SEVERE IMPACTS WITH TRAFFIC SAFETY RAILS

by M.D. Macdonald, Transport and Road Research Laboratory, Crowthorne, Berkshire, United Kingdom

Abstract

To aid the development of safety barriers for the containment of heavy trucks where a high level of containment is essential, accidents where barriers are damaged are being investigated. The type of accidents visited are all those where a fatality has occurred and those involving heavy trucks within an area of 130 km radius of the Transport and Road Research Laboratory. The data collected have been used to set up the conditions for full-scale controlled tests which relate to actual on-road impacts.

Introduction

The Transport and Road Research Laboratory is developing safety barriers particularly for use in localized applications, to restrain heavy trucks. The objectives of these barriers are to prevent a vehicle from crossing the median strip of a dual carriageway road and to redirect any vehicles that strike the barrier on to a path alongside it. To establish the conditions that barriers have to withstand in service, the weights, speeds and impact angles of vehicles that strike highway barriers are being determined. As well as the impact conditions, data are collected on the damage to the barrier and the performance of the barrier in redirecting the vehicle. As the total number of accidents in which vehicles strike the barriers are large and the interest is in high energy impacts, data collection has been limited to severe impacts within an area of about 130 km radius from the Laboratory. A severe accident is defined as one involving a fatality or a heavy commercial vehicle (a bus or heavy truck (heavy goods vehicle HGV)); these form a small proportion of all impacts with barriers but about 10 percent of impacts involving HGVs.

Data Collection

The police notify the Laboratory when a highway barrier accident involving a fatality or a heavy vehicle occurs. The nature of the accident is checked and if it falls within the correct category a team of investigators visit the scene of the accident as soon as possible. A reporting form, Figure 1, is used to assist the investigator in collecting the essential data and a brief report is made on the damage to the barrier. This includes the type of vehicle, its weight, speed and angle of impact and a description of the accident mechanism. The vehicle description is limited to that of either a car, or rigid, or articulated truck. The weight for cars is established from the manufacturer's data, but for trucks the unladen plated weight plus payload is used. Vehicle speed is estimated by either the police or witnesses to the incident in the case of cars; for trucks it is generally determined by examination of the vehicle's tachograph. This is a device which simultaneously records vehicle speed and time of day on a card disc. Angle of impact can be estimated in many cases from road marks caused by heavy braking or tire scuffing. Interviews with the police and on occasions with drivers together with a photographic record of the accident complete the data collection. Although accidents were reported to the Laboratory at all times, manpower resources restricted data collection to normal working hours.

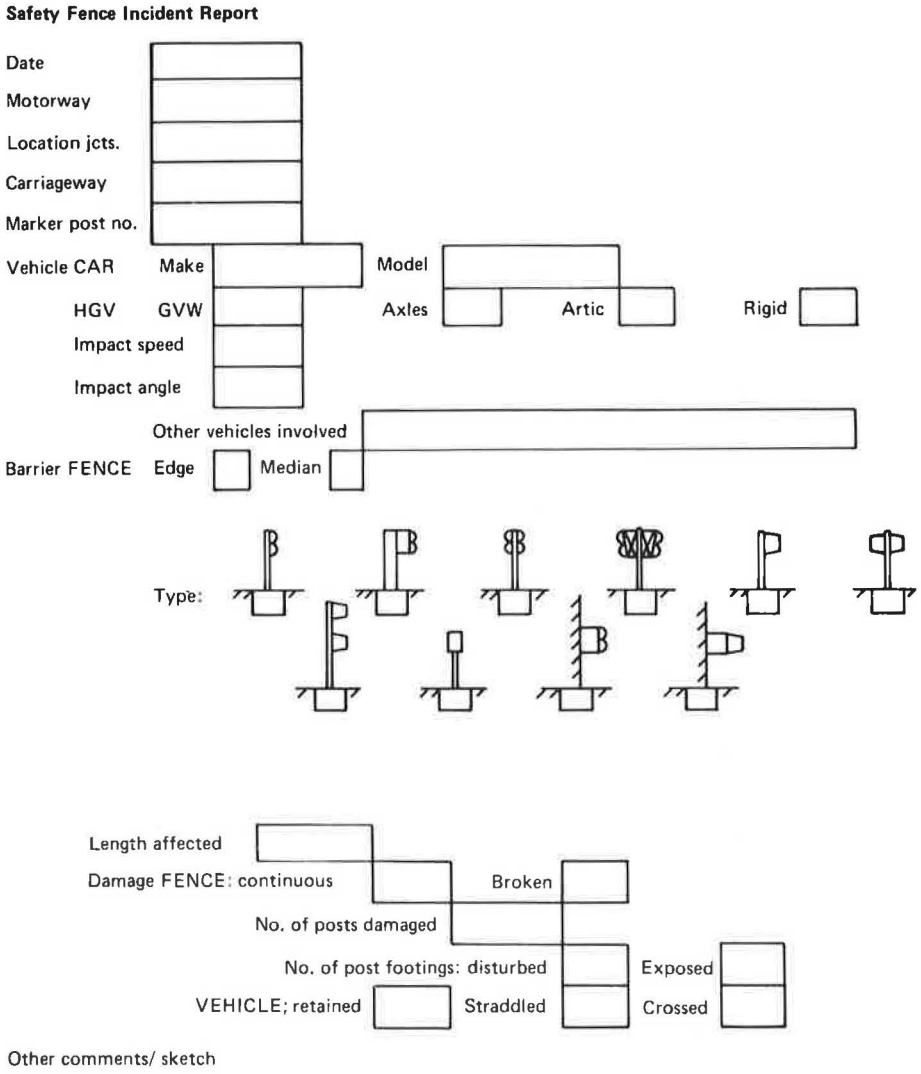

FIGURE 1 - Reporting Form for Motorway Safety Fence Accidents

A total of 33 severe accidents have been recorded over a period of 22 months of which 31 involved heavy trucks. This compares with 1063 accidents (median barrier and guardrail) for United Kingdom motorways in 1984 of which 152 involved either HGVs (148) or buses (4). The data therefore represent a sample of about 10 percent of barrier accidents per year involving HGVs, though it is not a random sample.

The data collected for 33 severe impacts are shown in Table 1; they have been divided into three categories, (a) heavy trucks -- median barriers, (b), heavy trucks -- guardrail, (3) cars -- median barrier and guardrail. There were 28 incidents of HGV impacts with tensioned corrugated beam safety barriers (guardrail and median barriers). Three of the other five accidents involved HGVs two of which struck the end of the safety barrier (ramping) and one struck a concrete parapet. The remaining two were one fatal car impact and one car ramping accident (non-fatal). A total of three ramping accidents have been noted.

In the early stages, a variety of incidents were reported which did not fall within the defined categories (fatal and/or heavy vehicle accidents). Visits

Trucks: Median Barriers

TRRL No.	Laden wt. (tonne)	Speed (km/hr)	Angle (degrees)	Lateral vel. (m/sec)	Lateral R.E. (k.Joules)	Veh. type (Rigid/Artic)	Comments
1	16	109	25	12.80	1310	R	X-over
5	17	99	35	15.77	2114	A	X-over
6	22	88	15	6.33	441	A	Contained (soft ground)
8	23	96	15	6.90	548	A	Contained
9	8 1/2	61	40	10.89	504	R	Contained
12	16 1/4	80	5	1.94	31	A	Contained (soft ground)
17	--	72	(rotating)	--	--	R	Contained
19	12	80	(rotating)	--	--	R	Contained
20	16	--	15	--	--	R	Contained (soft ground)
21	--	--	10	--	--	A	Contained (soft ground)
26	15 1/2	88	<5	2.13	35	A	Contained (soft ground)
28	20	56	<5	1.36	18	R	Contained (french drain)
29	10	80	30	11.11	617	A	Contained
31	6 1/2	80	10	3.86	48	R	Contained (soft ground)
32	--	64	--	--	--	A	X-over (fatal)
33	16	--	60	--	--	A	X-over (fatal)
37	3	48	15	3.45	18	R	Contained
38	32 1/2	80	20	7.60	939	A	X-over
39	12	88	13	5.50	182	R	Contained
41	23	80	6	2.32	62	R	Contained (french drain)
42	18	96	15	6.90	428	A	X-over
43	30	99	7	3.35	168	A	Contained (soft ground)
45	12	120	15	8.63	447	A	X-over
47	7	99	25	11.62	473	A	X-over

Trucks: Guardrail

TRRL No.	Laden wt. (tonne)	Speed (km/hr)	Angle (degrees)	Lateral vel. (m/sec)	Lateral R.E. (k.Joules)	Veh. type (Rigid/Artic)	Comments
2	5 1/2	96	10	4.63	59	R	X-over
3	27	80	6	2.32	73	A	Ramping
22	18 1/2	96	10	4.63	198	A	Contained (conc parapet)
36	12	80	<5	1.94	23	A	Contained
39	3	64	18	5.49	45	R	Contained
44	--	--	<5	--	--	A	Contained
46	7 1/2	80	0	0	0	R	Ramping (fatal)

Cars: Median Barrier and Guadrail

TRRL No.	Laden wt. (tonne)	Speed (km/hr)	Angle (degrees)	Lateral vel. (m/sec)	Lateral R.E. (k.Joules)	Veh. type	Comments
27	1	112	20	10.64	57	Saloon	Contained (fatal)
35	--	--	0	--	--	Saloon	Ramping

Table 1 - Severe Impacts with Highway Safety Barriers

were made to familiarize the police with both the activities and intentions of the TRRL; those cases are not reported here. A few accidents outside the operating range of 130 km have also been included. Occasionally the police and highway maintenance staff had cleared the debris of the accident before the investigating team arrived; where vehicles had been removed, weight and speed were difficult to assess because documentation such as tachograph records had been removed with the vehicle. On some occasions weather conditions or high traffic flow prevented a full investigation.

Results and Analysis

The data in Table 1 for heavy trucks impacting the median barrier are plotted in Figure 2 to show the cumulative distributions of vehicle weight, impact speed and impact angle. Detailed comments are given below for these factors.

Figure 2a. Vehicle Weight

Of the 31 reported cases of HGV accidents, 18 (58%) were either articulated (17) or draw-bar trailer (1). The distribution shows that, where the GVW's were known or estimated (a total of 21 cases), just over 50 percent of the vehicles exceeded GVW of 12 tonnes. The highest weight recorded was 32.5 tonnes (and in this case the impact was at 80 km/hr or 20° impact angle). The legal maximum weight without special permission for trucks in the United Kingdom is 38 tonnes.

Figure 2b. Impact Speed

The vehicle speed distribution indicates that in nearly 10 percent of the accidents, the vehicles were exceeding the 96 km/hr speed limit for trucks on United Kingdom highways. This compares with the speeds of vehicles measured in 1983[1] where 39 percent of HGV's were found to exceed the speed limit. The maximum speed noted was 120 km/hr (and the vehicle weight was 12 tonnes with a 15° impact angle.)

Figure 2c. Impact Angle

The distribution shows that 75 percent of the vehicles impacted at angles less than 25°, and nearly half of these impacts occurred within the range of 15° - 25°. The highest impact angle recorded was 60° (with a vehicle weight of 15 tonnes and an unknown speed). There is little sign of a correlation between impact speed and angle. One might expect higher speeds to be associated with smaller angles, but this does not appear from the 31 HGV accidents studied. The distribution is shown in Figure 3.

Of the 31 HGV impacts, in nine cases the HGV crossed over the safety barrier. In the remaining 22 impacts, there were two cases of HGVs rising up to the edge of the safety barrier (ramping) and 20 instances where they were contained.

There were several reasons for the safety fence being so effective. First, in many cases there was soft ground on the approach side of the safety barrier, particularly for the median impacts, and these conditions would have absorbed some vehicular energy before impact. This suggests that the actual impact speed may be less than the estimate made from the vehicle tachometer. Secondly, there were reports of vehicles slewing or rotating when impact occurred. It is probable that tire failure or driver loss of control contributed to this

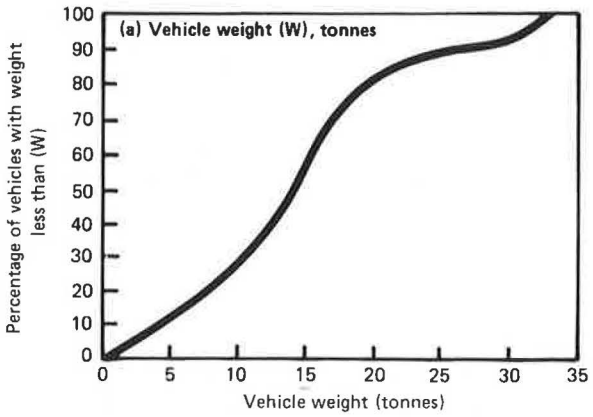

FIGURE 2a Vehicle Weight

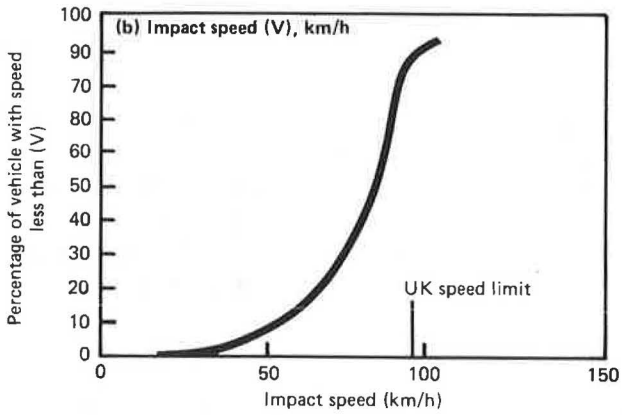

FIGURE 2b - Impact Speed

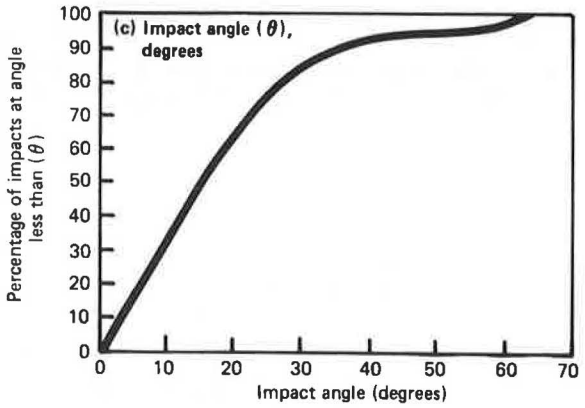

FIGURE 2c - Impact Angle

FIGURE 2 - Impact Conditions Data (21 HGV median impacts)

behavior. This also could have an effect on the severity of impact and the performance of the barrier in retaining the vehicle.

Nevertheless, it was thought useful to examine the results in table 1 on the basis of the estimated lateral kinetic energy for the impacts, i.e., the energy normal to a line of the fence. Although the speeds, angle and energy are given in table 1 to several significant figures, it should be recognized the data does not really allow this degree of precision. Bearing this in mind, the data are presented in table 2 for HGV median impacts and show the number of contained and cross-over accidents for increasing levels of lateral energy. Table 2 suggests that below an energy level of about 400 k Joules all the accidents were

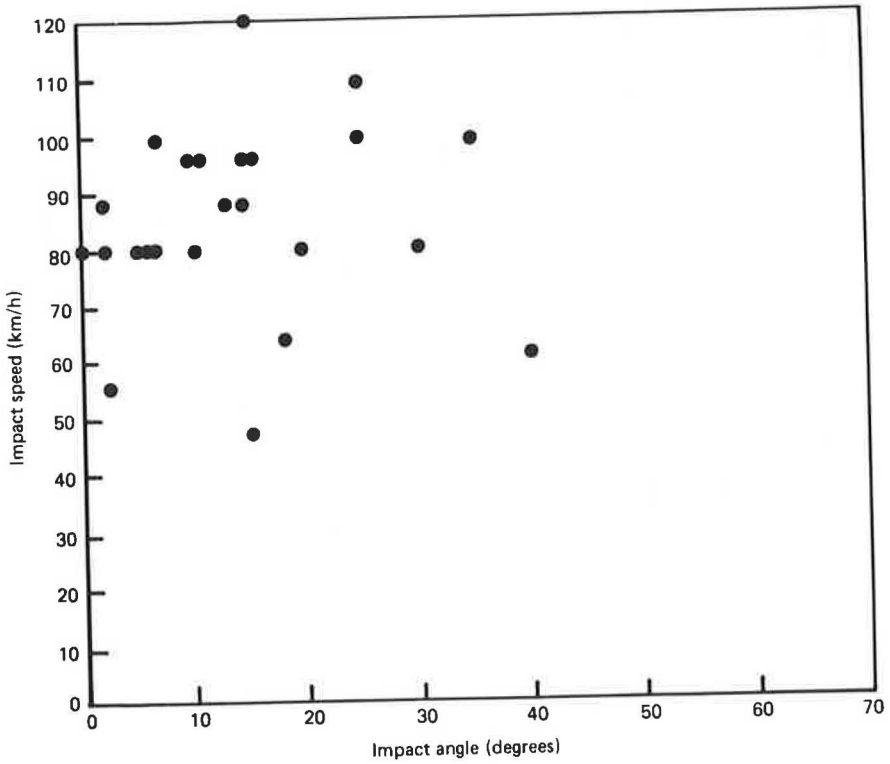

FIGURE 3 - Impact Speed and Impact Angle for HGVs (median and edge impacts)

contained and there were no cross-overs. Between 400 k Joules and 700 k Joules about equal numbers of accidents were contained or involved cross-overs. Above 700 k Joules the remaining accidents all resulted in cross-overs. As noted before, however, there are many factors other than impact energy that affect barrier performance. These include ground conditions, vehicle wheel size, height of vehicle center of gravity, and the stiffness of the vehicle body and suspension. Nevertheless, the results in table 2 give a useful indication of the performance of the barrier in terms of nominal lateral energy. It is worth noting that the standard Tension Corrugated Beam safety barrier in the United Kingdom is designed to provide containment up to a lateral energy of 85 k Joules. The present results show that the highest value of lateral energy recorded with successful containment was about 600 k Joules, and the lowest lateral energy where cross-over occurred was about 400 k Joules. It, therefore, appears that the safety barrier is performing in practice better than might have been expected.

A summary of the occurrences of HGV and car accidents is given in table 3 for each type of barrier, and comments are given on whether the vehicle ramped, was contained, or crossed over. Fatalities are identified with the table.

Conclusions

Severe accidents in which there have been either a fatality or a heavy truck striking a safety barrier have been investigated to determine the impact conditions (vehicle weight, speed and impact angle) and how the barrier performed. The 33 accidents reported over a period of 22 months and within an area of 130 km radius of the Transport and Road Research Laboratory can only be regarded as a small sample and it is likely that, in the early stages of the

Lat. energy (k.Joules)	0-99	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900+
No. contained No. X-over	6 0	2 0	0 0	0 0	1 3	2 0	1 0	0 0	0 1	0 2
Totals	6	2	0	0	4	2	1	0	1	2
Percentage of all accidents	<---------- 44% ---------->				<---------- 39% ---------->			<--------- 17% ---------->		

Table 2 - Accident Energy Levels - HGB median

Vehicle	Median Barrier			Guardrail			Parapet	Totals
	Contained	X-over	Ramping	Contained	X-over	Ramping		
HGV Car	16 0	6+2F 0	0 0	3 1F	1 0	1+1F 1F	1 0	31 2

Table 3 - Safety Barrier Performance

work, not every incident was reported to the Laboratory. The following general conclusions are drawn:

1. There were 31 accidents involving trucks and 58 percent of the vehicles concerned were articulated.

4. There were 19 instances (61%) where the truck was contained by the tensioned corrugated beam safety barrier. A contributory factor was probably the presence of soft ground or gravel (french drain) on the approach side to the barrier.

3. The highest values recorded for truck accidents, but each from different accidents were, weight 32 1/2 tonne, speed 120 km/h and impact angle 60 degrees. Conclusions relating to heavy trucks impacting the median barrier include:

   a. In nearly 10 percent of these accidents the vehicles were exceeding the maximum permitted speed of 96 km/h for heavy vehicles on United Kingdom highways.

   b. About 75 percent of truck impacts occurred at an angle of 25^{o} or less and about 25 percent of the truck impacts occurred within an impact angle range of 15 degrees to 25 degrees.

   c. The standard Tensioned Corrugated Beam safety barrier is in practice containing accidents involving much more impact energy than it was designed to withstand.

---

1. Department of Transport (1984). Transport Statistics. Great Britain 1973-1983. HMSO, London.

Acknowledgments

Thanks are due to the various police authorities whose assistance was essential for this work to be undertaken. The work carried out in this report forms part of the program of the Transport and Road Research Laboratory and the report is published by permission of the Director.

Any views expressed in this report are not necessarily those of the Department of Transport.

Appendix 1

Description of Selected Accidents

Cars

No. 27 Fatal	The car impacted a guardrail at high speed and ejected some of the passengers. It was probably unstable at the time due to sudden loss of tire pressure.
No. 35 Damage only	The car struck the ramped end of a safety barrier at a bifurcation formed by an off-ramp leading from one highway to another. It appeared that either the driver made a late decision to turn to his nearside or his speed was too high to negotiate the bend.

Heavy trucks (HGV)

No. 1 Fatal - cross over	A fully laden two axle 16t truck travelling at 109 kph crossed a double sided tensioned corrugated beam (TCB) safety barrier, at about 25 degrees, on the median of a three lane highway. It collided with a bus in the opposite lanes and continued further to impact a TCB guardrail at the edge of the highway. Severe damage was caused to the truck and bus and there were several fatalities.
No. 6 Straddled	An articulated truck laden to 22t travelling at 88 kph struck a double sided TCB safety barrier at 15 degrees. The vehicle did not cross into the opposite lanes and there was no personal injury. In this instance some braking was applied before impact and there was soft ground in front of the barrier.
No. 41 Retained	A four axle rigid truck laden to 23t struck a double sided TCB safety barrier at 80 kph and five degrees. The vehicle did not cross over or straddle the barrier although it was forced down to ground level. In advance of the barrier was a coarse gravel french drain.