Crash characteristics of motorcyclists impacting road side barriers

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Abstract

Motorcyclist serious injuries and fatalities significantly contribute to road trauma in Australasia. The role of road side safety barriers in such trauma is an area of growing concern amongst motorcyclists, road authorities and road safety researchers and advocates. This paper is the second of a series of papers presenting results from a retrospective case study of motorcyclists that were fatally injured following a collision with a road side barrier during the period 2001 to 2006 in Australia and New Zealand. In this paper, characteristics of the crashes such as barrier and motorcycle types, crash modes, motorcyclist kinematics, pre-crash speeds and impact trajectory angles are documented.

Keywords

Motorcycles, fatalities, road side safety barriers, W beam, wire rope, concrete barrier

Introduction

Motorcyclist serious injuries and fatalities significantly contribute to road trauma in Australasia. In 2007, Australian motorcyclists were 30 times more likely to be killed and 37 times more likely to be seriously injured than car occupants per distance travelled [1]. The proportion of fatal motorcycle crashes involving road side barriers in Australia and New Zealand between 2001 and 2006 was around 5.4% [2,3]. Road side barriers include safety barriers positioned both at road edges and within medians.

A number of international studies have investigated the characteristics of motorcycle-barrier crashes. In Europe, Ruiz et al [4] reported a mean collision angle with metal barriers of 13°, a mean barrier impact speed of 100km/hr amongst fatal crashes, and that impacts into barriers occurred equally often in the upright mode as in the sliding mode. Berg et al [5] showed that in 51% of 57 barrier cases in Germany the motorcyclist impacted the barrier while driving in an upright position, 45% of the impacts occurred where the motorcycle slid on its side on the road surface before it first struck the barrier, and in the remaining 4% of the crashes the motorcycle impacted the barrier driving in an inclined position. Quincy et al [6] reported that in 58% of barrier crashes in France the motorcyclist was in the sliding mode, with the remaining 42% impacting without sliding. Peldschus et al [7] determined that around three quarters of collisions with fixed objects in Germany are in the upright position and typically occur at shallow angles, with 13 crashes at less than 15°, two between 15° and 30° and three between 30° and 45°. Bryden and Fortuniewicz [8] reported that amongst 83 barrier crashes in the US, 60% of motorcyclists were redirected, 27% were stopped in contact with the barrier, 5% went under and 5% went over. To date no such detailed studies of the characteristics of motorcycle-barrier crashes in Australasia have been reported. This paper presents the crash characteristics of fatal motorcycle-barrier crashes that occurred during the period 2001 to 2006 in Australia and New Zealand. The work follows a previous study of the human, vehicle and environmental crash factors associated with the same fatal motorcycle-barrier collisions [2,3].

Crash data

Data were collected retrospectively between 2001 and 2006 on all fatal motorcycle crashes in Australia (AUS) and New Zealand (NZ), using the Australian National Coroners Information System (NCIS) and the New Zealand Crash Analysis System (CAS). The cases involving road side barriers were then isolated, and the full coronial case files were collected from the various authorities. This resulted in 78 case files of motorcyclists that were fatally injured as a result of a collision with a road side safety barrier. The full methodology is detailed in [2] and [3]. The coronial case files typically included a police report, a report on the mechanical condition of the vehicle, an autopsy report and a toxicology report. Of the 78

coronial files collected, 72 contained police reports, 56 contained mechanical inspections, 77 contained autopsy reports and 74 contained toxicology reports. The police reports contained a varying amount of information. However, as per police procedure for fatal crashes in most cases police crash team investigators were in attendance at the crash scene. Such investigators are typically trained and experienced in crash scene investigation. In 66 case files scene photographs were included, in 62 cases measurements of the crash scene were documented (skid/scrape mark lengths, location of impact points, resting positions of the motorcycle and motorcyclist and any parts thereof, etc), in 54 cases the pre-crash speed of the motorcycle was estimated and in 14 cases scene diagrams produced from a surveying instrument were included. Many cases also included witness accounts and statements from police attending the scene. It is noted that the majority of motorcyclists crashed while on a recreational ride [2, 3], and it was common for motorcyclists to ride with others. Thus there was a significant amount of useful information provided in witness statements as to the circumstances of the crash. The pre-crash speeds were determined by the crash scene investigators and typically relied on varying combinations of calculations based on scene measurements, analysis of the scene, witness statements and in some cases ride-throughs of the scene by experienced motorcyclists. Where speed ranges were provided, the minimum value has been conservatively used in this study.

Results and discussion

Human, vehicle and environmental crash factors

The papers by Grzebieta et al [3] and Jama et al [2] detail and discuss the human, vehicle and environmental crash factors associated with the fatal motorcycle-barrier collisions reported in the present paper. Of particular note were the findings that 97% of the motorcyclists were wearing a helmet prior to the crash, 86% of crashes were single vehicle run-off crashes, 80% occurred on a corner, 92% of motorcyclists were male with a mean age of 34.2 years, 72% were less than 40 years and 81% of motorcyclists died at the crash scene. Motorcyclist behaviour such as speeding and alcohol/drug use were identified as common causal factors.

Barrier and motorcycle types

In Australia and New Zealand the main barrier types installed are steel W beam barriers with steel C-section or timber posts, followed by concrete and wire rope (steel cable) barriers. Amongst motorcyclists fatally injured in barrier crashes, 77% involved W beams, 10% involved concrete barriers, 8% involved wire rope barriers and 5% involved other barriers. Other barriers include timber and tubular steel post and beam barriers. The barrier types involved in fatal crashes reflect the exposure of motorcyclists to such barriers on Australian and New Zealand roadways [2,3].

The type of motorcycle that was being ridden was typically provided in the case files, and was classified by a motorcycling expert into the general categories of sports, touring and off-road motorcycles. Sports motorcycles are of the type typically ridden with the body leaning forward on the motorcycle, and are designed to be leant over to the inside of a corner. The touring category includes cruiser, chopper and touring motorcycles. Off-road motorcycles include dirt bikes and enduro bikes. In the 78 cases the majority of motorcycles were sports motorcycles (n=51), followed by touring motorcycles (n=17) and off-road motorcycles (n=3), with insufficient information to classify the motorcycle in seven cases.

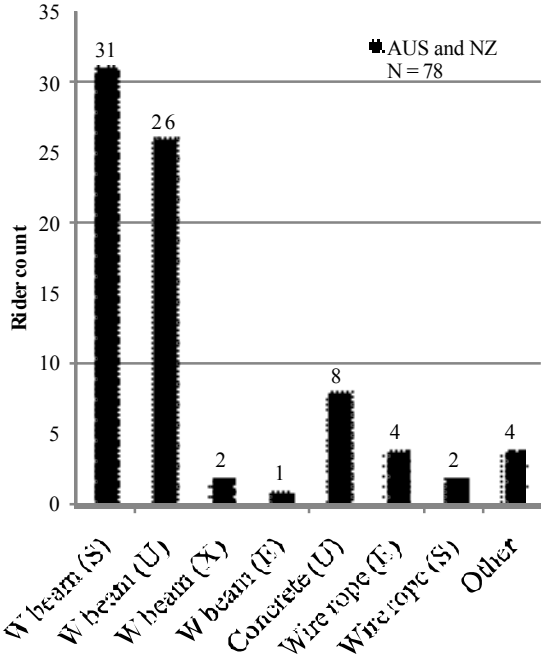
Crash modes

The crash modes are summarised in Table 1, along with the motorcyclist kinematics and the occurrence of motorcyclist impacts with barrier posts. The crash modes relative to the barrier types are shown in Figure 1. The crash modes in which motorcyclists collided with the barriers were classified into the three categories of upright (37 cases), sliding (34 cases) or ejected (5 cases). In two cases the crash mode could not be determined. In the sliding crash mode the motorcycle falls to the roadway, and the motorcyclist and motorcycle slide along the road surface and into the barrier. Witness reports often comment on the fact that the motorcyclist and the motorcycle are separated prior to contacting the barrier in this mode. However a reliable criterion to establish separation could not be established from the case files. The sliding crash mode may be further categorised in some cases into cases of low-siding or high-siding. Low-siding involves the motorcycle falling to the roadway on the side of the motorcycle that is on the

inside of the corner. High-siding involves the motorcycle being flipped over from the inside of the corner to contact the roadway on the outside side of the motorcycle (opposite to the leaning side). Evidence of the motorcycle low- or high- siding could be determined in 23 of the sliding cases, from the skid and scrape marks on the roadway and/or damage to the motorcycle.

Motorcycle into barrier crashes (AUS and NZ) 78 cases	Upright 37 cases (47%)	Scraped along the top 20 cases (54%)	Redirected >3m (7 cases, of which 7 hit a post) Over (6 cases, of which 4 hit a post) Adjacent >3m (4 cases, of which 3 hit a post) Stopped <3m (3 cases, of which 1 hit a post)
		Over the top without scraping 9 cases (24%)	Over (9 cases, of which 3 hit a post)
		Unknown 8 cases (22%)	1 hit a post
	Sliding 34 cases (44%)	Low-sided 18 cases (53%)	Stopped <3m (11 cases, of which 2 hit a post) Adjacent >3m (5 cases, of which 3 hit a post) Over (1 case, of which 1 hit a post) Unknown (1 case)
		High-sided 5 cases (15%)	Stopped <3m (3 cases, of which 2 hit a post) Under (1 case) Unknown (1 case)
		Unknown 11 cases (32%)	5 hit a post
	Ejected 5 cases (6%)	Hit gutter 3 cases (60%)	Ejected into barrier (2 cases, of which 1 hit a post) Ejected over barrier (1 case)
		Hit object 2 cases (40%)	Ejected into barrier (2 cases, of which 1 hit a post)
	Unknown 2 cases (3%)		

Table 1: Summary of crash modes, motorcyclist kinematics and post impacts for the 78 motorcycle-barrier crashes



U = upright mode S = sliding mode E = ejected X = unknown

Figure 1: Summary of barrier types and crash modes

In the upright crash mode the motorcyclist collides with the barrier in the upright position while seated on the motorcycle. The motorcycle is typically redirected along the barrier. Due to the impact trajectory angle of the motorcycle relative to the barrier, momentum causes the upper body of the motorcyclist to want to continue over the barrier. In nine cases the motorcyclist was ejected over the barrier upon impact. In 20 cases this momentum and the redirection of the motorcycle along the barrier resulted in the motorcyclist scraping/tumbling/skidding along the top of the barrier. After scraping along the top of the barrier for some distance the motorcyclist was then ejected from the barrier, and in 15 of the 20 cases this occurred as a result of the motorcyclist impacting a barrier post. It could not be determined from the case files to what extent the motorcyclist remained in contact with the motorcycle during the process of scraping along the top of the barrier. Some crash tests in the upright mode have shown crash test dummies (ATDs) may separate from the motorcycle during this process [5,7]. In eight cases it could not be determined if the motorcyclist had scraped along the top of the barrier.

In the ejected crash mode the motorcycle came into contact with the gutter (three cases) or an object (two cases), and the motorcycle rapidly decelerated ejecting the motorcyclist forwards from the motorcycle and into the barrier. It is noted that in none of the eight cases where a fatality resulted from a collision with a concrete barrier did the motorcyclist impact in the sliding crash mode.

Motorcyclist kinematics

The response of the motorcyclist as a result of the collision with the barrier may be classified into five categories: the motorcyclist went over the barrier (Over); the motorcyclist went under the barrier (Under); the motorcyclist stopped within 3m of the impact with the barrier without going over or under the barrier (Stopped); the motorcyclist was redirected for more than 3m from the impact point and came to rest adjacent to the barrier (Adjacent); or the motorcyclist was redirected for more than 3m from the impact point and came to rest in the lane(s) of the roadway (Redirected). The frequencies of the modes stopped, adjacent, over, redirected and under were 22, 20, 17, 11 and one respectively, and unknown in seven cases. The motorcyclist kinematics relative to the crash mode are shown in Table 1. The distance of 3m was used in the classifications since the crash scene investigators tended not to measure the distance unless it exceeded this value (approximately).

	Mean	Count	Range
Total distance motorcyclist travels after first impact – all modes (m)	21.8	62	0 - 100
Total distance motorcyclist travels after first impact - Upright mode (m)	26.3	34	2 - 82
Total distance motorcyclist travels after first impact - Sliding mode (m)	12.7	27	0 - 95
Distance motorcyclist scrapes along the top of the barrier (Upright mode) (m)	13.9	20	2 - 40
Distance motorcyclist slides before barrier impact (Sliding mode) (m)	28.9	26	9 - 56
Impact trajectory angle – all modes	15.4°	52	5 - 33
Impact trajectory angle - Upright mode	15.4°	26	5 - 33
Impact trajectory angle - Sliding mode	15.9°	24	5 - 32
Impact trajectory angle - motorcyclist redirected adjacent >3m	11.6°	14	
Impact trajectory angle - motorcyclist redirected into roadway>3m	10.6°	7	
Impact trajectory angle - motorcyclist stops <3m	16.7°	13	
Impact trajectory angle - motorcyclist goes over	19.7°	16	

Table 2: Summary of motorcyclist kinematics from cases where scene measurements were provided in the case files

Further details of the motorcyclist kinematics were determined from those cases in which measurements were taken of the crash scene and are summarised in Table 2. The mean distance the motorcyclist travelled from the impact point with the barrier was 21.8m (SD = 23.4m) in all crash modes. Amongst motorcyclists that impacted the barrier in the sliding crash mode the mean distance was 12.7m (SD =

20.6m) and in the upright mode 26.3m (SD = 20.4m). The longer distance covered when in the upright mode results from the momentum retained by motorcyclists as they scrape/tumble/skid along the top of the barrier. The mean distance motorcyclists scraped along the top of the barrier in the upright mode was 13.9m (SD = 12.4m). Given that W beam posts are typically spaced 2m apart, this presents multiple opportunities for the motorcyclist to impact with a post, resulting in the high incidence noted in this crash mode (15 from 20 in Table 1). The mean distance motorcyclists slid on the roadway prior to impacting the barrier in the sliding crash mode was 28.9m (SD = 13.8m).

Impact angle

Impact trajectory angles were determined with excellent accuracy from the 14 cases in which scene diagrams produced from a surveying instrument were included. In another 38 cases the impact angles were determined with reasonable accuracy from scene measurements. The mean impact angle in all crash modes was 15.4° (SD = 8.6°), and the mean impact angles for the sliding and upright crash modes were approximately the same (Table 2). Motorcyclists that went over the barrier tended to have impacted the barrier at angles larger than the mean. Motorcyclists that were redirected tended to have impacted the barrier at angles shallower than the mean, and both results are to be expected when one considers the momentum of the motorcyclist.

Pre-crash speed

The pre-crash speed was estimated in 54 cases. The speeds varied between 60km/hr and 200km/hr, with a mean of 100.8km/hr (SD = 31.1km/hr).

Conclusions

A retrospective study of motorcyclists that were fatally injured following a collision with a road side barrier during the period 2001 to 2006 in Australia and New Zealand has been presented. The majority of crashes resulted from collisions with steel W beam barriers, which is representative of exposure [2]. In 47% of cases the motorcyclist impacted the barrier in the upright mode, and in 44% of cases the motorcyclist slid into the barrier. Around half of the crashes in the upright mode resulted in the motorcyclist scraping/tumbling/skidding along the top of the barrier. The mean pre-crash speeds and impact angles were found to be 100.8 km/hr and 15.4° respectively. Future work will investigate the injury profiles of the motorcyclists, and injury causation with respect to the characteristics of the collision with the barrier.

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References

1. DITRDLG, 2008. Fatal and serious road crashes involving motorcyclists. Research and Analysis Report, Road Safety Monograph 20. Department of Infrastructure, Transport, Regional Development and Local Government, Australia.

2. Jama, H.H., Grzebieta, R.H., Friswell, R., McIntosh, A.S., 2010. Characteristics of fatal motorcycle crashes into roadside safety barriers in Australia and New Zealand. Accident Analysis & Prevention, under review.

3. Grzebieta R.H., Jama H., McIntosh A., Friswell R., Favand J., Attard M., Smith R., (2009) Overview of Motorcycle Crash Fatalities Involving Road Safety Barriers, Journal of the Australasian College of Road Safety, November, Vol. 20 No. 4, pp. 42 – 52. (also published in Proceedings Road Safety Research, Policing and Education Conference, Sydney, Australia, November 2009).

4. Ruiz, D.G., Magallon, B.P., Peldschus, S., Schuller, E., Gallo, A.M., Bidal, S., 2010. Overview on the development of a test standard for the evaluation of motorcyclists' impacts on road infrastructure elements. Int J Crashworthiness 15(1), 1-17.

5. Berg, F.A., Rucker, P., Gartner, M., Konig, J., Grzebieta, R., Zou, R., 2005. Motorcycle Impacts into Roadside Barriers - Real-world Accident Studies, Crash Tests and Simulations Carried Out in Germany and Australia. In: Proceedings of the 19th International Conference on the ESV, Washington , USA, Paper number 05-0095.

6. Quincy, R., Vulin, D., Mounier, B., 1988. Motorcycle impacts with guardrails. Transportation Research Circular 341, 23-35.

7. Peldschus, S., Schuller, E., Koenig, J., Gaertner, M., Ruiz, D.G., Mansilla, A., 2007. Technical basis for the development of a test standard for impacts of powered two-wheelers on roadside barriers. In: Proceedings of the 20th International Technical Conference on ESV, Paper 07-0332.

8. Bryden, F.A., Fortuniewicz, J.S., 1986. Traffic barrier performance related to vehicle size and type. Transportation Research Record 1065, Transportation Research Board, pp. 69-78.