

Motorcyclist collisions with roadside barrier motorcyclist protection systems

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Abstract

In Australia, around 12 motorcyclists per annum are fatally injured following a collision with a roadside barrier. With a goal of reducing such trauma, the Australian and New Zealand Road Safety Barrier Systems and Devices Standard (AS/NZS 3845.1:2014) recently introduced a crash test requirement for 'motorcyclist protection systems', intended to improve the safety of roadside barriers for motorcyclists. The crash test is based on the European CEN technical specification (CEN/TS 1317-8:2012). However, there are some limitations to such crash testing, including the biofidelity of the anthropomorphic test device (ATD) and the fact that only one collision orientation is tested.

The aim of the present study is to provide information regarding the effectiveness of motorcyclist protection systems under a variety of field-observed collision scenarios. Finite element simulations of a human body model sliding into a roadside barrier with a rub-rail system were undertaken. Two different impact orientations, three impact angles and four impact speeds were considered. It is shown that the injury potential of the W-beam barrier is substantially reduced with the rub-rail, where motorcyclist serious thoracic and head-neck injuries are likely prevented for most sliding collision orientations, except those at the highest angles and speeds. It is envisaged that the present simulation results will complement existing test data using ATDs, providing substantive information to regulators and road authorities confirming the large injury reduction potential of rub-rail systems, thereby promoting their installation and assisting in reducing trauma related to motorcyclist collisions with roadside barriers.

Introduction

In Australia, around 12 motorcyclists per annum are fatally injured following a collision with a roadside barrier (Bambach et al 2012). The Australian and New Zealand Road Safety Barrier Systems and Devices Standard AS/NZS 3845.1:2014 (2014) recently introduced a crash test requirement for devices intended to improve the safety of roadside barriers for motorcyclists, based on the European CEN technical specification CEN/TS 1317-8:2012 (2012). While this crash test protocol has been demonstrated to be a robust procedure, with many crash tests performed in Europe, there are some limitations (typical to crash testing) (Grzebieta et al 2013): only one impact trajectory is tested (head-leading at 30° and 60 km/h); the head-leading orientation does not consider direct chest impacts and associated injuries; and the crash test uses a Hybrid III anthropomorphic test device (ATD), which has proven biofidelity, however does have limitations (particularly under vertical head-neck axis loading and side impacts to the thorax in the coronal plane).

Recent motorcyclist-barrier crash studies (Bambach et al 2012, Bambach et al 2013, Grzebieta et al 2013) have indicated that: the most frequent crash type was a collision with a steel W-beam barrier (guardrail) of which half are in the sliding posture (i.e. the motorcyclist is separated from the motorcycle) and half remain seated in the upright posture; impact angles varied between 5° and 33°, with a mean of 15.4°; impact speeds varied between 60 and 200 km/h, with a mean of 101 km/h; and the most frequently occurring serious injuries were thoracic injuries, followed by head and lower extremity injuries.

Considering the limitations of crash testing, a human body Finite Element model was used to assess human kinematics and injury potential for a wide range of sliding impact configurations, thereby assessing devices for a full range of field-observed collision modes. Devices considered were fixed to steel W-beam barriers. This paper provides a summary of the findings.

Methods

The device selected for this study is a public domain rub-rail system manufactured and sold in Australia and installed on steel W-beam barriers. Many kilometres of this device has been installed in New South Wales, Victoria, Queensland and South Australia. The rail consists of a flat steel surface with tapered edges, and is bolted to the face of the blockout via a steel plate connector (Figure 1a). A finite element (FE) model was generated from engineering drawings of the device (Figure 1b). Two interior bays of a W-beam barrier were modelled (Figure 1c).

The Total Human Model for Safety (THUMS) average size male human body model was used to simulate the motorcyclist in this study, developed by Toyota Motor Corporation. The FE mesh consists of nearly 2,000,000 elements representing the components of the human body, and the response to dynamic loads has been shown to be within acceptable biomechanical limits (Bambach and Grzebieta 2013, Iwamoto 2002). The collision orientations of THUMS with the W-beam barrier were based on the CEN crash test orientation and the Australian crash data impact orientations discussed in the Introduction, including orientations of head-leading and chest-leading, impact angles of 15°, 30° and 45°, and speeds of 20, 40, 60, 80 and 100 km/h (Figure 2). The latter orientation was selected to create a direct chest impact in order to assess thoracic injury potential.

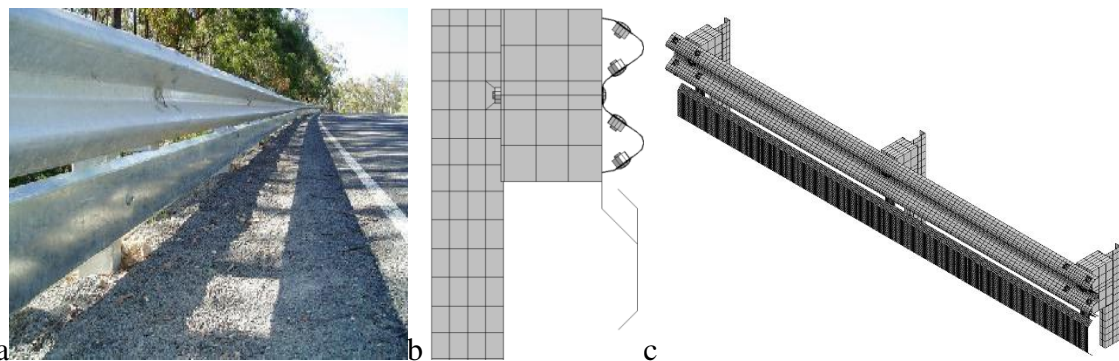


Figure 1. a) Australian rub-rail device, b) FE model of the rub-rail and W-beam barrier, c) isometric view of the rub-rail and barrier

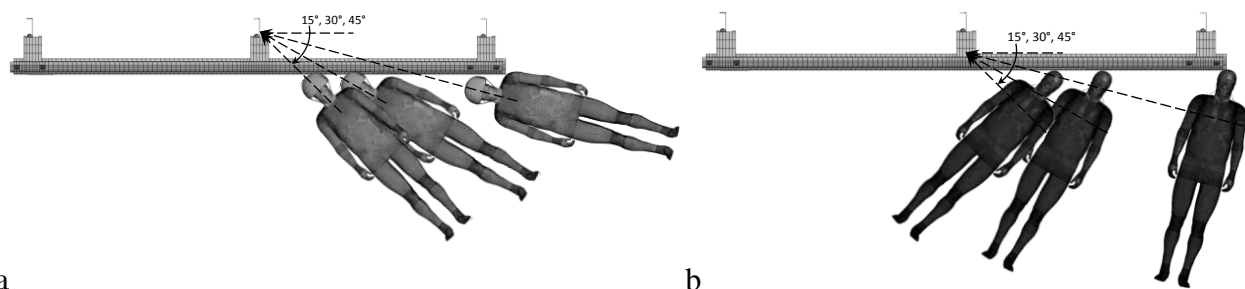


Figure 2. a) Head-leading orientations, b) Chest-leading orientations

Results

The results of the collisions in the head-leading orientation are summarised in Tables 1 and 2. Cervical vertebral fractures (fx, AIS 2+) were assessed using a plastic strain to fracture in the cortical bone of 3%. Brain injury was assessed using the Cumulative Strain Damage Measure (CSDM), where threshold strains of 10%, 15% and 30% were used to indicate mild traumatic brain injury (MTBI, AIS 2), diffuse axonal injury (DAI, AIS 4) and severe brain injury (SBI, AIS 5+), respectively. Serious head/neck injuries were predicted to occur around 20 – 40 km/h for unprotected W-beam posts, 80 – 100 km/h for the rub-rail impact at 30°, and 60 – 80 km/h for the rub-rail impact at 45°. Injuries were not predicted for the rub-rail impact at 15° for all speeds.

The results of the collisions in the chest-leading orientation are summarised in Figure 3. Thoracic injury was assessed using the normalised chest compression, being the maximum rib deflection divided by the original width of the chest. Values of 0.383 and 0.496 were used to indicate threshold values between moderate (AIS 1,2), serious (AIS 3,4) and critical (AIS 5+) injury (derived from cadaveric studies of chest injury, Viano et al 1989). Serious thoracic injuries were found to occur at around 30 km/h for unprotected W-beam posts, and were found to not occur for rub-rail impacts at all angles and speeds.

Table 1. Brain injuries simulated with THUMS in the head-leading orientation

| | Impact angle | 20 km/h | 40 km/h | 60 km/h | 80 km/h | 100 km/h |
|-------------------------|--------------|---------|---------|---------------------|---------|---------------------|
| Unprotected post | 15° | MTBI | MTBI | <i>Not modelled</i> | | |
| Rub-rail | 15° | | | | | |
| Rub-rail | 30° | | | MTBI | DAI | DAI |
| Rub-rail | 45° | | MTBI | DAI | SBI | <i>Not modelled</i> |

Note: Blank cell indicates no injury unless stated otherwise.

Table 2. Cervical spine injuries simulated with THUMS in the head-leading orientation

| | Impact angle | 20 km/h | 40 km/h | 60 km/h | 80 km/h | 100 km/h |
|-------------------------|--------------|---------|---------|---------------------|---------|---------------------|
| Unprotected post | 15° | 3 fx | 4 fx | <i>Not modelled</i> | | |
| Rub-rail | 15° | | | | | |
| Rub-rail | 30° | | | | | 2 fx |
| Rub-rail | 45° | | | 1 fx | 6 fx | <i>Not modelled</i> |

Note: Blank cell indicates no injury unless stated otherwise, fx = cervical vertebral fracture

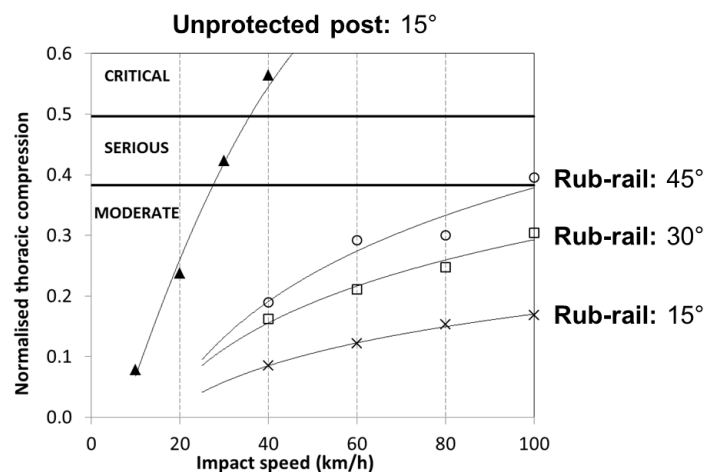


Figure 3. Chest injuries simulated with THUMS in the chest-leading orientation

Conclusions

Collisions with unprotected W-beam posts present a severe injury potential for a sliding motorcyclist, even at relatively low speeds. The Australian rub-rail device successfully redirected the motorcyclist and prevented a post impact, thereby greatly reducing the injury potential. This study found that the rub-rail will likely prevent serious thoracic injury at all practical impact angles and speeds, and likely prevent serious head/neck injury at low impact angles and higher impact angles at low speeds. However, the potential for severe head/neck injury exists at high angles and high speeds.

While European crash tests with ATDs have demonstrated that rub-rails prevent serious injury for head-leading sliding collisions at 30° and 60 km/h, this study compliments these results, and demonstrates the substantial injury reduction potential of rub-rail devices for a wide range of other collision orientations observed in the field.

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