



THE FEASIBILITY OF USING ROLLER BRAKE TESTERS FOR ROADSIDE CHECKS OF HEAVY VEHICLE BRAKES INSTEAD OF TESTS ON THE ROAD

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ABSTRACT

Brake tests on the road are getting more and more difficult to perform due to increased traffic density and are therefore not very often carried out by the police when heavy vehicles are inspected on the road. At the same time the Swedish Road Administration finds it desirable to increase the number of brake tests of heavy vehicles in traffic. One of the reasons being that the percentage of heavy vehicles with defective brakes at the annual inspection is relatively high.

The use of roller brake testers at the roadside, stationary or mobile is regarded as a possibility of solving the testing problems. As a first step in establishing such a test procedure, the National Swedish Road and Transport Research Institute (VTI) was assigned by the Swedish Road Administration to carry out an investigation divided in two parts, the first being research on the correlation between two types of roller brake testers, one stationary as used by the annual inspection and a mobile device with smaller rollers and lower testing speed. The second part comprised experimental research, literature search and theoretical analysis for the development of an improved test procedure for the use of roller brake testers in order to get results as far as possible equal to the results of braking tests on the road and also taking more factors into account than has till now been the case at the annual inspection. The first part was carried out with a prototype mobile roller tester with roller diameter of 148 mm and test speed 0.8 km/h in comparison with two stationary roller testers with a roller diameter of 260 mm and a test speed of 2,5 km/h. Different types of heavy vehicles were used with varying axle loads from 10 kN to about 125 kN with tyres of varying diameter, tread, and inflation pressure.

The results showed that the devices gave very similar results. The mobile device gave about 3 to 4% higher values, a difference so small that it is questionable whether a correction factor should be used. The rolling resistance on the two types of testers was of equal magnitude and proportional to the vertical load i. e. the rolling resistance coefficient was constant and typically about 3% of the load .

The experimental research part of the second part of the investigation was carried out in co-operation with the traffic police and consisted of comparative brake testing of heavy vehicles on the road and on stationary and mobile roller brake testers on four sites in different parts of Sweden. A total number of

160 vehicles were tested, 58 Scania trucks, 48 Volvo trucks, 6 other trucks and 48 trailers.

The road tests were performed from about 50 km/h to full stop using electronic accelerometer, a pressure gauge and pedal force transducer. All data were recorded on a PC and processed to give mean fully developed deceleration at the actually used air pressure and the deceleration predicted at maximum air pressure. On the roller testers rolling resistance, initial brake application pressure, air pressure and braking force at wheel lockup limit as well as axle weight was measured. Additionally

the axles were weighed on scales normally used by the police. The results show that compared to the road test results , predicted at maximum pressure, the corresponding calculation method with linear extrapolation from zero pressure used at the annual inspection in Sweden gives as an average 30 % higher values for the Scania trucks 38 % higher values for the Volvo trucks 46% higher for the other trucks and 81 % higher for the trailers where the extrapolated values are multiplied by 1 ,25. Alternative calculation methods taking initial brake application pressure and rolling resistance into account showed even higher values. Better and more equal results for the different vehicle groups were obtained by a formula considering only the rolling resistance. A simple reduction factor of 0.9 on the present motor vehicle formula which is used in Norway also for trailers gave the next best improvement giving from 16% to 31% too high values. The equalising effect of the formula considering rolling resistance was apparent only for the trailers and the Scania trucks which all have S-cam brakes, but as these are frequent vehicles in Sweden this calculation method is recommended. Furthermore the investigation comprises an analysis of what factors that are desirable to check besides the mean fully developed deceleration. As a result of this analysis it is recommended to also include checking the maximum available glad-hand pressure at cut in pressure of the compressor, load sensing valve function check at kerb weight and maximum weight by means of load simulation with a hydraulic or electric device attached between chassis and ground. For an efficient testing without risking vehicle damage it is proposed that it should be mandatory with suitable standardised attachment points on the chassis of heavy vehicles, Furthermore it is proposed that brake application and release delay times shall be measured and also that the proper brake force distribution between axles is checked against the manufacturer's specification. Brake temperature measurement as a quick check of the need of a more thorough brake check is regarded as promising but its possibilities and limitations need further study.

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1 INTRODUCTION

Brake tests on the road are getting more and more difficult to perform due to increased traffic density and are therefore not very often carried out by the police when heavy vehicles are inspected on the road. At the same time the Swedish Road Administration finds it desirable to increase the number of brake tests of heavy vehicles in traffic. One of the reasons being that the percentage of heavy vehicles with defective brakes at the annual inspection is relatively high. The use of roller brake testers at the roadside, stationary or mobile is regarded as a possibility of solving the testing problems. The correlation of roller brake tester results to road tests has however been questioned especially for small rollers and low test speed.

2 AIM

The aim of the investigation was to improve the inspection procedures for heavy vehicle brakes on road side by the police and at periodical inspection. One part of the project was to study the compatibility of stationary brake testers normally used for periodic inspection with a mobile roller brake tester with lower test speed and smaller roller diameter intended for use by the police. A second part to compare roller tester results with results from braking stop tests on ordinary roads with the aim of as far as possible replacing tests on the road with valid roller brake tests. The influence of different parameters such as wheel load, tyre dimensions tread depth and inflation pressure should be clarified. Calculation methods for extrapolating brake forces measured on roller tester to maximum deceleration performance should be investigated in order to if possible improve the present method. Also a general analysis of the inspection procedure should be carried out and improvements be proposed.

3 TEST OBJECTS

- 1) Mobile brake tester BM20200 from BM Autoteknik, Denmark with test speed 0,8 km/h and roller diameter of 148 mm. The device is shown in [Figure 1](#).
- 3) Stationary brake tester from EWJ, Denmark with test speed 2,5 km/h and a roller diameter of 260 mm.

[Figure 2. Wheel load transducer](#)

[Figure 3 BM 17200 Stationary roller brake tester](#)

[Figure 4 Control pressure transducer](#)

4 TEST VEHICLES

8 heavy trucks one light utility vehicle and 2 heavy trailers were used for the correlation study between the mobile and the stationary roller brake testers.

For the comparison between the roller brake testers and braking stop tests on ordinary roads the 8 vehicles mentioned before and further 112 heavy trucks and 48 heavy trailers were used taken directly from the traffic flow to stationary and mobile roadside test equipment.

5 TEST SITES

The correlation tests between stationary and mobile roller brake testers were carried out in Linköping at the Swedish vehicle inspection (ASB) and at Volvo Hälleröd test track in Sweden and in Aalborg, Denmark at the Aalborg Technical School.

Four different test sites were used for road side testing.

1. Test site Armsjön near Sundsvall in northern Sweden:

Stationary Roller brake tester BM 17200

2. Test site Linköping mid south of Sweden :Mobile roller brake tester BM 20200

3. Test site Jönköping mid- south of Sweden: Mobile roller brake tester BM20200

4. Test site Viared near Borås south western Sweden.:

Stationary Roller brake tester BM 17200

6 MOBILE AND STATIONARY ROLLER BRAKE TESTER CORRELATION

6.1 Test procedure

The tests for comparing the roller brake testers were carried out according to the test schedule ABBAABBA for each vehicle where A is the mobile tester and B a stationary tester. At the tests with the BM testers rolling resistance was initially recorded, next ovality and at last the maximum braking force and corresponding reference air pressure at the coupling head or in the front axle circuit. The measurements with the EVG were similar except that the rolling resistance could not be recorded. The brake forces were recorded individually for each wheel of a vehicle.

6.2 Parameter variation

Axle loads, tyre diameters, tread depths and inflation pressure were varied.

6.3 Data analysis

The measured braking force was extrapolated to a common reference pressure 0,65 MPa by multiplying the measured braking force with the reference pressure and dividing it with the measured pressure. For the small utility vehicle that had hydraulic brakes the pedal force was used instead of the air pressure and the reference pedal force was set to 400 N. The mean value of the 4 recorded values for each wheel was calculated and used in the comparison.

Statistical data analysis was carried out as simple and multiple regression with the ratio M/S between the mean values of the braking forces of the mobile tester M and the stationary testers S as dependent and wheel load wheel diameter air pressure and tread depth as independent variables

6.4 Results

6.4.1 General

The result of the multiple regression of the normalised test data values was that no variable had the level of significance of 0,05 required for use in the model. Thus according to this analysis the ratio M/S can be regarded as a constant with the value 1,042 independent of the tested variables. In other words the mobile tester gives 4 % larger values than the stationary testers. A simpler Excel regression shown in [figure 5](#) gave a difference of about 3 %.

6.4.2 Wheel load

Wheel load (P) between 4,66 and 63 kN were used at the tests. Linear regression gives $M/S = 1,028 + 0,0003P$. The 95% confidence interval for M/S is between $1,0799+0,0018P$ and $0,9767 - 0,0011P$. As said before the P-term is not significantly separated from zero.

The results are shown graphically in [figure 6](#).

Figure 5 shows the forces measured with S as function of corresponding M-values. Figure 6 shows M/S as function of wheel load.

6.4.3 Wheel diameter

The wheel diameters varied between 0,74 m and 1,09 m. No significant influence on the force ratio M/S could be shown.

6.4.4 Tread depth

The tyres had tread depths between 3 and 15 mm. No significant influence of the tread depth on the force ratio M/S could be shown.

6.4.5 Tyre inflation pressure

The smallest tyre with the lowest inflation pressure tested on the smallest roller diameter was considered to be the worst case based on the justification that the relative change in radius would be largest for a small tyre and that at low pressure a certain absolute pressure change will cause a larger relative deformation in the rolling contact area. The pressure range was from 100 to 350 kPa: larger range was regarded as unrealistic [Figure 7](#)

The wheel size was 235/70 R15 M+S with a wheel diameter of 0,74m, a tread depth of 5 mm and a wheel load of 4,66 kN.

The test result was that between 200 and 350 kPA no influence of the pressure on the measured braking force could be observed. At 100 kPa there was a slight increase. The conclusion is that within normal variation ranges of inflation pressure no correction of the braking force is needed due to these variations.

6.4.6 Rolling resistance

The average rolling resistance coefficient was 5% higher for the mobile tester compared to the stationary testers independent of wheel load as shown in [figure 8](#). The difference has no significant influence on the ratio M/S.

The rolling resistance force increased linearly with load i. e. the rolling resistance coefficient was constant and the average value was about 3%.

7 ROLLER BRAKE TESTER VERSUS BRAKING STOP TEST ON THE ROAD

7.1 Test procedure

The braking stop tests were performed from initial speeds between 50 and 60 km/h at least two times V1 and V2 for each vehicle. In the second test V2 the deceleration was higher. In the case of a vehicle combinations two tests were made first with both vehicles braked and then two tests with only the towing vehicle braked. By means of calculation the performance of each vehicle could be evaluated.

$$a_m = a_{cm} \cdot \frac{M_m + M_t}{M_m}$$

$$F_t = (a_{c(m+t)} - a_{cm}) \cdot (M_m + M_t)$$

$$a_t = \frac{F_t}{M_t}$$

a_m = mean fully developed deceleration of the motor vehicle alone(m/s^2)

a_t = mean fully developed deceleration of the trailer alone(m/s^2)

a_{cm} = mean fully developed deceleration of the combination braked by the motor vehicle only (m/s^2)

$a_{c(m+t)}$ = mean fully developed deceleration of the combination braked by the motor vehicle and the trailer(m/s^2)

The deceleration was measured with a vehicle fixed accelerometer mounted on the windscreen of the cab of the motor vehicle. To compensate for vehicle pitch, the integrated signal from a rate gyro was used. The brake pressure at the coupling head or at the most convenient pressure output connector and pedal force was also measured.

The measurements were recorded on a PC and the mean fully developed deceleration was calculated according to the Swedish SMS Standard 2982 and the corresponding mean pressure were calculated by means of a computer program developed at VTI. The SMS 2982 defines the mean fully developed deceleration as the mean deceleration over time in the time interval from 0,3 T to 0,9 T, where T is the time from the beginning of a rapid brake application to the time when the deceleration has dropped to zero the first time at the end of the stop. It is also required that the deceleration in this time interval does not vary more than 25% of the mean value. At present the police most commonly uses a pendulum based direct reading decelerometer with a maximum indicator. Compared to the SMS standard method the police instrument will tend to give somewhat higher deceleration values.

7.2 Evaluation of methods for calculation of maximum deceleration

In Europe several calculation methods exist with more or less complex structure for the calculation of the braking force(F_{max}) at maximum control pressure (p_{max}). These are presented in annex 1.

The formula used in Sweden and Norway is the simplest and only uses measured brake force (F) and corresponding brake pressure (p) without correction factor for motor vehicles and with the correction factor 1,25 for trailers. In Norway the correction factor 0,9 is used for all vehicles.

- a) Sweden, Motor vehicles: $F_{max} = F_{xpmax}/p$
- b) Sweden, Trailers: $F_{max} = 1,25 (F_{xpmax}/p)$
- c) Norway , all vehicles: $F_{max} = 0,9 (F_{xpmax}/p)$

The formula for maximum deceleration based on the Swedish formula a) used by the Swedish periodical inspection(ASB) has been named R1 in the correlation study between road test and roller brake test and a corresponding formula based the Norwegian calculation c) has been named R4.

The international technical control association CITA recommends a formula considering the rolling resistance which was originally proposed by ASB: $F_{max} = 1,05(F-Fr)p_{max}/p$. Compared to the previous formulas there is a significant difference in that the rolling resistance (Fr) is subtracted from the braking force(F), which means that the calculated maximum force is reduced. For motor vehicles the reductions is reduced by the factor 1,05 which however is smaller than the one used in Sweden for trailers.

In the investigations made by VTI the rolling resistance has been around 3% of the wheel load, i.e. for a 10 ton axle about 3 kN. The effect is evidently greater if the braking force is low compared to the rolling resistance. On the road the rolling resistance for non driven wheels is about 1% and for driven wheels 1,5%. As the rolling resistance contributes to the braking performance it is justified to add a realistic braking force value to the value calculated by subtracting the rolling resistance on the roller brake tester. This value could replace the factor 1,05.

A new formula(R2) is therefore proposed as follows:

$$r_{max} = (F-Fr)p_{max}/ (p \cdot m) + 0,125$$

r_{max} = maximum deceleration

F= measured braking force

Fr = measured rolling resistance

p = measured control pressure, pmax lower limit for max control pressure

m = vehicle mass

In this formula the CITA formula has been modified by replacing the factor 1,05 by 1 and adding 0,125 representing the effect of a theoretical rolling resistance based on the mean value for a driven and a non driven axle according to ECE/EEC

Theoretically the formula should use the starting pressure for the brake force build up as starting point for the linear extrapolation and not from the pressure zero. In certain countries formulas are used in which theoretical or measured starting pressure is used. In this investigation a formula R3 has therefore also been studied. This is the formula R2 modified by that the starting pressure calculated by the roller brake tester is subtracted from both the reference pressure and the actual maximum pressure during the test. In Figure 7 the principal differences between the formulas R1, R2 and R3 are demonstrated.

7.3 Results

The results from the first set of tests made in Linköping and Aalborg showed that the road test results with 95 % confidence were 80 +/- 15 % of those from the mobile roller brake tester using the simple

linear normalisation based on brake pressure only used for motor vehicles by ASB in Sweden. This can also be expressed as that the ratio R1/V2 between roller brake tester results and road test results is 1,25.

The results from the second test series are shown in Table 1 and 2. With the same calculation as in test series 1, the mean ratio between roller brake tester and road test results R1/ V2 was 1,35 for the trailers, 1,29 for the Scania trucks and 1,36 for the Volvo trucks and 1,46 for trucks of other types. With the formula R2 considering that the rolling resistance is higher on the roller tester the ratio decreased to 1,27 for the trailers, 1,19 for the Scanias, 1,26 for the Volvos and 1,32 for other trucks.

In table 2 results using the formulas R3 and R4 are shown. It can be seen that in this case the difference from the road tests was considerably greater than for the simpler methods R1, R2 and R4. In the tables 1 and 2 also the 15 and 85 percentile of the same data are shown. The 15 percentile for R2/ V2 lies between 0,98 and 1,10 and the 85 percentile between 1,37 and 1,61. For the Norwegian formula R4 the 15 and 85 percentile values of R4/V2 are between 0,88 and 1,13 and between 1,34 and 1,50.

Table 3 and 4 show the effect of using different correction factors on the proposed formula R2 compared to the road test results on the percentage of the vehicles in the investigation that would be prohibited from being driven immediately (evaluation code 3 because the calculated maximum deceleration is below 3 m/s^2) and that would have had to come back for repeated inspection within a month (evaluation code 2 because the deceleration figure was below $4,5 \text{ m/s}^2$)

Table 1. Relation between deceleration from roller brake tester calculated with different formulas(R1 and R2) and road test(V2),normalised to same reference pressure 0,65 MPa

Vehicle	R1(ASB, motor veh.)/V2							R2(modified CITA formula)/V2						
	Mean	stddev	max	min	15 perc.	85 perc.	Mean	Stddev	Max	Min	15 perc.	85 perc.		
Trailers	1,35	0,67	5,34	0,88	1,05	1,67	1,27	0,49	3,34	0,62	0,98	1,61		
Scania	1,29	0,43	3,19	0,47	0,98	1,43	1,19	0,38	2,81	0,42	0,92	1,37		
Volvo	1,36	0,33	2,51	0,86	1,06	1,53	1,26	0,30	2,28	0,82	1,01	1,39		
Others	1,46	0,25	1,87	1,12	1,26	1,60	1,32	0,24	1,66	1,05	1,10	1,57		
Comb	1,24	0,67	5,34	0,88	1,06	1,49	1,19	0,49	3,34	0,62	0,99	1,41		

Table 2. Relation between deceleration from roller brake tester calculated with different formulas(R3 and R4)and road test(V2),normalised to same reference pressure 0,65 MPa

Vehicle	R3(Roll.res.+start pressure)/V2							R4(0,9R1)/V2						
	Mean	stddev	max	min	15 perc	85 perc	Mean	Stddev	Max	Min	15 perc	85 perc		
Trailers	2,11	2,19	15,97	0,74	1,17	2,43	1,22	0,60	4,81	0,79	0,94	1,50		
Scania	1,29	0,43	3,19	0,47	0,98	1,49	1,16	0,39	2,87	0,42	0,88	1,34		
Volvo	1,61	0,54	3,67	0,92	1,18	1,99	1,22	0,29	2,26	0,78	0,96	1,38		
Others	1,67	0,23	1,97	1,39	1,46	1,92	1,31	0,22	1,69	1,01	1,13	1,44		
Comb	1,69	2,19	15,97	0,74	1,23	2,03	1,14	0,60	4,81	0,79	0,96	1,34		

Table 3. Comparison of results from road tests with roller brake tests with different evaluation calculation formulas. Calculation weight as tested.

	R2 (Rollerbr.test.)	0,9 R2	0,8R2	V2(Road test)	Evaluation
Trailers	2,1 %	2,1 %	6,3 %	4,2 %	3(< 3 m/s ²)
Trailers	16,7 %	25,0 %	33,3 %	22,9 %	2(<4,5 m/s ²)
Scania	0,0 %	0,0 %	0,0 %	2,1 %	3(< 3 m/s ²)
Scania	1,7 %	3,5 %	19,0 %	12,1 %	2(<4,5 m/s ²)
Volvo	0,0 %	0,0 %	4,2 %	4,2 %	3(<3 m/s ²)
Volvo	8,3 %	12,5 %	18,9 %	22,9 %	2(<4,5 m/s ²)

Table 4. Comparison of results from road tests with roller brake tests with different evaluation calculation formulas. Calculation weight is maximum legal gross weight.

	Rt2 (Rollerbr.test.)	0,9 Rt2	0,8Rt2	Vt2(Road test)	Evaluation
Trailers	27, 1 %	33, 3 %	41, 7 %	35,4 %	3(< 3,0 m/s ²)
Trailers	62, 5 %	72, 9 %	33, 3 %	72, 9 %	2(< 4,5 m/s ²)
Scania	0,0 %	0, 0 %	1,7 %	6, 9 %	3(< 3,0 m/s ²)
Scania	3,5 %	15, 5 %	36, 1 %	27, 6 %	2(< 4,5 m/s ²)
Volvo	0,0 %	0, 0 %	4, 2 %	10, 4 %	3(< 3,0 m/s ²)
Volvo	8,3 %	12, 5 %	18, 9 %	52, 1 %	2(< 4,5 m/s ²)

Tables 1 and 2 show that the formula R2 and R4 are closest to the road test results and in general give very similar results.

From the tables 3 and 4 can be seen that for the laden trailers the formula 0,9 R2 is closest to the road test results and also fits in best for the trucks.

The formula 3 gave the most optimistic values compared with the road test results in spite of its theoretical advantages. This finding agrees with a similar investigation by Karlse in Norway 1992.

As a first cautious revision the formula R2 is proposed with the Norwegian formula R4 as an alternative on older equipment where rolling resistance cannot be measured.

7.4 General considerations concerning the heavy vehicle inspection test procedure.

The road side test procedure involves many operations and consequently possibility for errors . A test team of two persons turned out to be too small to cope with all that had to be handled . A third man from the police for taking in the vehicles, take care of the driver and write police reports was needed.

The testing was easier to perform with the stationary type of test equipment and quicker due to the higher roller speed. For both types the large mobile display was not ideal for outdoor work due to sun glare and exposure to wind and rain. Also the cables for the pressure sensors were vulnerable.

Registration of vehicle data should be automated by electronic techniques such as smart cards. The display should be integrated in the handhold control used in the vehicle by the test driver and data transmission should be wireless.

In order to be able to test the vehicle in both laden and unladen condition and check the function of load sensing devices it is desirable that future vehicles are equipped with standardised attachment points on the frame that allows the use of efficient strap down and lift devices.

At present the brake system response times at brake application and release are not checked and the calculation of the deceleration does not consider the brake force distribution although these functions are important for evaluating the total stopping performance of the vehicle or vehicle combination. The maximum pressure at the coupling head should also be checked. Pressure transducer connectors other than at the coupling head should be easier to reach and protected from dirt.

8 PROPOSAL FOR A REVISED BRAKE INSPECTION TEST PROCEDURE

Based on the experimental test results and theoretical considerations it is proposed that the test procedure at a complete brake inspection at the road side or at periodical inspection shall comprise the following checks.

1. Maximum deceleration based on braking forces measured by a roller brake tester extrapolated from measured test pressure in the control line to lower limit of maximum control pressure unladen and laden to maximum allowed gross weight using a new calculation formula.

$$r_{\max} = (F - F_r) \cdot p_{\max} / pm + 0,125$$

r_{max} = maximum deceleration

F = measured braking force

F_r = measured rolling resistance

p = measured control pressure, p_{max} = lower limit for max control pressure

m = vehicle mass unladen and at max allowed Gross Weight

If the rolling resistance cannot be measured on older equipment the formula used in Norway F = 0,9 F · p_{max} / p may be used.

2. Brake force distribution between the axles for the two load cases .The distribution shall be based on the extrapolated forces at maximum braking pressure and be within the tolerances set by the manufacturer in order to fulfil the type approval requirements. For ABS equipped vehicles this could mean that the brake force distribution does not change with the load.

3. Brake force/ pressure adaptation to the EU corridors for brake force versus control pressure laden and unladen. For ABS equipped vehicles without load sensing valves.
4. Checking of the lower limit for maximum control pressure at the coupling head with the vehicle stationary.
5. Checking of pressure rise time to 75% of maximum control pressure with the vehicle stationary at the coupling head of a motor vehicle or at the least favourable axle of a trailer.
6. Checking of brake force symmetry left-right for every axle at maximum measured brake force the brake force shall be the mean over about one wheel revolution.
7. Checking of the pressure drop time from maximum to 10% of maximum pressure with the vehicle stationary.
8. Checking of the stroke of the brake cylinders at maximum pressure.

9 SUMMARY

Brake tests on the road are getting more and more difficult to perform due to increased traffic density and are therefore not very often carried out by the police when heavy vehicles are inspected on the road. At the same time the Swedish Road Administration finds it desirable to increase the number of brake tests of heavy vehicles in traffic. One of the reasons being that the percentage of heavy vehicles with defective brakes at the annual inspection is relatively high. The use of roller brake testers at the roadside. stationary or mobile is regarded as a possibility of solving the testing problems.

By means of experimental studies it has been shown that a mobile roller brake tester with smaller rollers and lower test speed than the commonly used stationary roller testers gives practically the same results.

A comprehensive correlation study between road tests and roller brake tests has shown that in average a roller brake tester with the present calculation methods used in Sweden gives too optimistic results compared to road tests measuring pitch compensated mean fully developed deceleration. With new calculation formulas the difference can be reduced. The variability in the ratio between the results of the two test types is however relatively high. Therefore a full compensation of the mean value to equalise the road test is not proposed at this time.

Improvements on the roller brake test equipment are proposed as well as on design changes on the vehicles to enable more efficient inspection of the complete braking system . More complete testing is proposed for the future by adding measurement of response times and checking proper brake force distribution between the axles both laden and unladen.



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10 LITERATURE

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ANNEX 1. EXAMPLES OF EXISTING INTERNATIONAL CALCULATION METHODS FOR EVALUATING ROLLER BRAKE TESTER RESULTS

Compilation of calculation methods for determination of braking performance for heavy vehicles from roller brake tester results (Source AB Swedish Vehicle Inspection, Inspection and investigations).

Country	Formula	Example 1	2	3
Denmark	$F_{ref} = \frac{F \times (p_{ref} - p_p - p_{0t}) \times 0,9}{(p_m - p_{0t})}$	$R_{ref} = \frac{F_{ref}}{m}$	= 4,9 ; 5,1 ; 5,3	
Germany (BSU)	$F_{ref} = \frac{F \times (p_{ref} - p_{0t})}{(p_m - p_{0t})}$	$R_{ref} = \frac{F_{ref}}{m}$	= 5,6 ; 5,8 ; 6,1	
Germany (HU)	$F_{ref} = \frac{(F - F_r) \times p_{ref}}{(p_m - p_0)}$	$R_{ref} = \frac{F_{ref}}{m}$	= 5,7 ; 5,9; 6,1	
Sweden(Motor vehicle)	$F_{ref} = \frac{F \times p_{ref}}{p_m} ;$	$R_{ref} = \frac{F_{ref}}{m}$	= 5,2 ; 5,2; 5,2	
Sweden(Trailer)	$F_{ref} = \frac{F \times p_{ref}}{p_m \times 0,8} ;$	$R_{ref} = \frac{F_{ref}}{m}$	= 6,5 ; 6,5; 6,5	
Switzerland	$F_{ref} = \frac{F \times (p_{ref} - p_{0t}) \times 0,833}{(p_m - p_{0t})} ;$	$R_{ref} = \frac{F_{ref}}{m}$	= 4,7 ;4,8 ; 5,1	
CITA	$F_{ref} = \frac{(F - F_r) \times p_{ref} \times 1,05}{p_m} ;$	$R_{ref} = \frac{F_{ref}}{m}$	= 4,8 ; 4,9 ; 5,0	

Symbol explanation

		Example		
		1	2	3
F	= Measured brake force (kN) for complete vehicle, axle or wheel	= 8,00; 10,00; 12,00		
F_{ref}	= Calculated brake force (kN) at reference pressure p_{ref} for complete vehicle, axle or wheel			
p_{ref}	= Reference pressure (mPa)	=0,20; 0,25; 0,30		
p_p	= Estimated pressure loss due to leakage (mPa)	= 0,02; 0,02; 0,02		
p_0	= Measured starting pressure(mPa)	= 0,05; 0,05; 0,05		
p_{0t}	= Theoretical starting pressure(mPa)	= 0,04; 0,04; 0,04		
F_r	= Measured rolling resistance (kN)	= 1,00; 1,00; 1,00		
R_{ref}	= Deceleration at reference pressure (m/s^2)			
m	= Vehicle mass (mass carried by axle or wheel) (ton)	= 5,00; 5,00; 5,00		

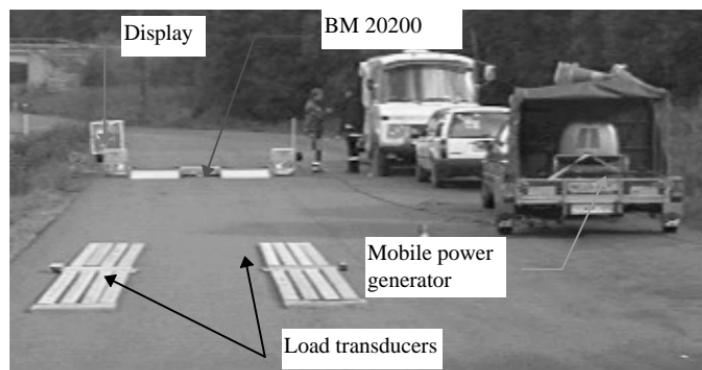


Figure 1 BM 20200 mobile roller brake tester

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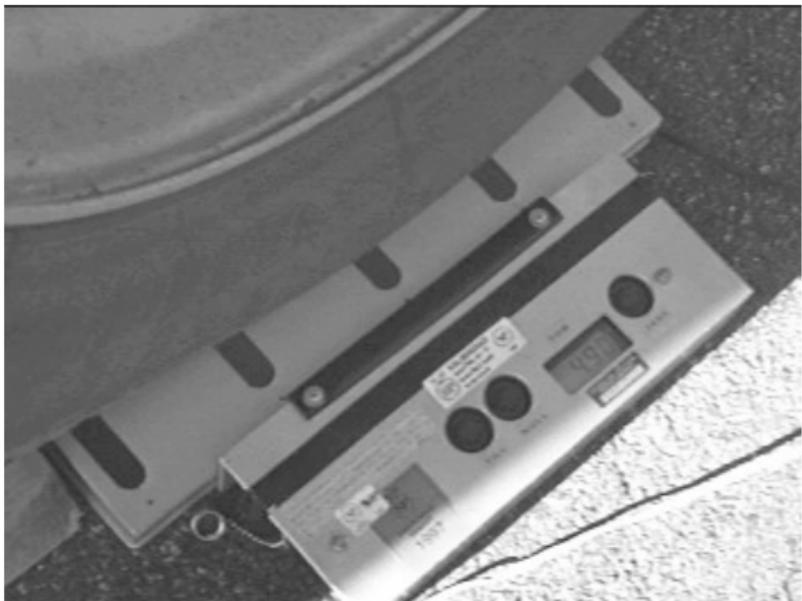


Figure 2. Wheel load transducer





Figure 3. BM 17200 Stationary roller brake tester

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Figure 4 Control pressure transducer

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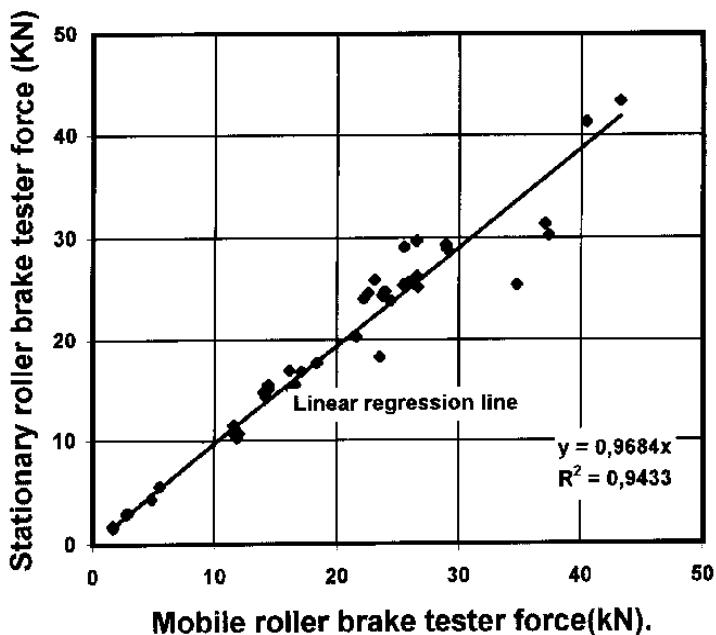


Figure 5. Correlation study of stationary and mobile roller brake testers

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Figure 5. Deceleration measurement equipment

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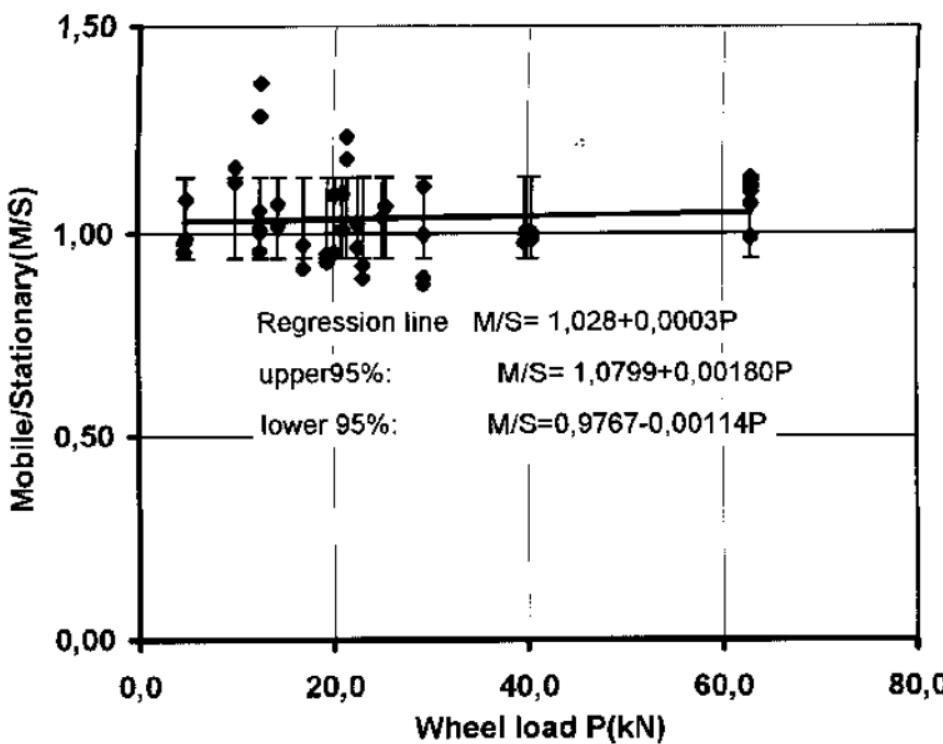
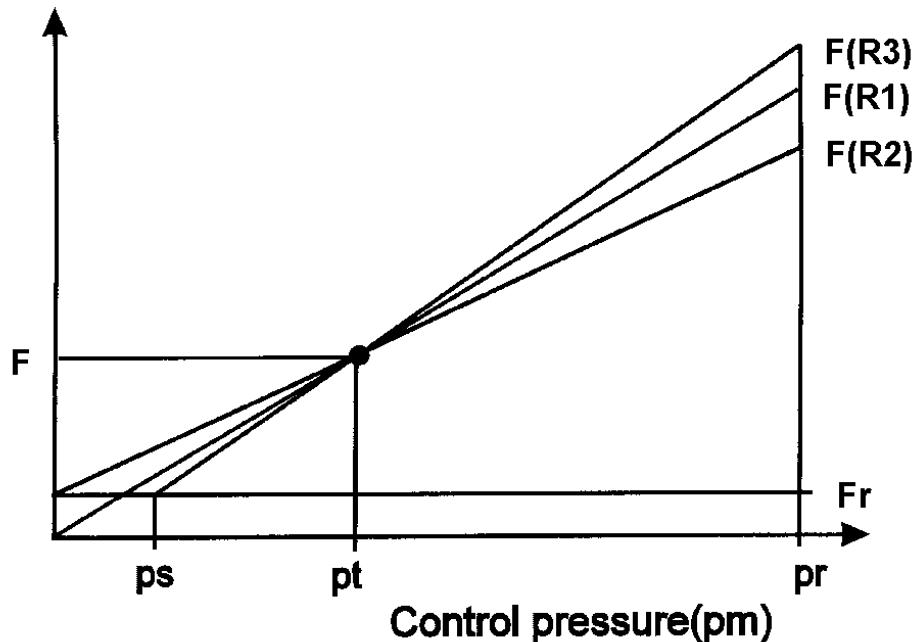


Figure 6. Correlation between stationary(S) and mobile (M) roller brake testers. Ratio M/S as function of wheel load

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Braking force



*Figure 7. Three different calculation methods that have been compared to the road test results.
F = measured braking force, p_s = starting pressure, p_t = measured pressure, p_r = reference pressure(max. control pressure). $F(R1)$, $F(R2)$ and $F(R3)$ are calculated brake forces according to method R1, R2 and R3. F_r = rolling resistance force.*

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Braking force

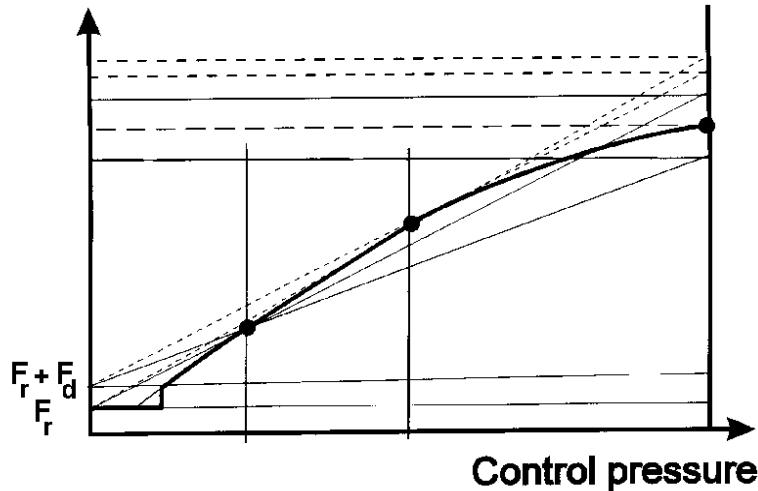


Figure 8. Illustration of the sensitivity of the calculated braking force according to formula R2 to the size of the braking force and of a dragging brake