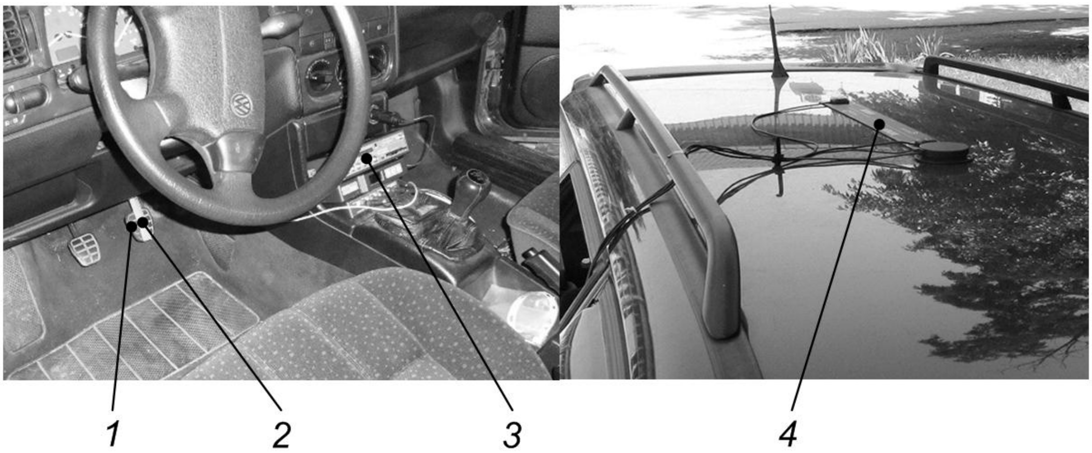

Fig. 4. Equipment of the test car: 1 - Brake pedal; 2 - Brake trigger; 3 - VBOX 3i logger; 4 - GPS antenna

Рис. 4. Оборудование автомобиля - лаборатории: 1 - тормозная педаль; 2 - тормозной датчик; 3 - VIBOX 3i logger; 4 - GPS антенна

The test starts from the moment the pedal is pressed, it measures the response of the braking system, as well as the vehicle reaction time, the time for increase the braking deceleration, the performance of the tyre, brake pedal free-play, and other factors.

3. RESULTS AND DISCUSSION

The results in this work were obtained by VBOX Tools software (Fig. 5) which is based around the Report Generator' data-processing engine, with links to graphing tools, mapping tools, live data windows and VBOX Setup tools. Using a combination of these elements, and existing default profiles, allows the user to generate complex testing scenarios with ease.

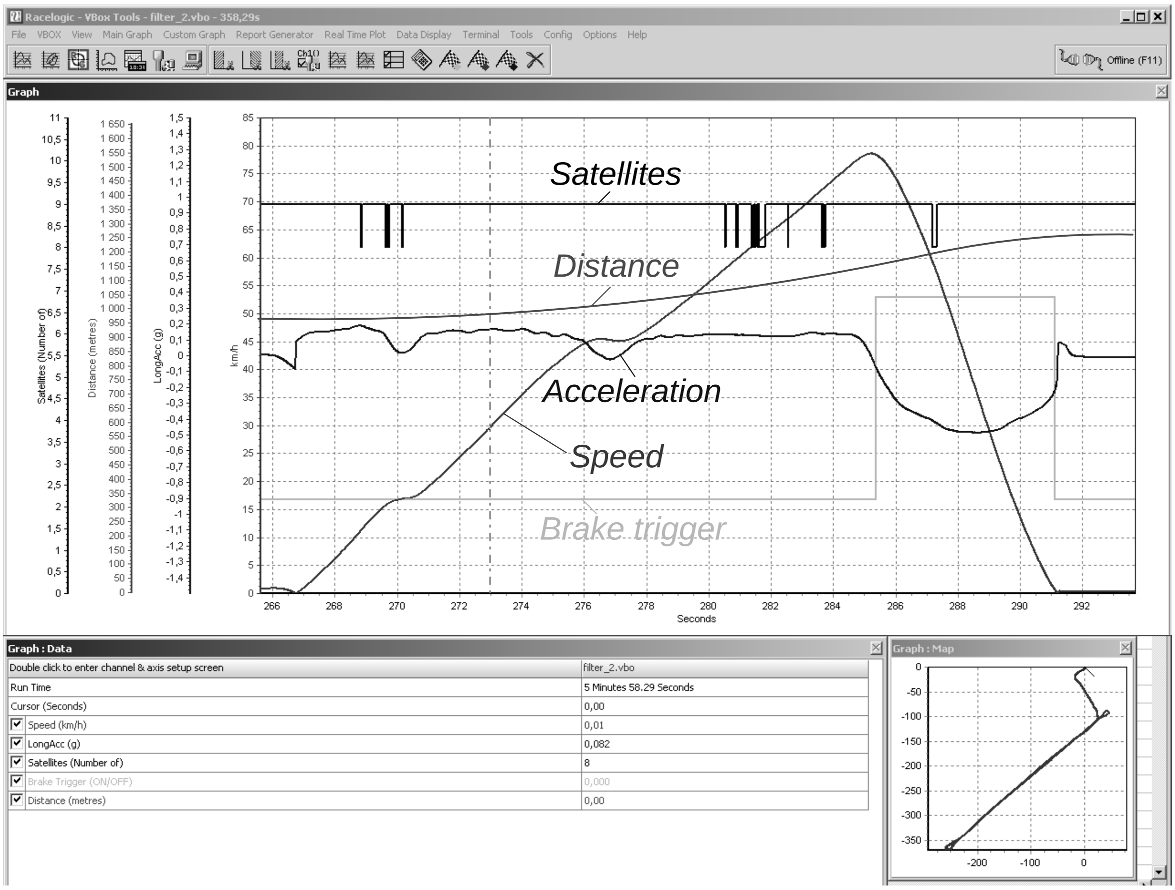

Fig. 5. Main menu bar of the VBOX Tools software
Рис. 5. Главное меню программного обеспечения VBOX Tools

The graph screen displaying the data from your logged file in three windows: graph - this main window shows speed against time or distance; graph data – contains a table of data collected and graph map – shows the path of the vehicle.

Fig. 6 and fig 7 shows graphically the results for the total stopping distance of a vehicle at emergency braking for different road conditions. These tests are repeated a number of times and the results are averaged. The driver reaction time used in calculations is 1.0 second (equation 1). To allow comparison was determine the stopping distance of the same car on the same road conditions, but without leaves.

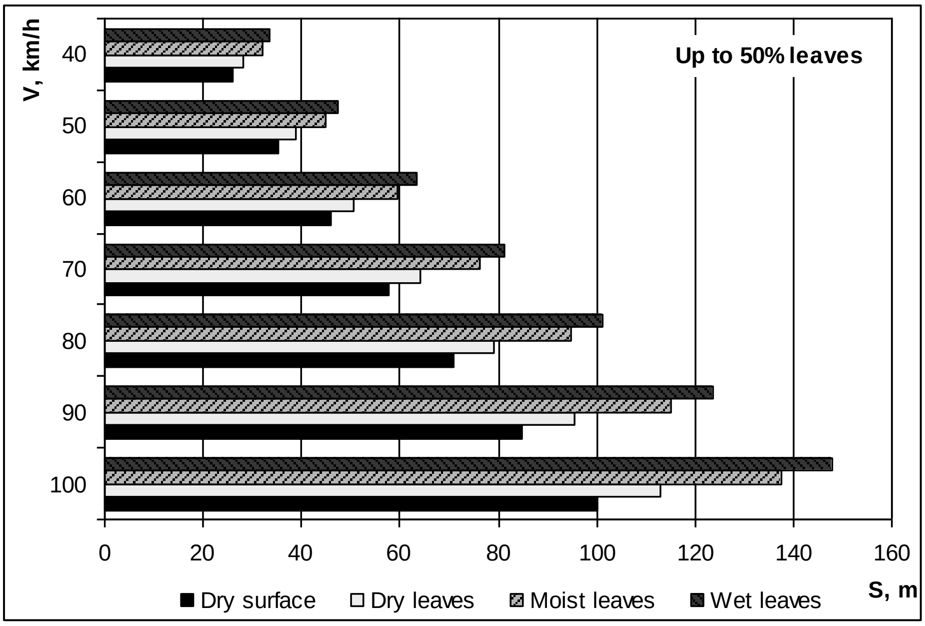

Fig. 6. Relation between stopping distance and the speed by road surface covered with up to 50% leaves
Рис. 6. Путь торможения в зависимости от скорости для поверхности дороги покрытой листьями менее 50% и временем реакции водителя 1,0 сек

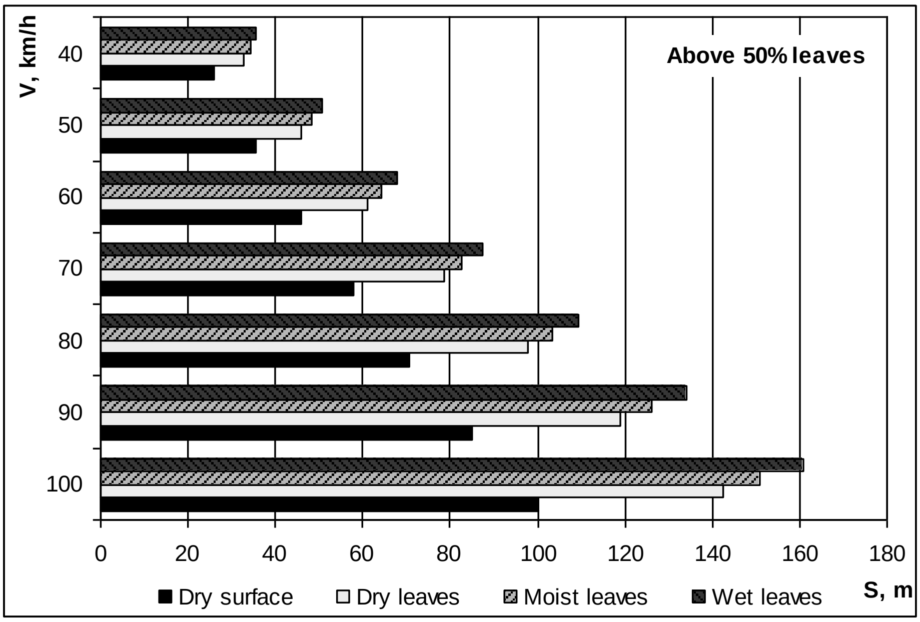

Fig. 7. Relation between stopping distance and the speed by road surface covered with above 50% leaves
Рис. 7. Путь торможения в зависимости от скорости для поверхности дороги покрытой листьями более 50% и временем реакции водителя 1,0 сек

Comparing the stopping distance during emergency braking on dry clean surface with the surface covered with up to 50% leaves (Fig. 6) follows: for a speed 50 km/h (max. permitted speed in settlement) for surface with dry leaves the total stopping distance increases with 9.2%, for surface with moist leaves the total stopping distance increases with 26.5% and for surface with wet leaves the total stopping distance increases with 33.7%; for a speed 90 km/h (max. permitted speed outside settlement) for surface witha dry leaves the total stopping distance increases with 12.4%, for surface with moist leaves the total stopping distance increases with 35.8% and for surface with wet leaves the total stopping distance increases with 45.7%.

Comparing the stopping distance during emergency braking on dry clean surface with the surface covered above 50% leaves (Fig. 7) follows: for a speed 50 km/h, for dry leaves surface - 29.8% increase, fora moist leaves surface - 35.9% increase and for wet leaves surface - 42.8% increase; for a speed 90 km/h fora dry leaves surface - 40.4% increase, fora moist leaves surface - 48.5% increase and for wet leaves surface - 57.9% increase.

Using modern methods, such as is presented in this work, leads to improved accuracy and convenience to measuring the stopping distance. The VBOX 3i GPS Data Logger is a instrument with very high accuracy, small size and ease of fitting, flexibility to carry out many different tests. The results for total stopping distance are for specific technical condition of the test car, time and place of this study. Under different conditions the results would be different. Such results can be very useful in expert practice.

4. CONCLUSION

- A modern method for determination of stopping distance of a vehicle is represented. VBOX 3i 100Hz GPS Data Logger speed and distance measurement system is an instrument with very high accuracy and easy to use.
- Research of the stopping distance of a vehicle for different road conditions using VBOX 3i 100Hz GPS Data Logger has been made.
- Comparing the stopping distance on dry clean surface with the surface covered up to 50% leaves follows: for a speed 50 km/h and surface with wet leaves the total stopping distance increases with 33.7%; for a speed 90 km/h – with 45.7%.
- Comparing the stopping distance on dry clean surface with the surface covered above 50% leaves follows: for a speed 50 km/h and wet leaves surface - 42.8% increase; for a speed 90 km/h and wet leaves surface - 57.9% increase.
- The results in this work can be very useful in expert practice.

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