DETERMINATION OF BRAKING DISTANCE AND DRIVER BEHAVIOUR BASED ON BRAKING TRIALS.

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ABSTRACT

Stopping sight distance is an important design parameter which influences e.g. geometric design, road safety, construction cost. The stopping distance consists of the reaction distance and the braking distance. The recommended braking distances in the Danish Road Standards and Guidelines are in the main based on earlier American findings. In order to be able to assess the validity of the recommended braking distances in relation to contemporary vehicles and motorists in Denmark, the Danish Road Directorate has conducted a study designed to shed light on braking behaviour and braking distances among ordinary (non professional) motorists, at different speeds.

This was done through a measurement programme in which 22 test drivers performed braking manoeuvres at different speeds (80, 110 and 130 km/h). Both professional and non professional test drivers were used in the trials. Two different recent cars with ABS brakes were used as test cars. The braking manoeuvres were carried out on dry and wet road on three test tracks with different friction. The measurement program consisted of a total of 172 emergency stops and 23 comfort braking manoeuvres.

For professional test drivers, a good correlation was found between braking distance on wet road, friction and initial speed. The braking distances for non professional test drivers were in average 20-30% longer compared to the professionals, but also showed large variations.

Based on the findings plus knowledge concerning the significance of other parameters for braking distance (condition of tyre, vehicle, etc.), we have sought to establish a new set of recommended braking distances.

1. INTRODUCTION

The Danish Road Directorate has conducted a study designed to shed light on braking behaviour among non professional drivers and their braking distance at different speeds (*1*). The study will be included in an assessment of the current values for braking distances recommended in the Danish Road Standards and Guidelines.

1.1 Background and Object

Braking distance is applied as a significant basic parameter in e.g. calculations of stopping sight distance. A vehicle's braking distance depends on a number of factors pertaining to the vehicle, the road and the driver's behaviour. The most important factors are:

- speed
- coefficient of friction
- braking behaviour/technique
- braking system and condition
- tyre condition
- road's vertical grade

All these factors affect braking distance to a greater or lesser extent depending on the actual conditions when decelerating. A general method for determining braking distance at different speeds, which is representative for the composition of cars, drivers and friction, requires knowledge of the significance of the individual factors for overall braking distance.

The purpose of this study is to assess the braking behaviour of non professional drivers, including braking distances under different physical conditions. The findings will be included in an assessment of the present methods for calculating braking distance in the Danish Road Standards and Guidelines which is essentially based on early American findings.

1.1.1 Methods to estimate braking distance

The present method, as described in the Danish Road Standards and Guidelines (*2)*, is based on measurements of friction values for tyre/roadway and the physical laws of deceleration. Here the braking distance is obtained from the speed, coefficient of friction and the roadway grade by applying the following formula:

$$l_{brake} = \frac{V^2}{2 \cdot g \cdot (\mu_{brake} + s) \cdot 3.6^2}$$

l_{brake}	=	braking distance (m)
V	=	speed (km/h)
g	=	acceleration due to gravity (9.81 m/s^2)
μ_{brake}	=	mean coefficient of friction
s	=	roadway grade

The recommended friction values and the calculated braking distance (on level road) from the current Danish Road Standards and Guidelines are shown in Table 1. It should be noted that the Danish Road Standards and Guidelines often operate with an extra safety margin of +20 km/h when determining the braking distance.

In the latest version of the AASHTO Green Book from 2001 (*3*), determination of the braking distance for use in calculating stopping sight distances has been altered from the more traditional calculation method using coefficients of friction (like the Danish) to a calculation method based on behavioural recordings and measurements from braking trials. Based on the findings of a large-scale measurement programme indicate that by far the majority of all motorists brake with a deceleration of more than 3.4 m/s^2 (*4*). By applying 3.4 m/s^2, we obtain braking distances as shown in Table 1. As can be seen, some differences in the Danish and Green Book values are found, especially at high speed levels.

TABLE 1 Coefficients of friction and braking distance from the Danish Road Standards and Guidelines and braking distances from AASHTO Green Book

Speed (km/h)	Danish Road Standards and Guidelines		AASTHO Green Book
	Coefficient of friction	Braking distance (m)	Braking distance (m)
50	0.38	26	29
60	0.36	39	41
70	0.35	55	56
80	0.34	74	73
90	0.33	97	93
100	0.31	127	115
110	0.30	157	139
120	0.29	195	165
130	0.28	234	194

2. MEASUREMENT PROGRAMME

In order to investigate braking distances and driver behaviour a measurement programme in which 22 test drivers (professional and non professional drivers) performed braking manoeuvres at different speeds (80, 110 and 130 km/h) was conducted. The professional test drivers were chosen among trained drivers from the traffic police. Two different recent cars with ABS brakes were used as test cars. (More than 90% of cars in Denmark are equipped with ABS brakes). The braking manoeuvres were carried out on three test tracks with different friction. Separate road sections on each test tracks were used for braking trials on dry and wet road surface respectively. The majority of the manoeuvres performed were emergency stops, in which the test driver was required to bring the vehicle to a complete standstill as quickly as possible. In addition, a small number of comfort braking manoeuvres

were performed in which the test driver was required to bring the vehicle to a comfortable stop.

A total of 172 emergency stops and 23 comfort braking manoeuvres were performed. Two highway roads (closed for traffic during braking trials) and one closed airfield running taxiway were used as test tracks. Separate road sections (on each test track) were used for wet and dry braking trails. The friction on the test tracks was measured by the Danish Road Institute's measurement vehicle. Table 2 shows the recorded friction values at 60 km/h and 20% slip (standard measurement method).

The number of test drivers at each test track can also be seen in Table 2. Every test driver had to make emergency stops in both cars at 80, 110 and 130 km/h on dry and wet road respectively. However, not all non professional test drivers performed emergency stops from 130 km/h. Several drivers did not feel confident performing the manoeuvre at this speed, in which case it was omitted in the measurement programme.

TABLE 2 Measured friction and number of test drivers at each track

Test track	Measured Friction		No of test drivers	
	Wet brake road section	Dry brake road section	Professional	Non professional
1	0.49	0.49	2	2
2	0.52	0.64	2	4
3	0.75	0.74	2	10

2.1 Measurement equipment

In order to record braking behaviour, a measurement wheel was mounted on the car, a pressure sensor was fitted to the brake pedal, and a notebook PC was installed for data collection. During the braking trials, data on distance travelled, time code and the recorded pressure on the brake pedal were logged and stored on the PC. Based on these data, it was possible to calculate speed, deceleration, etc.

2.2 Test cars

For the braking trials, two cars were used: a small and a medium-sized car, which were judged to be fairly representative of recent makes of car in Denmark. The cars were a Fiat Grande Punto and an Opel Vectra. Both cars had ABS brakes and manual transmission. The cars were fitted with new summer tyres (Continental EcoContact 3) prior to the first braking trials. The tyres were however 'run in' by 500 kilometres' ordinary driving prior to the first measurement day. The tyres used were judged to be average, typical summer tyres with medium to good braking capability according to tyre tests (*5*).

The same tyres were used for all the braking trials. The tread depth from the start was measured as 7-8 mm and the total wear during the entire programmes was recorded as < 1 mm.

2.3 Test drivers

On each of the three test tracks, both professional and non professional test drivers performed braking manoeuvres. The results from the professional test drivers were assumed to be able to describe the optimal emergency stop under the given conditions. The non professional test drivers (a total of 16) were mainly recruited among staff in the Danish Road Directorate. They consist of 11 men and 5 women, mainly in the age-range 25-39. The results from the non professional test drivers are intended to shed light on the individual differences in braking behaviour presented by ordinary drivers.

2.4 Water truck for wet surface

The wet road surface was achieved with the aid of a water truck, which dispersed water onto the braking section immediately before each braking trial. The calculated volume dispersed by the truck was 1.3-1.6 litres/m^2 (water depth = 1.3-1.6 mm). Due to the road's cross slope, some of the water would naturally have run off the road again before the trial was conducted. Typically it took a couple of minutes from the water truck dispersing the water until the braking trial was performed.

3. FINDINGS FROM BRAKING TRAILS

3.1 Results for professional drivers

The average braking distances (L_{brake}) for professional test drivers at 80, 110 and 130 km/h on the three test tracks are shown in Table 3. Car 1 and Car 2 values are combined since the difference were negligible. As will be seen, the difference in L_{brake} on dry road is insignificant, but for wet road is somewhat larger.

TABLE 3 Average L_{brake} by speed, test track and dry/wet road surface

Speed	Test track 1		Test track 2		Test track 3	
	dry	wet	Dry	wet	dry	wet
80 km/h	30 m	35 m	30 m	34 m	30 m	29 m
110 km/h	55 m	64 m	55 m	61 m	55 m	55 m
130 km/h	76 m	88 m	76 m	84 m	76 m	76 m

The average deceleration (Dec_{brake}) for professional test drivers, based on the entire braking run has been analysed. Overall, the difference between the two cars was small. Dec_{brake} was measured as 8.4 m/s^2 for dry road and 7.9 m/s^2 for wet road. The difference between the 3 test tracks must be attributable to differences in friction (discussed later). Further, higher deceleration values are seen at higher initial speeds, which is due to the fact that braking was

more effective at higher speeds, since the braking initiation time accounts for a smaller proportion of the total braking time at higher speeds.

Figure 1 shows the average deceleration values for speed intervals 120-100, 100-70, 70-50 and 50-30 km/h for the professional test drivers. The deceleration values are generally higher on dry compared with wet road. Furthermore, the deceleration values are higher within the low speed intervals compared with the high speed intervals. On dry road, $Dec_{50\text{-}30}$ was approx. 9.5 m/s^2, while $Dec_{100\text{-}70}$ was approx. 9.1 m/s^2. In addition, there is some difference in the measured deceleration values depending on whether braking started from 130, 110 or 80 km/h. For example, braking from 80 km/h has the poorest $Dec_{50\text{-}30}$, while breaking at 110 or 130 km/h is more effective in the shape of higher deceleration values. The reason for this may be that an extended braking trajectory, from e.g. 130 km/h, raises tyre and brake temperature, which in turn boosts braking capability.

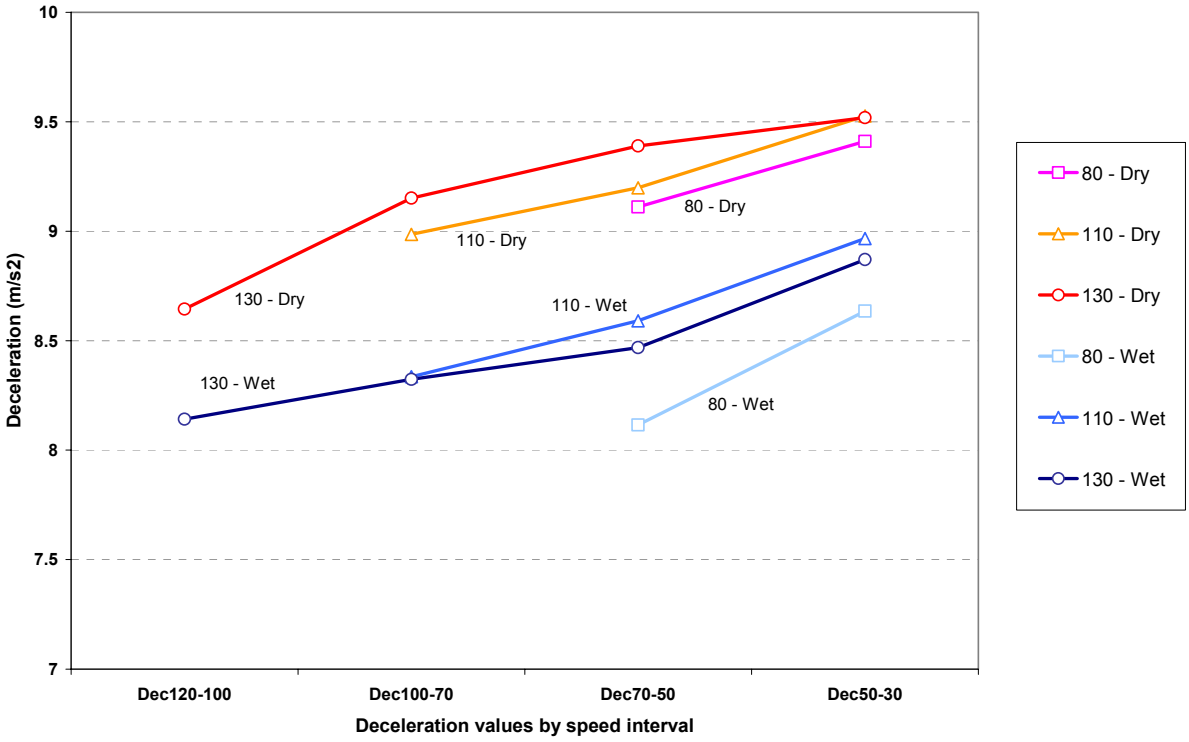

FIGURE 1 Average deceleration values (m/s^2) on dry and wet road, by speed intervals and initial speed.

3.1.1 Braking distances and friction

Figure 2 shows the measured braking distances (L_{brake}) for 80, 110 and 130 km/h, respectively, on dry and wet road with different friction values (professional test drivers only). On dry road, L_{brake} is almost constant for friction values in the range 0.5 – 0.7. On wet road, we see gradually increased braking distances the lower the friction. This is true of all speeds. At 130 km/h, L_{brake} for example, increases from 76 m to 91 m when friction is reduced from 0.75 to 0.5. This corresponds to an increase in L_{brake} of approx. 20%. The same

percentage increase in L_{brake} is also seen in the case of the other speeds. It should also be noted that, at high friction, L_{brake} is the same for dry and wet road.

The corresponding values for Dec_{brake} are also shown in Figure 2. Dec_{brake} for dry road is at 8-8.5 m/s^2 irrespective of friction, while for wet road, it drops from approx. 8.5 m/s^2 to approx. 7 m/s^2, when the friction is reduced from 0.75 to 0.5.

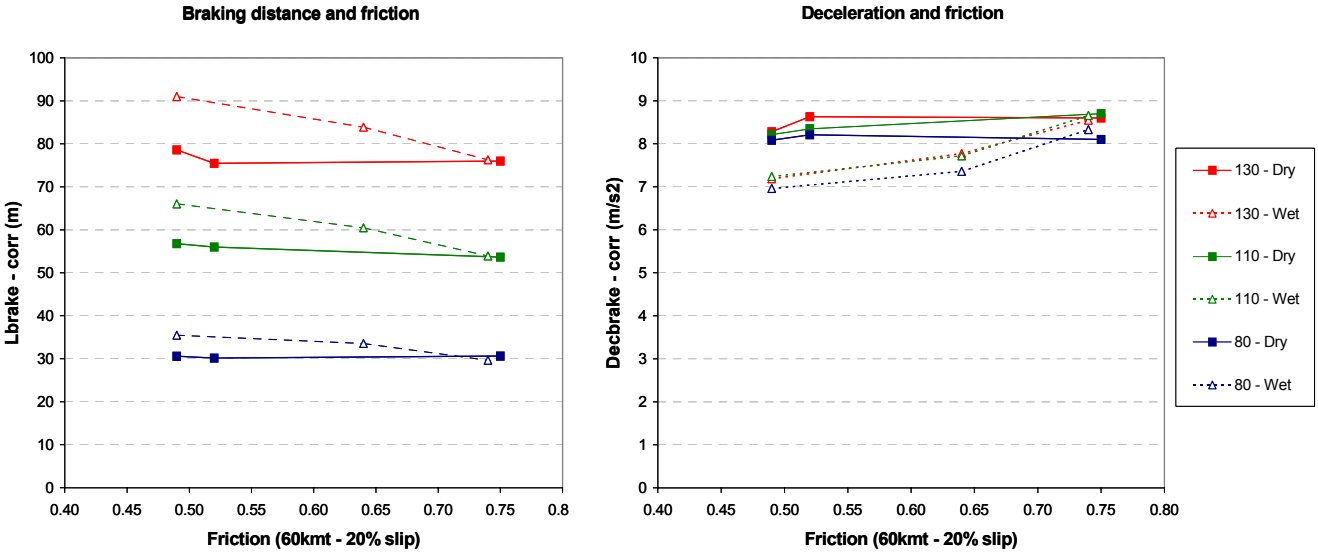

FIGURE 2 Braking distance (L_{brake}) and deceleration (Dec_{brake}) as a function of friction.

A regression analysis to describe Dec_{brake} as a function of friction and initial speed was carried out. This was done using the same model as in (*6*), where deceleration is described using a function in which the square root of the friction is used.

The model is shown below:

$$Dec_{brake} = a \cdot \sqrt{\mu_{fric}} + b \cdot V_0$$

where

Dec_{brake}	is the average deceleration for the entire braking run (m/s^2)
μ_{fric}	is the recorded friction on the test track at 60 km/h – 20% slip
V_0	is the initial speed before braking (m/s)
a and b	constants found by regression

For the recorded deceleration values on wet road (33 observations), the following results were obtained:

$$Dec_{brake} = 8.79 \cdot \sqrt{\mu_{fric}} + 0.028 \cdot V_0 \qquad R^2 = 0.97$$

This allows L_{brake} to be calculated using various friction values by the formula:

$$L_{brake} = \frac{V_0^2}{2 \cdot Dec_{brake}} = \frac{V_0^2}{2 \cdot (8.79 \cdot \sqrt{\mu_{fric}} + 0.028 \cdot V_0)}$$

The calculated values for Dec_{brake} and L_{brake} using the formulas is shown for 80, 110 and 130 km/h in Table 4.

TABLE 4 Estimated deceleration (m/s^2) and braking distance (m) for wet road. Based on regression analysis.

Friction	80 km/h		110 km/h		130 km/h	
	Dec_{brake} (m/s^2)	L_{brake} (m)	Dec_{brake} (m/s^2)	L_{brake} (m)	Dec_{brake} (m/s^2)	L_{brake} (m)
0.4	6.2	40	6.4	73	6.6	99
0.5	6.8	36	7.1	66	7.2	90
0.6	7.4	33	7.7	61	7.8	84
0.7	8.0	31	8.2	57	8.4	78
0.8	8.5	29	8.7	54	8.9	74

According to the table, a wet road surface with a friction of 0.4 will produce a Dec_{brake} of 6.2-6.6 m/s^2 depending on initial speed. According to the Danish Road Standards and Guidelines, a friction value of 0.4 is the minimum requirement for roads in operation.

3.2 Results for non professionals

The measured braking distances in emergency stops show, that non professional test drivers in average have longer braking distances compared to the professionals' for all speeds and dry/wet conditions. At the same time, we see a larger spread in braking distances for the non professional test drivers. In addition, we find that higher speed produces higher spread. Several test drivers brake on a par with the professionals, and some even have minimum values that are better than those of the professionals. But there are also test drivers whose average braking distance is more than 40-50% longer than the professionals, and in some cases exceeds 100%.

To analyses this in more detail, we calculated the $L_{brake\%}$ which is the percentage difference in braking distance for the non professional test driver in relation to braking distance for the professional under the same conditions (speed, road surface, test track and car).

Overall, the $L_{brake\%}$ is in the order of 20-25%, but the figures hold great variation. Figure 3 shows the individual test drivers mean value for $L_{brake\%}$. Besides, the mean, the min. and max. values are shown. The majority of the test drivers have an $L_{brake\%}$ that averages less than 20%, but some test drivers whose average $L_{brake\%}$ is more than 40-50%.

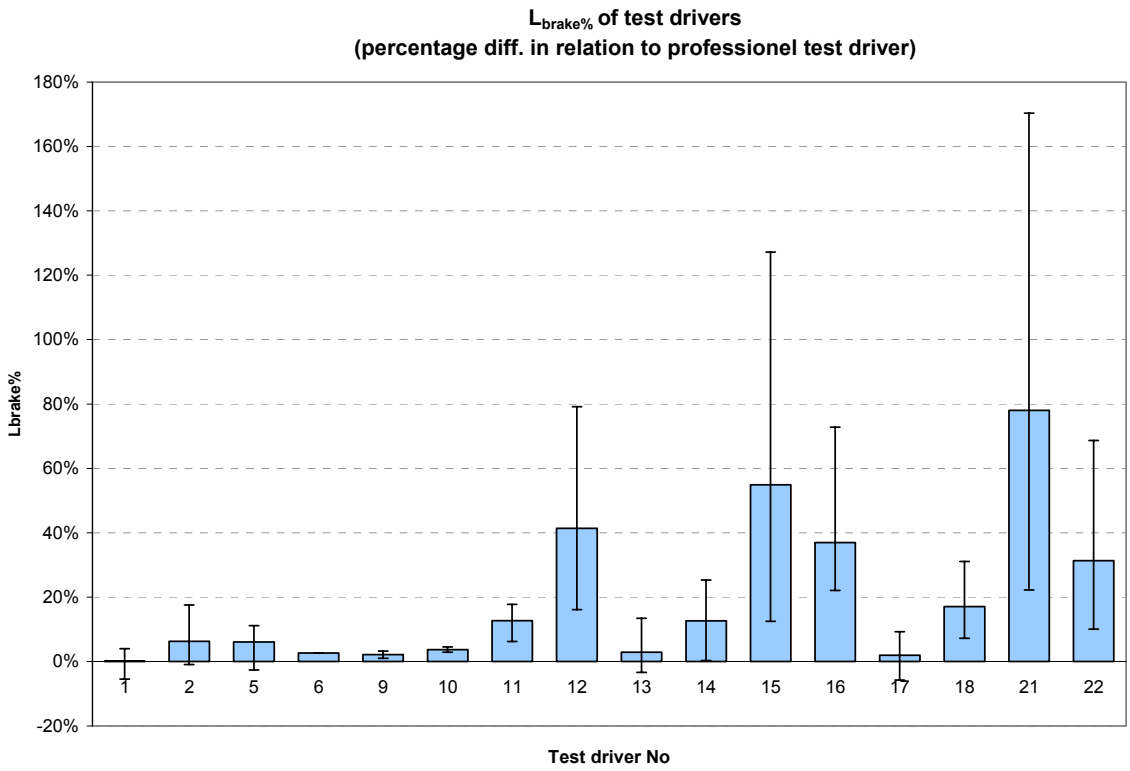

FIGURE 3 $L_{brake\%}$ for non professional test drivers, expressed as a mean, min. and max. value.

If we look at the recorded braking distances on wet road at 80 and 110 km/h in isolation, the $L_{brake\%}$ breaks down as follows: For 14% of all the recorded braking distances on wet road, the $L_{brake\%}$ is negative (i.e. shorter than the professionals'); for 29% the $L_{brake\%}$ is between 0-10, while for 22% the $L_{brake\%}$ is 10-20. By far the majority (80%) of the braking distances have an $L_{brake\%}$ that is less than or equal to 30.

One of the parameters responsible for great variation in $L_{brake\%}$, is the number of braking trials carried out. The more times the test drivers carried out the manoeuvre, the more effective their braking became. In the 1st braking trial, which was always at 80 km/h on dry road, the $L_{brake\%}$ averages 23%. After 5-6 trials, the majority of test drivers have tried both dry and wet road at different speeds, and begin to feel more confident about the manoeuvre, and the $L_{brake\%}$ falls.

Other results for the non professional test drivers are summarized below:

- the Dec_{brake} (average deceleration for the entire braking run) was in average 7.4 m/s^2 on dry road and 7.0 m/s^2 on wet road. This is approx. 10% less than those of the professionals
- male test drivers in the age-group 25-50 have the shortest braking distances compared to female test drivers in the same age-group. For age-group 50-70 (all male), the longest braking distances were found. The number of test drivers in the study is however, modest, which means that the figures barely can be used to generalise.

- the $L_{brake\%}$ expressed by speed, dry/wet road and car 1 and car 2 showed only minor differences.
- on average, the pressure on the brake pedal for the whole of the braking run, was recorded as 34.8 kg for the non professional test drivers and 74.0 kg for the professionals.
- analysis shown that deceleration drops once the pressure on the brake pedal drops below approx. 10-15 kg. However, there is no consistent difference in deceleration once the pressure exceeds 10-15 kg.
- on average, the time it takes from the pedal being touched until the pressure reaches at least 10 kg, was recorded as 0.83 sec. for the non professional test drivers and 0.05 sec. for the professionals.
- braking on wet road and at high speeds, is the situations in which the non professional test drivers brake most tentatively
- in the comfort braking trials, were non professional test drivers were required to bring the vehicle to a comfortable stop, the test drivers had an average deceleration of 3.2 m/s^2 in the speed interval from 70-20 km/h.

4. THE SIGNIFICANCE OF OTHER PARAMETERS FOR BRAKING DISTANCE

The measurement programme contained a selection of the parameters of significance for braking distance. Other important parameters that were not included in the measurement programme are (among others):

- Make of tyre
- Summer tyres versus winter tyres
- Tyre tread depth
- Make of car
- Loaded or non-loaded car

Information about the significance of the listed parameters for braking distance is based on literature and is summarised in Table 5. The table shows the effect on braking distance on wet road for the various parameters compared with either an average state or an altered state.

TABLE 5 Effect on braking distance on wet road.

Parameter	Effect in relation to:	Effect % [min/max]	Average in relation to measurement programme	Effects based on literature:
Make of tyre	Average tyre	-10% - +10%	+0%	(*7*), (*8*), (*9*)
Winter tyre	Summer tyre	+5% - +35%	+15%	(*7*)
Tread depth 1.6 mm	8 mm	+0% - +50%	+25%	(*6*), (*9*), (*10*), (*11*)
Make of car	Average car	-10% - +10%	+0%	-
Loaded	Non-loaded	-10% - +15%	+4%	(*6*), (*12*)

Winter tyres for example have a braking distance +5% to +35% longer than summer tyres. This puts the average at 15%. In relation to our measurement programme, which was conducted on summer tyres, the braking distance thus has to be increased by an average of 15% to be applicable to vehicles with winter tyres.

The question is whether the effects on braking distance can indeed be summed. A poor vehicle with poor tyres that are loaded will, if the effects are summed, risk producing a 10%+35%+50%+10%+15% = 120 % longer braking distance compared with those observed in the measurement programme. In the best case, the braking distance might be 25% shorter. However, the probability of finding a vehicle with these extreme min./max. values is presumably very small. Overall, the conclusion is that a large spread in the braking distance is likely, depending on the listed parameters, if one permits the listed effects to be summed. A better description of how tyres, brakes, car makes and the interaction of these affect braking distance would require supplementary data or further practical trials.

5. NEW RECOMMENDED BRAKING DISTANCES

An attempt is made in the following to establish a new set of recommended braking distances for use in Denmark. This is done on the basis of the findings from the measurement programme as well as knowledge of the different parameters' influence on braking distance. New recommended values for braking distances are provided on the basis of the following considerations:

- the braking distance should reflect worst-case-scenario road conditions, which equate to wet road with low friction. Low friction is set at 0.4, which is consistent with friction requirements for roads in operation. Wet road is assumed to be in the same state as that during the measurement programme, i.e. clean, but with a water membrane of approx. 1 mm.

- the braking distance should reflect the braking capabilities of a vehicle whose braking capabilities are at the weak end of the scale among ordinary cars, but which otherwise conforms to legal brake, tread pattern requirements, etc.

- the braking distance should reflect the braking behaviour found among the worst performing drivers (among non professional) travelling on the roads.

- the braking distance assumes that the vehicle is fitted with ABS brakes.

The braking distance for wet road with friction of 0.4 is determined from the results in Section 3.1.1. Here we find that a professional test driver is able to achieve a Dec_{brake} of approx. 6.5 m/s^2 under these conditions (extrapolated from the recorded data).

By far the majority of the non professional test drivers produced braking distances 0-20% longer than the professionals' (see Section 3.2). It is assumed that the weakest half of the non professional drivers have a braking distance 30% longer than the professionals.

The braking distance for a legal vehicle in which the braking capability is poor due to worn and poor tyres, poor brakes etc. is set (rounded figures) at 45% longer than the observed braking distances for the test cars used in the measurement programme.

Overall, this results in recommended braking distances as shown in the Table 6.

TABLE 6 New recommended braking distances. Based on wet and clean road (on level) with a friction of 0.4.

	80 km/h	110 km/h	130 km/h
L_{brake} – professional in test car	40 m	73 m	99 m
Behavioural increment (+30%)	12 m	22 m	30 m
Vehicle increment (+45%)	18 m	33 m	45 m
Recommended L_{brake} (sum)	70 m	128 m	174 m

The recommended braking distances correspond to an average Dec_{brake} of 3.7 m/s^2.

Figure 4 shows the new recommended braking distances compared with the existing ones from the Danish Road Standards and Guidelines and the Green Book, together with those recorded in the measurement programme.

As shown by Figure 4, the new recommended braking distances are almost identical with the current ones for speeds below 90 km/h. For higher speeds, e.g. 130 km/h, the new recommended braking distances are approx. 25% shorter than the current ones. In relation to the current recommendations, incl. safety increment, the braking distance for 130 km/h is approx. 50% shorter. In relation to the braking distances from the Green Book, the new recommended braking distances are approx. 5-10% shorter.

The method for determining the new recommended braking distances based on the findings of this study calls for a few accompanying remarks:

The method for determining the vehicle increment of 45% is somewhat uncertain. Section 4 describes the significance of various parameters for braking distances. If these are summed uncritically, we find large spreads in the braking distance of vehicle with better or poorer braking capability (in relation to the test cars). The vehicle increment is set at 45%, based on a law of averages combined with what ”would appear fairly reasonable”, but in reality, the vehicle increment is not precisely known.

It is also debatable whether the recommended braking distance should be based on tyres that are only just compliant with the statutory requirement of 1.6 mm tread depth, or whether stricter requirements for tread depth would be preferable (e.g. 3 mm). The key factor in the vehicle increment is tyre tread depth.

In determining new recommended braking distances, the vehicle increment and behavioural increment were summed uncritically. It is debatable whether the recorded braking distance

can be translated directly to another vehicle with poor braking capability. One might, for example, imagine that the difference between a professional test driver and a non professional test driver would not be the same if the braking was performed in a vehicle with very poor braking capability. This then would make it incorrect to sum the vehicle increment (45%) and the behavioural increment (30%).

Overall, the position is that the new recommended braking distances have been determined somewhat "cautiously" with a good safety margin in relation to the cars and motorists driving on Danish roads.

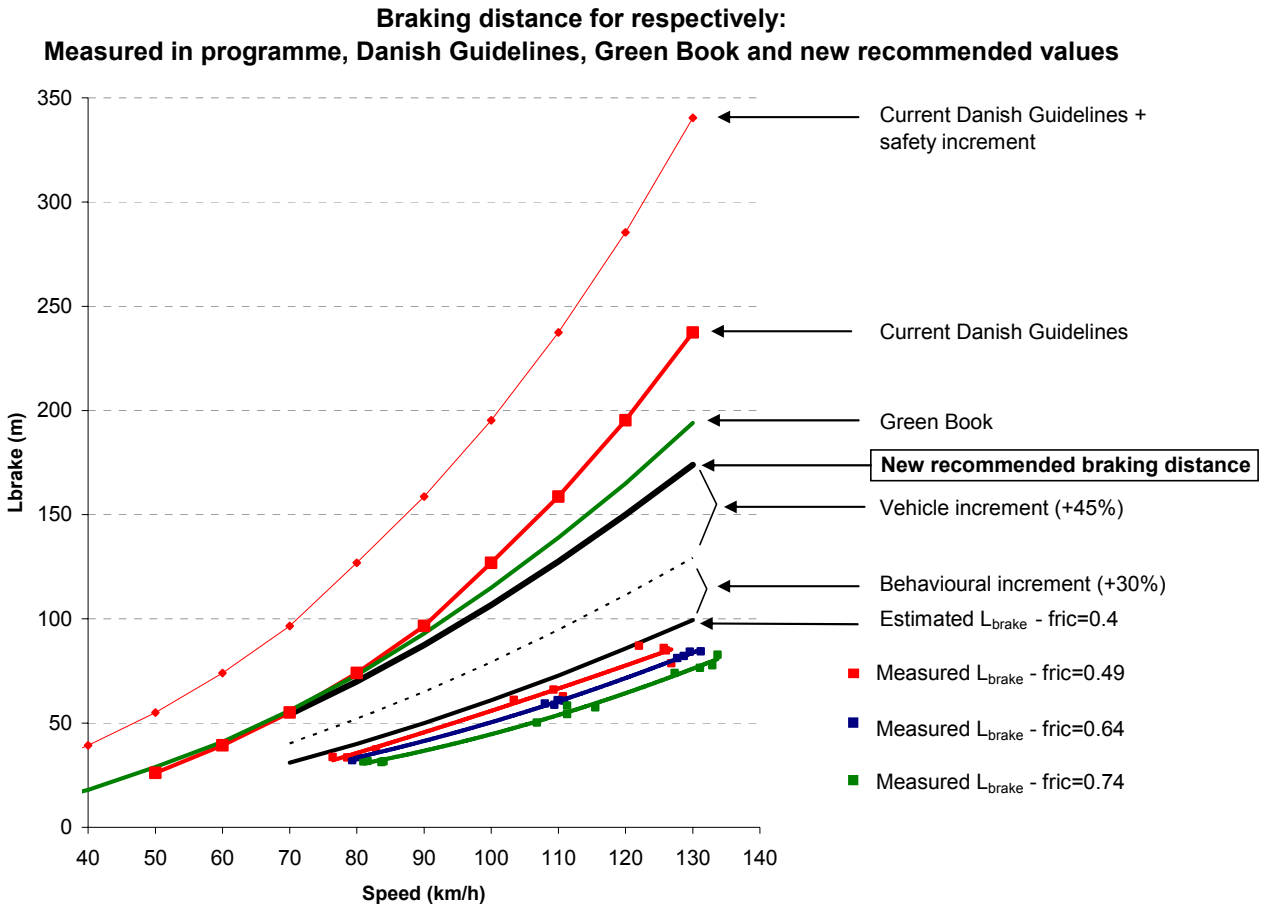

FIGURE 4 Recorded values for L_{brake} and new and existing recommended braking distances

6. SUMMARY

The current recommended braking distances in the Danish Road Standards and Guidelines are in the main based on earlier American findings. In order to be able to assess the validity of the recommended braking distances in relation to contemporary vehicles and motorists in Denmark, the Danish Road Directorate has conducted a study designed to shed light on

braking behaviour and braking distances among ordinary (non professional) motorists, at different speeds.

This was done through a measurement programme in which 22 test drivers performed braking manoeuvres at different speeds (80, 110 and 130 km/h). The majority of the test drivers who participated were recruited from among non professional drivers. However, 6 out of the 22 test drivers were professional test drivers with extensive experience in advanced driving technique. Two different recent cars with ABS brakes were used as test cars. The braking manoeuvres were carried out on dry and wet road on three test tracks with different friction. The majority of the manoeuvres performed were emergency stops, in which the test driver was required to bring the vehicle to a complete standstill as quickly as possible. In addition, a small number of comfort braking manoeuvres were performed in which the test driver was required to bring the vehicle to a comfortable stop.

Based on findings of the measurement programme (172 emergency stops and 23 comfort braking manoeuvres) and knowledge obtained concerning the significance of other parameters for braking distance (choice of tyre, vehicle, etc.), we have sought to establish a new set of recommended braking distances. These are based on “worst case scenarios”, i.e.

- wet road surface with poor friction (friction=0.4 – minimum requirement for roads in operation)
- driver with tentative braking behaviour
- vehicle with poor braking capability

The new recommended braking distances for speeds of 80, 110 and 130 km/h are 70 m at 80 km/h, 128 m at 110 km/h, 174 m at 130 km/h.

The braking distances are assessed as somewhat ”cautiously determined” with a good safety margin in relation to the cars and motorists driving on Danish roads.

For speeds below 90 km/h, the new recommended braking distances are almost identical with both the existing ones in the Danish Road Standards and Guidelines and with Green Book. At greater speeds, e.g. 130 km/h, the new recommended braking distances are approx. 25% shorter than the existing ones and 10% shorter compared to Green Book (see Figure 4).

7. REFERENCES

1. *Braking distance, friction and behaviour. Findings, analyses and recommendations based on braking trials.*
   Poul Greibe, Trafitec Report, July 2007

2. *Forudsætninger for den geometriske udformning. Veje og stier i åbent land – Hæfte 1*. Vejregelrådet, 1999 (Danish Road Directorate)

3. *A policy on geometric design of highways and streets.* Green Book
   AASHTO, 2001

4. *Determination of Stopping Sight Distances*.
   Fambro, D.B., K. Fitzpatrick, and R.J. Koppa, NCHRP Report 400. TRB, National Research Council, 1997

5. *Dæktest*
   Motor 4/2005, Motor 4/2006 (Motor magazine)

6. *Mögliche Bremsverzögerung in Abhängigkeit von der Griffigkeit.*
   Ralf Roos and Matthias Zimmermann. Universität Karlsruhe, 2004

7. *Sommerdæks og vinterdæks bremseegenskaber ved lav temperatur mv., forskningsresultater og målinger.*
   Færdselsstyrelsen (Denmark's Road Safety and Transport Agency), 2006

8. *Sommerdæk på glatis*
   Motor 5/2001 (Motor magazine)

9. *Personbilsdäcks bromsfriktion på våt asfaltbeläggning*
   Nordström and Gustavsson. Swedish National Road and Transport Research Institute, report 61-1996, 1997

10. *Tyre Safety Campaign*
    Tyre Specialists of Finland, 2005
    (Interest organisation for tyre companies)

11. *Continental's website*
    http://www.conti-online.co.uk/generator/www/uk/en/continental/portal/general/safety/3mmtread_en.html (seen February 2007)

12. *Consumer Braking Information*
    Final report – prepared by U.S. Army Aberdeen Test Center
    National Highway Traffic Safety Administration (NHTSA), 2003