Truck Braking Systems

and

Stopping Distances

June 2000

Truck Braking Systems and Stopping Distances

Summary

1. The scale of the truck accident problem
Every year 14,500 - 16,000 large goods vehicles are involved in crashes in the UK

2. Safety Advice
The advice provided in the Highway Code recommends that drivers give large goods vehicles (LGV) more room in which to stop. The issue is how much room do they need?

3. Experimental Demonstration
The braking distance of a range of vehicle types was compared both at 30 and 45 mph. This illustrated that LGVs can need up to three times the distance in which to stop when compared to a car.

The general principle of heavier vehicles needing more room to stop was supported in subsequent test conducted at the Army's driver training facility at Leconfield.

4. Braking theory & practice
Since the combined tyre footprint of a multi-axle LGV is proportionate to its weight the overall braking performance between vehicles should also be proportionate. But this is not so.

If both the car and the laden articulated combination had both braked from 30mph, the lorry would still have been travelling at more than 20mph when the car had stopped. The force of the resultant impact could have turned the car and occupants into a thin meat and metal sandwich!

The question was why truck braking systems were so relatively ineffective.

5. Vehicle Design and Construction

a) Type approval
All vehicle types have to at least satisfy European Standards. They tend to be determined through compromise and trade-off between vested interests and result in an adequate rather than optimum standard.

b) *Braking performance*
Type approval sets minimum standards of retardation rather than required stopping distances. This enables manufacturers to design braking systems that meet a common standard of adequacy rather than a higher standard.

The braking systems on cars and motorcycles have improved in step with the other performance factors. The braking performance of LGV's is subject to the following factors that can eat away at their effectiveness.

c) Hydraulic vs air brake systems

Cars use hydraulic braking systems but the pneumatic systems on LGV's creates an unavoidable time delay between brake pedal application and the transfer of air pressure to the brake units.

d) Drum vs disc brake systems

The favoured drums on LGV's, while suitable at lower speeds tend to fade and become less effective under sustained heavy braking.

e) Brake balancing

Truck braking force is also balanced between axle groups and between the tractor and trailer unit by a series of valves, the settings can be manually adjusted and may not create optimum performance

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f) Electronic braking systems

Electronic braking systems, currently being fitted to some Volvo and Mercedes Benz trucks, ensures optimum braking force in all situations and conditions.

g) Tyres

Different tyre compounds are chosen for different purposes. A soft compound tyre reduces skid risk but increases wear. The heat levels generated in compounds may increase pollution due to rubber deposits and carbon black and, because of increased drag, causes reduced fuel economy. A hard compound tyre will last longer, enhance fuel economy, but provide less grip and causes more damage to the road surface.

The general-purpose tyre will optimise durability and adhesion.

There is also a cost penalty and issues of environmental and operational effectiveness.

h) Driver behaviour

Lorry drivers are often blamed for travelling too close to other vehicles. Video footage of both motorway driving behaviour and crashes makes it clear that drivers may:

- **not be aware of the facts**
- **not believe them**
- **be convinced it won't ever happen to them**
- **simply not care**

These issues remain a challenge for road safety experts to deal with.

Is there a problem?

1. The scale of the truck accident problem

Every year 14,500 - 16,000 heavy goods vehicles are involved in crashes on GB roads. Although the trend is marginally downward, the amount of damage caused in truck crashes and the fatality rate renders the issue of major importance for treatment. There were 3,444 casualties in 1998, of which 2,944 were drivers of whom 52 were killed; and 500 passengers of whom 8 were killed.

2. Highway Code Advice

The advice provided in the Highway Code recommends that drivers give large goods vehicles more room in which to stop. But, just how far is *'more room'*? At 30 mph should that be a few feet, a few metres or more?

Very few drivers would know the answer, but an experimental demonstration at a recent Advanced Drivers' Association Training Day provided a helpful insight.

3. Experimental Demonstration

Phase 1. Initially the braking performance of a new medium family saloon was compared with that of a six-axle tractor and trailer unit both unladen and ballasted with concrete to 40 tonnes.

Each vehicle had working ABS, good tyres, effective brakes and the LGV's had obviously well maintained. The weather was fine, warm and dry, and the road surface was even and good.

All vehicles were driven up to, and then braked from, 30 mph[1].

The car stopped in 8.5 metres; better than the average value given in The Highway Code and indicating 100% braking efficiency.

The unladen tractor and trailer unit took 17.7 metres, an extra 9.2 metres of braking distance, or about an extra two car lengths.

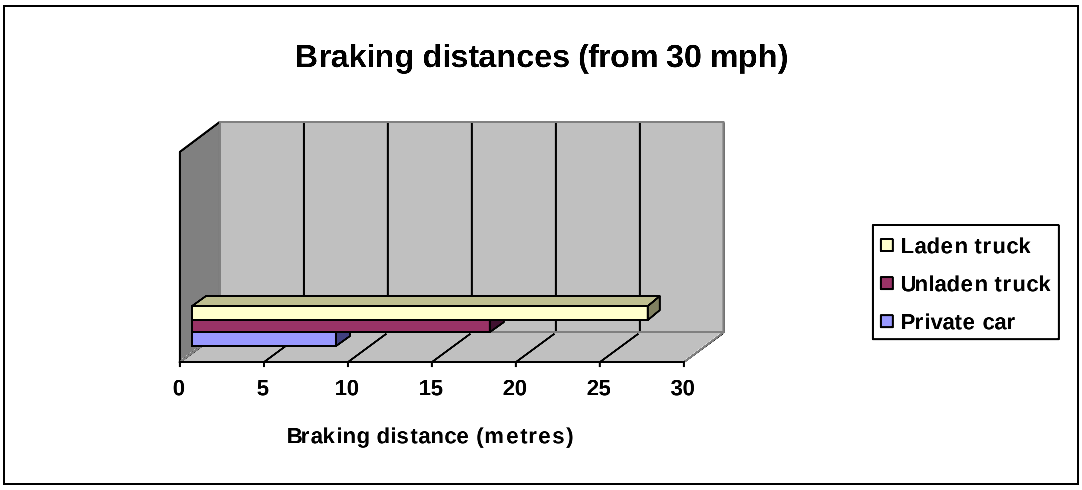
The laden unit took yet another 9.3 metres and stopped after 27 metres; about four car lengths further than the car.

Phase 2. A second set of more controlled braking tests[3] were conducted at the Army's base at Leconfield. This involved a selection of Army vehicles including a Honda Pan European Military Police motorcycle, Saxon Armoured Personnel Carrier, DAF 10.9 tonnes Bomb Disposal vehicle and a Foden 36 tonne 4axle artillery support vehicle.

Details of the vehicles and performance figures are shown in **appendix 1**.

Braking tests on each vehicle were conducted at 30 and 45 mph on a well maintained, even and slightly inclined surface on a dry, warm morning. To reduce any error the same army Master Driver conducted all braking tests (except motorcycles).

The general principle, identified in phase 1, of heavier vehicles travelling at 30 mph taking as much as three times the distance to stop, was supported. However, when the speed was increased to 45 mph the difference in stopping distance between LGV's and cars reduced but it was still double.



4. Braking theory & practice

Since the total tyre footprint of the six-axle, truck is significantly but proportionately larger than that of the one tonne car, it is reasonable to assume that the overall braking performance should be about the same. That would seem to be a reasonable assumption, but it is nevertheless completely wrong.

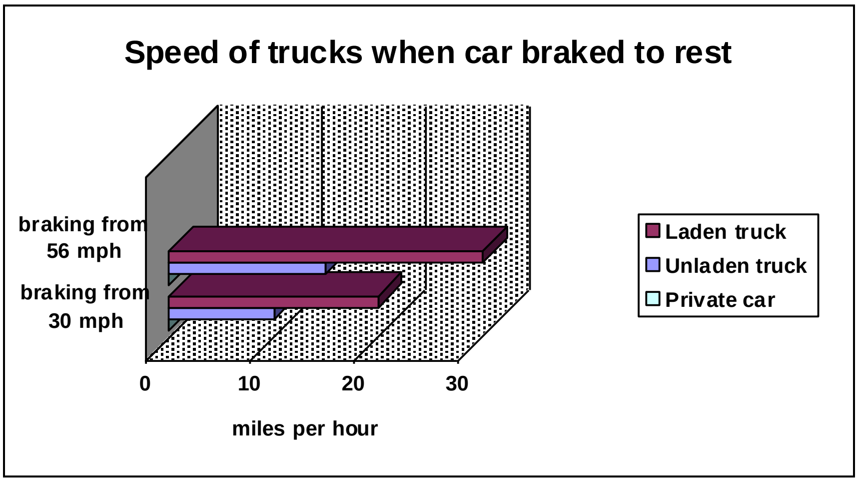
At even just 30mph the experiment proved that it is essential to give large goods vehicle up to three times the braking distance that would be allowed for a car.

In reality if both the car and the laden lorry had braked at the same time, the lorry would still have been travelling at more than 20mph after the car had stopped.

Had this been a crash, the 40 tonne lorry would have pushed the 1 tonne car forward a considerable distance with potentially serious results.

Had the initial braking occurred at the official LGV governed speed of 56mph, almost double the speed in the demonstration, by the time the car had come to a halt the lorry would still have been travelling at well over 30 mph.

Therefore of the resultant impact would have caused serious injury especially if the car was pushed forward by the ’30 mph, 40 tonne press’ into the back a stationary vehicle.



It is a fact that when a vehicle's speed is doubled the braking distance quadruples. It is essential that the gap is quadrupled! This information also needs to be applied to the gap in front, if a large goods vehicle is following closely behind.

The question remains as to why truck braking systems are so relatively inefficient and difficult to stop. There are a number of factors, including; gravity, kinetic energy, and their design and construction.

The first two are governed by the laws of physics and are to be considered immutable; the last is regulated by European *type approval* legislation.

Could anything be done to improve the situation? If so, what?

5. Vehicle Design and Construction

a). Type approval

All vehicle types have to at least satisfy European Standards. Designs that comply receive a *type approval* certificate. While the development of the criteria governing the award of *type approval* certificates is recognised to have been a regulated compromise, the process does at least ensure that all EC manufactured tractor units can operate with all EC designed trailers and vice versa. In arriving at the 'compromise' EC-wide agreement on *type approval*, there will inevitably have been a trade-off between different vested interests. This will undoubtedly have been driven by the desires of commercial operators; the needs of different environments, and operational requirements.

Such trade-off's are almost always likely to result in an *'adequate'* rather than an *'optimum'* safety standard.

b). Braking performance

Type approval sets minimum standards of retardation rather than setting specific required stopping distances. This enables manufacturers to design braking systems that meet that common standard.

The adequacy of the construction and performance standards combined, in this case, with the markedly different reactions of the two vehicle types to the natural forces serve to increase their stopping performance.

The first factor to recognise is that the braking systems on the two vehicle types are different.

The braking systems on cars have been improved in step with the other performance factors applied to them. Increased speed and acceleration characteristics have driven up braking performance. It is understood that ABS works more effectively on smaller diameter, lighter wheels than on lorries with their larger, heavier wheels.

c). Hydraulic vs air brake systems

Cars use hydraulic braking systems which immediately transmit braking effort, once triggered by pedal pressure, to the brake units at each wheel. The braking effort is balanced 60/40 in favour of front of the vehicle in recognition of the effective weight transfer from the rear of the vehicle to the front under braking.

Lorries use pneumatic (air) braking systems to operate the mechanical braking units at each road wheel. There is an unavoidable time delay between brake pedal application and the transfer of air pressure to the brake units. This delay can be as great as 0.3 of a second. At 30 mph this brief delay means that the truck may travel up to an additional car length before anything happens.

d). Drum vs disc brake systems

Goods vehicle designers tend to favour drum brakes, which are generally suitable for stopping heavy vehicles travelling at slow speeds. However drum brakes have drawbacks, since under sustained, heavy braking they are likely to suffer from brake fade (a significant loss of brake efficiency caused by a reduction in the frictional properties of the brake lining against the brake drum surface due to a temperature increase in the brake units).

Disc brakes on the other hand are more flexible in their application, are generally more effective and tend to suffer less from brake fade. However, they are usually more expensive.

e). Brake balancing

Truck braking force is also balanced between axle groups and between the tractor and trailer unit by a series of valves, the setting of which can be manually adjusted. In an industry where tractor and trailer units are often owned and used by different companies, and brought together for one journey, or part of a journey, the braking balance should be set to an average value.

It is understood that some unscrupulous owners adjust the settings, albeit marginally, to ensure that the majority of the braking force, and the consequent operating cost penalty, is borne by the unit they do not own.

These single and multiple variations, whether natural or operational, are likely to affect the overall braking effectiveness of the unit and add further to the stopping distance.

f). Electronic braking systems

Electronic braking systems, currently being fitted to some Volvo and Mercedes Benz trucks, is a dynamic process that ensures optimum braking force is distributed between the two parts of the vehicle unit, and their axle groups, in all situations and conditions. These trucks also use the more effective disc brakes
These systems are an expensive initial option but amortised over the vehicle's full operating life will be offset by improvements in safety, and in the majority of cases generate significant savings in repair and maintenance costs.

g). Tyres

Finally, there are the differences between tyre types to take into account. Different tyre compounds are chosen for different purposes. Simplistically, some tyres are designed for maximum adhesion and are made of a soft compound but wear relatively quickly. At the other end of the spectrum others are constructed using a hard compound, wear more slowly but provide less road adhesion.

A soft compound tyre reduces skid risk but increases wear. The heat levels generated in softer compound tyres may well increase pollution due to rubber deposits and carbon black (a component used in rubber to manage the relative levels of tyre 'hardness') and, because of increased drag, cause reduced fuel economy. There is also an increased risk of failure due to a blow-out or to the shedding of large tracts of tread.

A hard compound tyre will last longer and help reduce fuel consumption, but will provide less road adhesion and is likely to cause more damage to the road surface.

The optimum general-purpose tyre will involve choosing between durability and adhesion.

The price differences between different makes and types of tyre are well known. The choice is difficult enough when re-equipping a car since the tyre costs are multiplied by four.

Fleet managers operating in a very competitive market sometimes have to multiply the unit cost by 22 to re-tyre just one vehicle. In addition they are forced to assess which tyre compound will provide the best value for money balanced against known operational requirements and safety.

h). Driver behaviour

Lorry drivers are often justifiably blamed for travelling too close to other vehicles. It would appear that many drive close to the rear of other vehicles in the mistaken belief that they will be able to stop in time should the vehicle in front brake, or that their very proximity will reduce the level of damage to their vehicle and themselves in a crash.

Examination of the video footage of both motorway driving behaviour and crashes makes it clear that drivers may:

- **not be aware of the facts**
- **not believe them**
- **be convinced it won't ever happen to them**
- **simply not care**

This issue remains a challenge for road safety experts to deal with.

6. Conclusion

It might be argued that the case set out here is based on false assumptions or that the braking difference identified was due to a lack of experimental rigour. It is certainly true that the demonstration was not prepared or conducted in a scientific manner, but it is believed likely that the outcomes are very close to reality. They are certainly sufficient to indicate that there is a very real issue which has still to be adequately addressed.

The vehicles that were used in the experiment were in excellent condition. However, the number of prohibition (PG9) notices placed on trucks as a result of official road-side checks attests to the fact that a significant proportion are by no means well maintained. In many cases the stopping distance of those poorly maintained trucks will undoubtedly be far greater than the values found during the experimental demonstration.

It would appear from the results of this simple experimental demonstration that further work needs to be done in the following areas:

a). Public awareness raising for all drivers of motor vehicles
To ensure that adequate and appropriate information is available to and used and understood by all drivers. This may take a variety of forms, ranging from printed media, including the Highway Code, through radio and TV.

b). Research, development and fitment of 'station sensing and warning devices'
The present state of development of vehicle telematic and similar devices is such that vehicle, speed and situation-specific data could be used to inform and warn drivers of the fact that they were travelling too close to the vehicle ahead. This technology should be further developed, validated and fitted to all motor vehicles, especially to trucks.

c). Targeted enforcement activity
Speed enforcement is universally accepted as one of the many means of encouraging improved driver behaviour. Many thousands of pounds are being invested each year in equipment and manpower to this end. Close-following has long been recognised as a companion driver fault and yet little or nothing meaningful has been done to effect positive behavioural change. It must be possible to obtain acceptable evidence of close-following in the same way that evidence is collected for speed-related offences. This should be acted upon now.

d). Improved vehicle brake system design and performance standards
Since there appears to be prima-facie evidence to support the case for improved truck braking efficiency, UK Government should press Europe for such improvement.

Notes

[1] An allowance should be made for minor variations in the actual speed and the point when the brakes were applied.

[2] The values represented in the graph are closer to typical values and not those taken from the demonstration, which could be affected by variations in note 1 above.

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