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Determination of braking diagrams for vehicles of different body types

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Abstract: *The braking system is one of the most important technical parts of the vehicle and at the same time a defining factor in terms of safety. This study aims to determine the braking space diagrams for different types of vehicles on different running surfaces. The main objective of this study was to compute the braking space diagrams for vehicles with different body types (sedan, wagon, SUV, cargo vehicle, motorcycle) on dry asphalt and to establish a comparative analysis between them. Besides these, a comparison of the obtained braking distances for the motorcycle and the SUV on a gravel road was applied. The results revealed that the SUV-type vehicle recorded a higher braking performance than the other categories of vehicles, both on dry asphalt and gravel roads. In conclusion, we can say that the braking distance is directly influenced by the vehicle's body type and the SUV seems to be the best vehicle in terms of braking performance.*

Keywords: *adhesion coefficient, braking space,*

1. INTRODUCTION

With the solution of the mobility problem through the production of the motor vehicle, it was found to be absolutely necessary to implement and develop a system to ensure: the safe stopping of the motor vehicle, reduce the speed of the motor vehicle, or ensure its immobilization while stationary [1].

Since the beginning, the braking system has had a gradual and impressive evolution that has included many new technologies over the years, with a focus on improving efficiency and automotive safety [2].

The role that the braking system has in the motion of the vehicle on public roads is a special one, because no matter how much the driver tries to anticipate possible obstacles and reduce the speed of the vehicle, without activating the braking system, this is unfortunately impossible, and sudden braking has become a common habit in everyday traffic.

With the passage of time, the continuous and inexhaustible evolution of motor vehicles can be easily observed and never ceases to surprise ordinary users with the innovations and systems mounted on them. This rapid evolution of the vehicles could not be done without including the optimization of the braking system. A study published by Ting et al., (2004), which pursued the development of an anti-lock braking system (ABS) integrated with active suspension, showed that in the case of emergency braking, the braking distance can be reduced by the control torque with disc or drum brakes, but can be improved if the normal force generated by active suspension systems is also taken into account [3].

Mochammad A., (2018) started the development of an emergency braking system to equip electric vehicles. Autonomous Emergency Braking System (AEBS) is an automatic braking technology that combines sensors and brake controls to prevent collisions between cars or collisions between cars and various obstacles [4].

Considering the importance and the necessity to test and improve the braking system, the main objective of this study was to determine the braking distance for several vehicles with different body types (sedan, station wagon, SUV, cargo vehicle) on a dry asphalt surface and to establish a comparative analysis between them. Another important objective in carrying out the experimental study was the comparison of the braking space of a motorcycle and an SUV on dry asphalt and gravel roads.

2. TECHNICAL REQUIREMENTS

2.1 Test scenario and preparation of the experiments

The test scenario established from the beginning was based on the braking of a vehicle moving at specific speeds on a level road with a very good quality dry asphalt, that imitates as much as possible the situations of everyday road traffic. In the first phase, the vehicle ran until it reached a speed of about 10 km/h, after which the driver activated the braking system by pressing hard the brake pedal, thus forcing the vehicle to stop. Time and speed data were recorded by a GPS device, which was connected to a laptop computer and operated by a member of the test team. The same series of tests were repeated five times in a row for different travel speeds: 30 km/h, 50 km/h, 70 km/h. After testing the first type of motor vehicle, the same procedure was repeated for the other pre-determined motor vehicles for testing. Another stage of the test scenario corresponded to the driving and braking of a car and a motorcycle, both on an asphalt road and on a gravel road, at speeds of 10 km/h, 30 km/h, and 50 km/h.

The experimental part started with the identification of the vehicles needed to carry out the braking test, followed by their procurement and preparation. Thus, the vehicles used to carry out this study were chosen according to the body type: a sedan-type vehicle, with rear-wheel drive, a combi-type vehicle, equipped with all-wheel drive, a 4x4 off-road vehicle, and a cargo vehicle. As for the second part of the tests, a motorcycle was also used (Table 2.1.1).

Table 1. The main characteristics of vehicles

Vehicle type					
	Motorcycle	Sedan vehicle	Combi vehicle	Off-road vehicle 4x4	Cargo vehicle
Total weight [kg]	90	2145	2020	1875	3300
Power [kw]	7	133	122	80	75
Maximum speed [km/h]	96	230	226	168	100
Tires	130/70x17	225/55 R16	205/65 R16	215/65 R16	225/65 R16

In order to carry out the braking tests in the safest possible conditions, a section of road isolated from road traffic and pedestrian traffic was chosen. The running surface was represented by a straight road equipped with a layer of very good quality asphalt with an adhesion coefficient of 0.8, which was demarcated with a marking strip to warn and prevent entry into the testing zone by unauthorized persons. After preparing the test site, the vehicle was equipped with a GPS device. In this sense, the GPS device was mounted in an area as favorable as possible to achieve the connection with the satellite signal, in the present case being the dome of the vehicle.

The second stage of the experimental research involved a comparative test between braking with an all-wheel drive vehicle and a motorcycle on different road surfaces. Firstly, the test samples on an asphalted road in favorable weather conditions were performed, having an adhesion coefficient with a value of 0.8. Followed by braking tests on gravel roads, having a coefficient of adhesion with a value of 0.5. Thus, both the four-wheel drive vehicle and the motorcycle were subjected to a series of braking from the same set moving speeds for the test performed on the asphalt road.

After the brake tests were performed, the data recorded by the GPS device was processed using the Microsoft Excel software.

3. Results

Using the values for speed and braking distance, the diagrams of braking distance, as a function of speed were made, and the analytical equation was obtained.

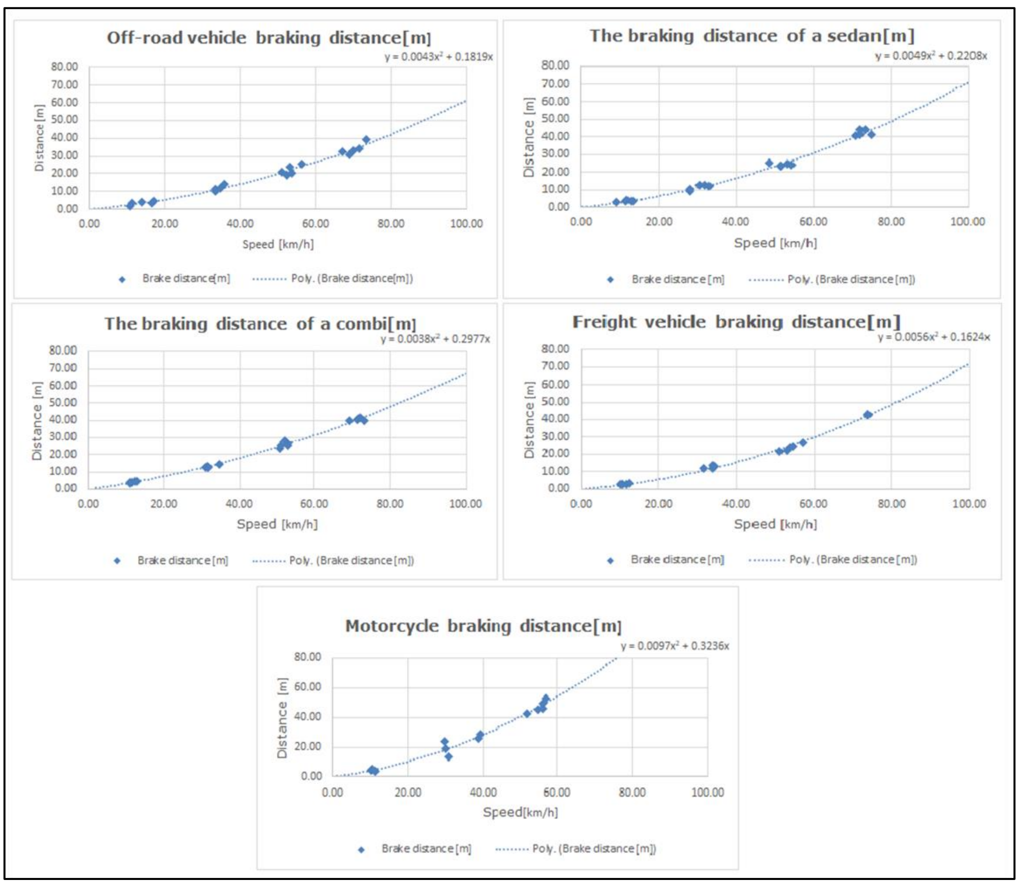

Figure 1: Braking space diagrams

The braking space diagram, presented in Figure 2, exemplifies the distribution of the braking space, on the asphalt road, depending on the travel speed, for all the vehicles studied. The best braking distance was obtained by the SUV and the lowest braking distance was obtained by the motorcycle.

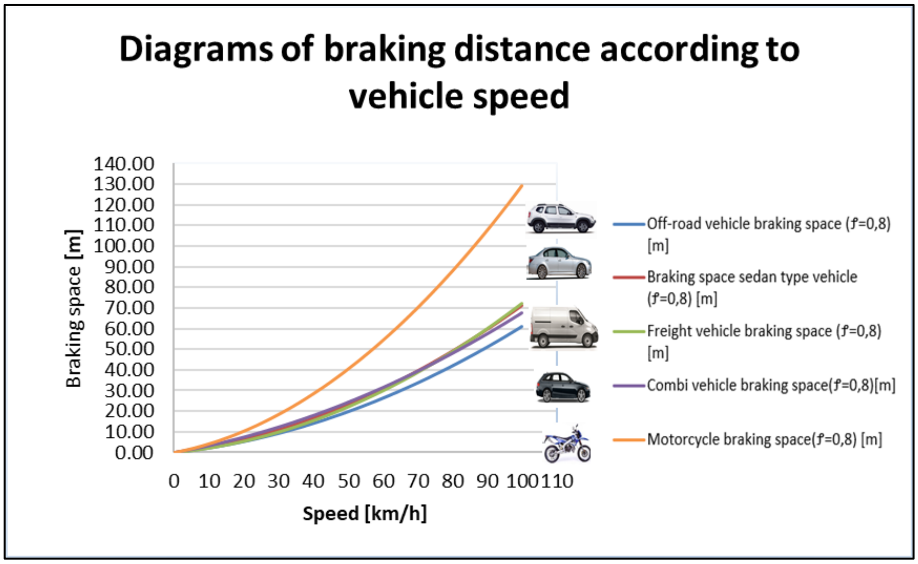

Figure 2: Braking Space Diagram

The comparative analysis performed for the minimum braking space obtained from the dynamic calculation, and the minimum braking space obtained through experimental tests, for the SUV-type vehicle, highlighted the existence of significant differences, differences that were more significant in the case of higher travel speeds (50 km/h).

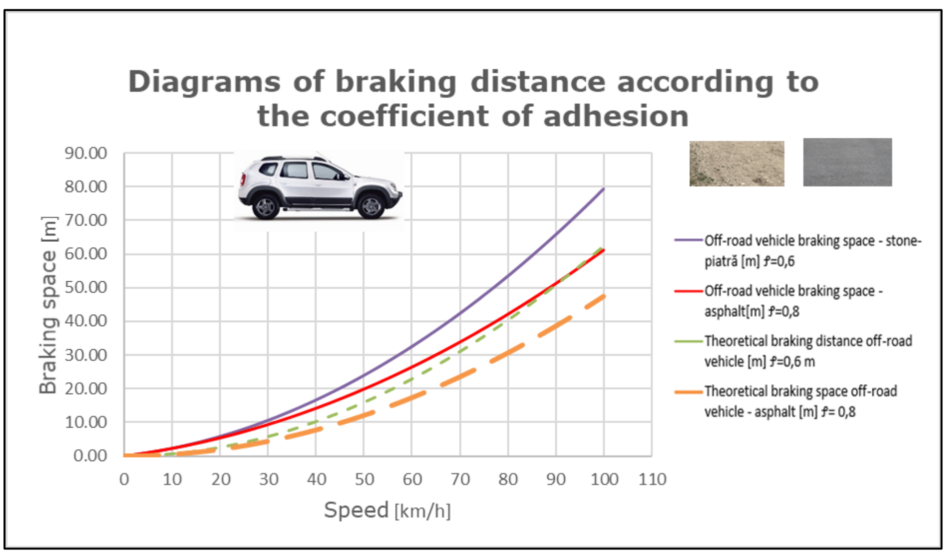

Figure 3: Braking distance according to the adhesion coefficient

A diagram was drawn with the braking distance of the off-road vehicle and the braking distance of the two-wheeled vehicle according to the value of the adhesion coefficient. Therefore, for the adhesion coefficient of 0.6 and the travel speeds of 10 km/h, 30 km/h, and 50 km/h, the off-road vehicle obtained the following braking distance values: 2.26 m, 10 .56 m, 23.90 m. The two-wheeled vehicle obtained, for the same coefficient of adhesion, the following braking distance values: 5.80 m, 22.13 m, 44.78 m.

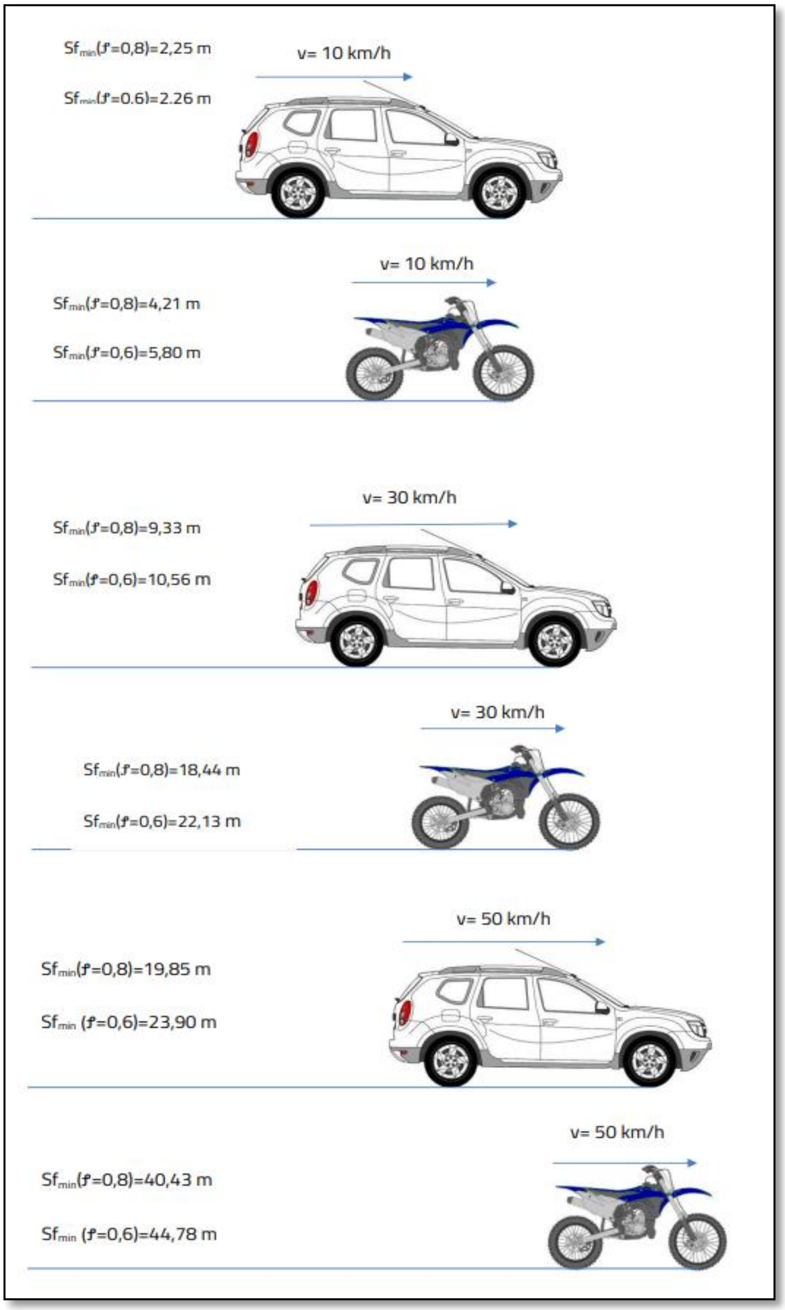

Figure 4: Braking scheme Off-road vehicle and motorcycle

In the case of braking tests on an asphalted road surface with an adhesion coefficient of 0.8, the values obtained for the minimum braking distance are indicated in the previous diagram. The all-terrain vehicle recorded, depending on the set travel speeds, the following values of the braking distance: 2.25 m, 9.33 m, 19.85 m, while the two-wheeled vehicle showed different values of the braking distance braking: 4.21 m, 18.44 m, 40.43 m.

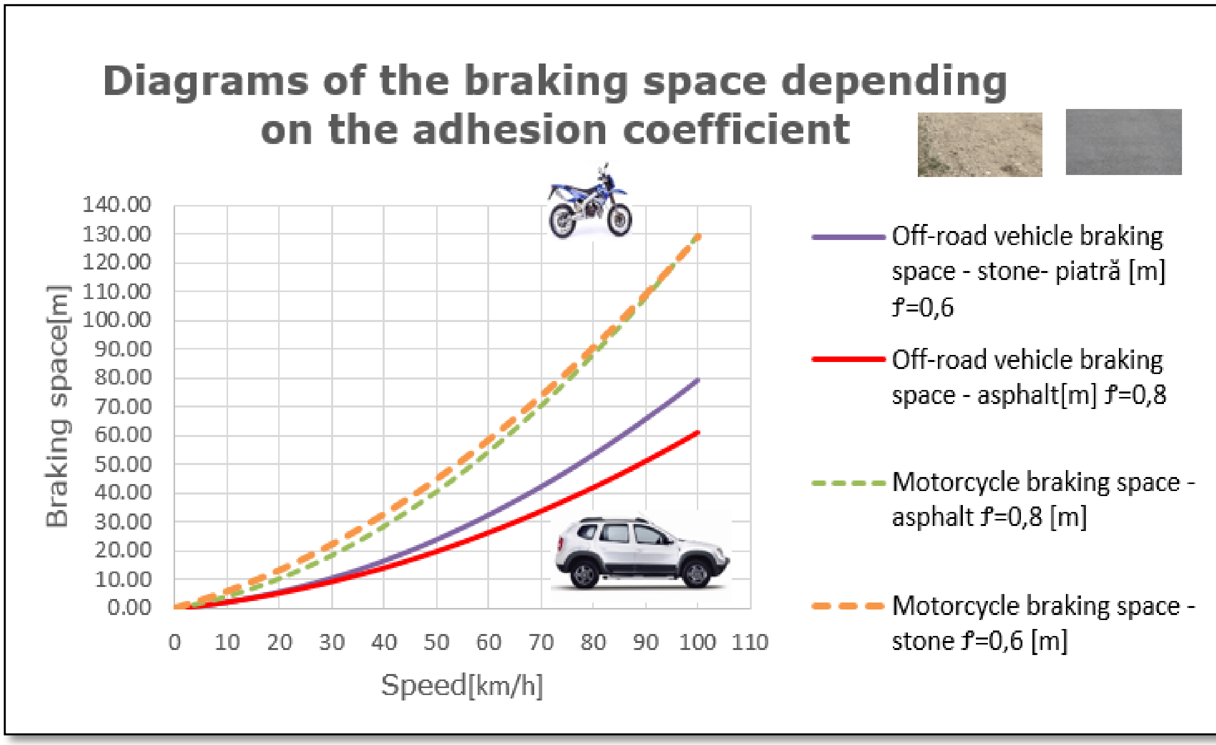

Figure 5: Diagrams of the braking space depending on the adhesion coefficient

In the case of the off-road vehicle, an error calculation was performed for the data obtained experimentally in order to establish the average absolute error of the braking distance and the relative error expressed in percentage.

Table 2. Error calculation

Travel speed [km/h]	Braking space [m]	$\bar{m}$	Δm	$\overline{\Delta m}$	$\overline{\Delta m}/\bar{m}$
10	2,72	2,276	0,444	0,2528	11%
	2,41		0,134		
	2,05		0,226		
	1,87		0,406		

	2,33		0,054		
30	10,63	9,386	1,244	0,7128	8%
	9,87		0,484		
	8,61		0,776		
	8,38		1,006		
	9,44		0,054		
50	21,82	19,908	1,912	1,1456	6%
	20,86		0,952		
	18,45		1,458		
	18,57		1,338		
	19,84		0,068		
70	36,28	33,83	2,45	1,592	5%
	35,36		1,53		
	31,56		2,27		
	32,43		1,4		
	33,52		0,31		

Following the completion of the error calculation, a certain relative error expressed in percentages was found, depending on the set travel speed. Thus, for travel speeds of 10 km/h, the relative error is 11%, in the case of braking from speeds of 30 km/h, the calculated relative error is 8%, for speeds of 50 km/h, the relative error is of 6%, and in the case of speeds of 70 km/h, the relative error has a value of 5%.

4. Conclusion

Following the comparative analyses for the tested vehicles, it was found that, after the performance of the braking system, the off-road vehicle achieved the best braking performance, and the lowest values, regarding the minimum braking space, were recorded in the case of the vehicle on two wheel.

Comparing the braking graph, resulting from the dynamic calculation, with the experimental data recorded by the vehicle from the SUV range, it is found that the differences are generally small, especially in the case of low travel speeds, these differences increasing with increasing speed.

In the case of the comparative analysis of the braking space between the off-road vehicle and the two-wheeled vehicle, major differences were obtained, mainly due to certain technical differences that condition the braking process. Among these, we mention: the inability to forcefully actuate the braking system of the motorcycle, major differences between the capacity and effectiveness of the braking systems, and significant differences between the mass and dimensional characteristics of the two vehicles.

From the experimental tests carried out, the best-performing vehicle type, in the case of braking space, was the SUV.

Creating final conclusion, we can say that the braking system was, is, and will always be one of the most important technical parts of the vehicle because it has a double utility, that of stopping the vehicle voluntarily and more than that the safety of the passengers in case of an emergency stop, without which the utility of the motor vehicle could not be fruitful for human society.

BIBLIOGRAFIE

[1] Limpert R., Brake design and safety, second edition, 1999
[2] www.gregmonforton.com
[3] Ting W., Nonlinear control design of anti-lock braking systems combined with active suspensions, 2004
[4] Mochammad A., Development of Low-Cost Autonomous Emergency Braking System(AEBS) for an Electric Car, 2018
[5] G. Ciolan, I. Preda, *Dinamica Autovehiculelor, partea 1,* Editura Universității Transilvania, 2009