Light Vehicle Brake Study

Feasibility Stage

Vehicle Design & Research

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Prepared by

Michael Paine BE, MIEAust, MSAEAust

Vehicle Design and Research Pty Limited

10 Lanai Place, Beacon Hill NSW 2100

(02) 4514870

for

Road Safety Section

RTA Sydney Region

83 Flushcombe Rd, Blacktown NSW 2148

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Executive Summary

This report sets out the results of a study into the feasibility of assessing car brake performance for both the general vehicle population and crash-involved vehicles. The study was commissioned by the Road Safety Section of the Sydney Region, Roads & Traffic Authority of NSW.

Three methods of objectively testing light vehicle brakes were evaluated; electronic on-board brake meter; road transducer plates and roller brake testing. All three were found to be suitable for testing brake performance but the Mobile Inspection Trailer (MIT or Truckalyser) was found to be the best device for conducting the proposed survey of the general light vehicle population. Its key advantages are that it is highly mobile and fully self-contained; it does not involve a motion test or any particular skill on the part of the driver; it gives reasonable correlation with average deceleration during road tests and it is able to detect imbalance across an axle.

Provided that several precautions about sampling methods are heeded, it would be possible to conduct the proposed survey by setting up MITs at about eight service stations throughout the Sydney Region and inviting persons filling up with petrol to undergo a brake test as they depart. It is expected that very few drivers would refuse such an invitation.

The trial of this method, at a service station in Rydalmere found that 29% of the 45 vehicles tested failed one or more of the proposed test criteria (the error range due to sample size is +/-12% at a 95% confidence level). Seven vehicles had low service brake performance, five vehicles had low park brake performance and two vehicles had excessive imbalance across the front axle. If these *tentative* results reflect the general vehicle population then brake defects are likely to be a much greater problem than anticipated on the basis of police accident reports. US studies indicate that braking problems contribute to one-third of all truck crashes. No results from equivalent studies of cars are available.

Objective testing of the brakes of crash-involved cars (a possible Stage 2 study) is fraught with difficulties. In cases of severe accident damage, any form of motion test is unlikely to be successful. Roller brake testing (eg using the MIT) might be possible on undamaged axles but in many cases it would be necessary to tap into the hydraulic braking system in order to activate the brakes - this is considered impractical.

Mechanical examination of brake components is possibly the only universal method of assessing crash involved vehicles but preliminary results indicate that there is little correlation between visual signs of brake defects (eg worn brake pads) and degraded brake performance. An alternative would be to test brake performance after crash-involved vehicles have been repaired but this is likely to be non-representative of the pre-crash condition of vehicles. Therefore an approach utilised by US researchers investigating defects in crash-involved trucks is recommended for the proposed Stage 2 study.

Light Vehicle Brake Study - Appendix A

Survey form

The three types of brake testing equipment each produced a printout of test results. A coversheet was designed to assist in collating the test printouts and to provide a method of recording vehicle details and the results of mechanical inspections. The coversheet is illustrated overleaf.

Light Vehicle Brake Study - Appendix B

Description of Brake Testing Equipment

Arex Road Transducer Plates

Four low-profile plates are mounted on the ground. The vehicle is driven across the plates at low speed (10 to 15km/h) and the brakes are applied. Force transducers in the plates measure the (shear) braking force from each wheel. The vehicle is then driven slowly across some weight scales. Readings are electronically processed to give equivalent G. Brake forces at each each, balance across an axle and front/rear balance are also calculated. A graph showing brake force over time is available. Readings are displayed on a monitor and may be printed. Electronic data capture is not available on the unit which was used for the tests.

Several operating modes are available. This allows automated testing, parking brake tests and other functions.

The system requires a flat level area for mounting the plates. No major civil works are required. 240VAC power is required, together with a weather-proof area for the computer module.

Circuitlink Electronic Brake Meter

It is understood that this device was developed in response to a specification issued by the RTA for proposed use by Authorised Inspection Stations. It has only just been released on the market. It is designed and manufactured in Australia.

The unit works on the same principle as the antiquated Tapley meter except that an electronic decelerometer is used and the inbuilt microprocessor can integrate back over time to calculate average deceleration and initial speed. A device for sensing brake pedal effort is also provided.

The unit has an built-in printer for printing test results. Graphs of deceleration and pedal effort over time are printed, together with calculated values and test information.

The unit is placed on the floor ahead of the front passenger seat, or on the front passenger seat. It automatically compensates for level, within a range of about +/-10 degrees.

The Circuitlink has rechargeable batteries.

Mobile Inspection Trailer (Mark II)

The Mobile Inspection Trailer was invented by Mr Rodney Vaughan and developed by the NSW Roads &Traffic Authority. It is a fully self-contained mobile unit for testing a complete range of vehicles. The week after an MIT had been testing 50 tonne mining vehicles it was used in the current study for testing an 800kg Ford Laser vehicle!

The MIT includes a roller brake testing machine, moveable plates for checking wear in steering and suspensions and a hydraulic jack for use in conjunction with the plates. It is powered by a small diesel motor (approx 15kW) driving hydraulic pumps. This equipment is ingeneously built into a trailer chassis with wheels on swing arms. The wheels swing out of the way and the chassis is lowered to the ground with hydraulic rams. Aluminium ramps are installed on either side and the unit is ready for vehicles to be driven across and tested (see photograph on cover).

The MIT requires a flat firm surface approximately 4m by 4m together with suitable pavement for approach and departure of vehicles under test. No external power source is required.

Electronic weighing is built into the unit. This is intended for use in interpreting brake force readings and it is not used for axle weight enforcement. However, it can be used for screening purposes.

A rugged hand-control manages all testing operations. Its LCD display indicates wheel weights, brake forces and balance. The machine has an automatic slip detection system which detects imminent wheel lock-up and shuts off the power to the rollers. The brake forces on each each side at this point are then displayed, together with the balance across the axle.

A printer attachment is available for printing this information but calculated information (eg equivalent G) is not currently available. The RTA Fleet Management MIT team has a laptop computer for processing results but the software is considered to be very limited.

Sample print-outs from the three devices are included overleaf.

Circuitlink

The top section shows calibration and machine identification information.

The lower section shows a typical service brake test. The thick graph line shows instantaneous deceleration (% G). The thin graph line shows brake pedal effort in Newtons.

Overall test results, including peak deceleration, average deceleration (used as a benchmark for this study) and estimated initial speed (derived by integrating the deceleration reading over time) are printed below the graph.

Mobile Inspection Trailer

The MIT has a specially designed printer for recording brake force and wheel weight readings. Measured brake force is at the point where at least one of the wheels is about to lock, as detected by the slip detection system.

Equivalent G is not calculated but the necessary measurements for making such a calculation are available.

Light Vehicle Brake Study - Appendix C

Test Results

The following tables set out the key results of the test program. They include:

- A summary of vehicles tested at each location
- Detailed results of mechanical inspections, together with performance test results, where available.
- Results of repeatability tests, where four runs were undertaken for each axle of each vehicle under test.
- A graph illustrating the repeatability of the MIT readings.

Light Vehicle Brake Study - Appendix D

Scatter Graphs for Correlation Analysis

Where possible, back-to-back testing of the three types of equpment was undertaken. The benchmark for comparison was the avrage deceleration obtained during the road test (at about 30km/h).

The following scatter graphs illustrate the correlation of the various test methods with the benchmark. In each case the horizontal axis is the average deceleration during road test and the vertical axis is the deceleration (or equivalent deceleration) obtained with the equipment under evaluation.

1. Road test Av G Vs Equivalent G obtained with MIT
2. Road Test Av G Vs Road Test Peak G
3. Road Test Av G Vs Arex Equivalent G
4. Road Test Av G Vs Avarage G measured with the Circuitlink during the ARex test (ie motion test at a much lower initial speed)

Correlation co-efficients quoted in the main report are based on analysis of these results using the statistic package available in Open Access 3 software (database development and processing was also accomplished using this software).

Light Vehicle Brake Study - Appendix E

Statistical Theory

If overall compliance with the minimum performance standards is expressed in terms of vehicles passing or failing (for example whether a serious defect notice was warranted) then the population will have a binomial distribution and certain statistical values can be derived to test the level of confidence with the results of sampling that population - that is, how confident we can be that the result for the sample represents the whole population. This Appendix addresses these statistical issues. The reference document is "Theory and Problems in Statistics" by M.R Spiegel.

In a binomial distribution the probability of a "successful" result is given by p which can range from 0 to 1. Conversely, the probability of an "unsuccessful" result is given by $q = 1 - p$. For example, in the toss of a "fair" coin the probability of a head is

p = 0.5 and the probability of a tail is q = 0.5.

For a given sample size (N)

the mean is M = Np

the standard deviation is S = SQRT(Npq)

and the confidence interval, at a 95% confidence level, is obtained from

Interval = Observed Proportion +/- 1.96 SQRT((p(1-p)/N)

In effect, we can expect the results of 95% of surveys of sample size N from a population with a proportion of "p" successes to lie within the interval derived from the above formula.

The following table gives an example of the confidence intervals for various combinations of sample size and "failure" rates. For example, out of a random sample of 200 vehicles it is found that 10% "fail" the check. The confidence interval for this result, at a 95% confidence level, is 6% to 14% (10%+/- 4% : the shaded cell).

Table of Confidence Intervals for Binomial Distribution
(plus or minus the observed value)

	Proportion observed to "fail"				
Sample Size	**5%**	**10%**	**20%**	**40%**	**50%**
50	6	8	11	14	14
100	4	6	8	10	10
200	3	4	6	7	7
500	2	3	4	4	4
1000	1	2	2	3	3
2000	1	1	2	2	2
5000	1	1	1	1	1

10000	0	1	1	1	1

It can be seen from the table that a sample size of 50 or less with a failure rate under 20% will give unreliable results. There are statistical methods for dealing with small sample sizes but they are unlikely to be relevant to the monitoring of vehicle roadworthiness.

Note:This appendix was based on a draft discussion paper on heavy vehicle inspections prepared by VDR for Austroads (Report A115-03 "National Heavy Vehicle Roadworthiness Standards - Discussion Paper", June 1991).

Light Vehicle Brake Study - Appendix F

Implementation Plan for Stage 1

This appendix sets out a suggested plan for undertaking stage 1 of the study - a survey of the light vehicle population in accordance with the section "Recommended Procedures for Stage 1 Study". Estimated days for completion are for overall duration, not "effort" or person-hours.

Implementation Plan for Stage 1 Study											
Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
A. Arrange Sites for Vehicle Inspections											**Days**
A1	Finalise geographic areas										1
A2		Identify & contact sites owners (incl. oil companies)									10
A3			Arrange any necessary paperwork for site usage								5
B. Arrange Mobile Inspection Trailers											
B1	Contact Fleet Management & Motor Traffic Services										1
B2		Identify "Teams" to be used (equipment & personnel)									3
B3			Prepare a survey schedule for use of teams								3
C. Develop Data Collection System											
C1	Finalise Pass/Fail Criteria										4
C2	Assess Potential for Upgrading MITs (% G calculations)										2
C3		Arrange upgrade OR develop alternative (eg forms)									10/5
C4		Identify data requirements									5
C5				Develop data collection procedures/software							10
D. Undertake Surveys											
D1							Commence surveys				15
D2								Process & Review			10
D3									Report		10