Contributed articles

Road Safety Policy & Practice

Truck Rear Underrun Dynamic Crash Test in AS/NZS 3845.2:2017 Standard – a World's First for Heavy Vehicle Crashworthiness

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Key Findings

- Around 10 to 12 car occupants are killed in rear truck underrun crashes yearly;
- Cars crashing into trucks with rear overhangs represents extreme incompatibility;
- Car crashworthiness systems entirely negated in fatal truck rear underrun crashes;
- New AS/NZS 3845.2 Standard includes truck underrun dynamic test and safety criteria;
- Crashes into AS/NZS 3845.2 compliant truck rear underrun barriers are now survivable;

Abstract

Each year around ten to twelve fatalities occur as a result of truck rear underruns in Australia and New Zealand. The injuries are usually horrific. Any car impact protection devices such as crumple zones, frontal airbags, or pre-tensioning belts are completely negated by an obvious mismatch between truck with an extended rear frame and a car's crashworthiness systems. Given both Australia and New Zealand have adopted a 'Safe System Approach' road safety strategy, all such foreseen fatalities need to be addressed if a design countermeasure can be implemented. Despite the need for a standard having been recognised for some decades, there has been no effective legislation or Australian Design Rule requiring truck rear under run barriers. It was not until this year (2017) that the redrafted AS/NZ 3845.2 standard set out a crash test performance requirement for such barriers. This is the first time anywhere in the world such a dynamic crash test requirement has been specified in any official document agreed to by regulators. Brief details of the crash test matrix, the criteria for a barrier to be compliant with the standard and the basis on which requirements were established for a truck rear underrun protection device (barrier) is presented. A five star ANCAP rated car crashing into AS/NZS 3845.2 compliant truck rear underrun barriers at speeds of up to around 70 km/h are now survivable.

Keywords

Truck Underrun, AS/NZS 3845.2, Barrier, Crash Testing, Rear Underride

Glossary

AS/NZS	Australian Standard/New Zealand Standard
ADR	Australian Design Rule
NCAP	New Car Assessment Programme
IIHS	Insurance Institute of Highway Safety
NZ	New Zealand
RUPD	Rear Underrun Protection Device
US	United States (of America)

Background

Rear underrun car crashes into heavy vehicles with rear overhangs where the truck structure intrudes into the impacting vehicle's occupant compartment, represents the most extreme example of system incompatibility between heavy vehicles and passenger cars. Figure 1 shows some real world crashes where people have died as a result of such horrific impacts in Australia (Rechnitzer & Foong, 1991). Any car impact protection devices such as crumple zones, frontal airbags, or pre-tensioning belts are completely negated by the obvious mismatch between the truck's rear and car's crashworthiness systems as shown in Figure 2. This type of crash often causes severe or fatal injuries to car occupants due to the mismatch in mass ratio, stiffness ratios, compartment intrusion, and importantly interface geometry (Rechnitzer & Grzebieta, 2001, Grzebieta & Rechnitzer, 2001).

Haworth and Symmonds (2003) estimated that rear underrun crashes in Australia account for some 10 to 12 or so fatalities and around 150 serious injuries every year. Despite this, there currently is no legislation or Australian Design Rule (ADR) requiring crash testing of truck rear and side underrun barriers. Disturbingly, the Australian Federal Government office responsible for introducing and maintaining ADRs assessed over a decade ago that the cost benefit of introducing such a vehicle design rule as too small despite the horrific injuries identified in real world data. The United States (US) Insurance institute of Highway Safety (IIHS) has also identified that truck rear and side underrun fatalities and serious injuries are occurring as a result of inadequate truck underrun barriers and the lack of a US crash performance test standard (IIHS, 2014, 2017a, 2017b).

Truck Rear Underrun Protection Devices (RUPDs) (truck underrun barriers) can be thought of as a barrier or a crash cushion that prevents the vehicle from underrunning the truck, and hence injuries, as shown in Figures 3 and 4. RUPDs are permanently fixed to the rear of any truck or trailer. A considerable amount of research work was completed into establishing what is a suitably crashworthy RUPD almost two decades ago now (Rechnitzer, Powell & Sayer, 2001, Zou, Rechnitzer & Grzebieta, 2001, Rechnitzer, 2003).

Current vehicle crashworthiness technology indicates that cars can be designed to prevent occupants from serious injury at a frontal impact speed (ΔV) of 64 km/h into a deformable barrier and also when crashing into a rigid barrier at a narrow 25% offset, if the car is a modern five star New Car Assessment Programme (NCAP) crashworthy rated vehicle.

Hence, based on this recent technology and to address the ADR shortcomings within a 'Safe System Approach' paradigm, the new Australian Standard AS/NZS 3845.2: Road Safety Barrier Systems and Devices was recently developed and released as a 'world's first' underrun crash test for regulators and operators who want to specify crashworthy RUPDs fitted to trucks that operate in the work place as well as on public roads. This article presents the main components of the RUPD section.

How and Why the New RUPDs Standard Was Developed

All nature of trucks can operate within a road works site or be delivering materials to a road works or road maintenance site via a public road. The hierarchy of controls for managing fatality and injury risks within Australia's and NZ's Work Health and Safety legislation specifies that engineering controls which design out the hazard are considered more effective control measures than

Figure 1. Under Crashes (Rechnitzer & Fong, 1991)

Figure 2. Under Crashes (Rechnitzer & Grzebieta, 2001)

administrative controls (SafeWork Australia, 2011, Peace, 2016). A truck that is delivering materials or used in the workplace is considered as mobile plant in Work Health and Safety legislation. Given that the technology was already been developed by Rechnitzer and others (Rechnitzer, 2003, Rechnitzer, Powell & Sayer, 2001, Rechnitzer, Zou & Grzebieta, 1997) it was appropriate for the Australian/New Zealand CE 33 Committee commissioned with re-drafting AS/NZS 3845 (and within member's duty of care), to specify a crash test protocol and safety criteria for the design of a crashworthy RUPD.

RUPDs are usually attached to a truck or trailer of any large mass vehicle that is greater than 3500 kg Tare mass. The trailer would typically be towed such as in the example of a tip truck and dog or a prime mover towing a semi-trailer, B double or B-triple configuration. The vehicle with the RUPD attached can travel on any public road and is not necessarily associated with any road maintenance or roadwork. However, it was deemed that a public vehicle delivering materials to a roadwork site should have a RUPD attached.

To ease the process of accepting a suitable crash test protocol and safety criteria, it was decided to base the standard on existing internationally accepted crash test protocols and safety criteria already adopted in the US, Europe, Australia and NZ for testing and certifying roadside and median safety barriers. Around four decades of crash testing and crashworthiness technology that has been validated against real world crash data, computer simulations and engineering biomechanics, have been incorporated into road safety barrier test protocols and safety criteria. Hence, the underrun crash test was principally based on crash test using components from the US Manual for Assessing Safety

Figure 3. RUPD rigid barrier design (Rechnitzer, Powell & Sayer, 2001)

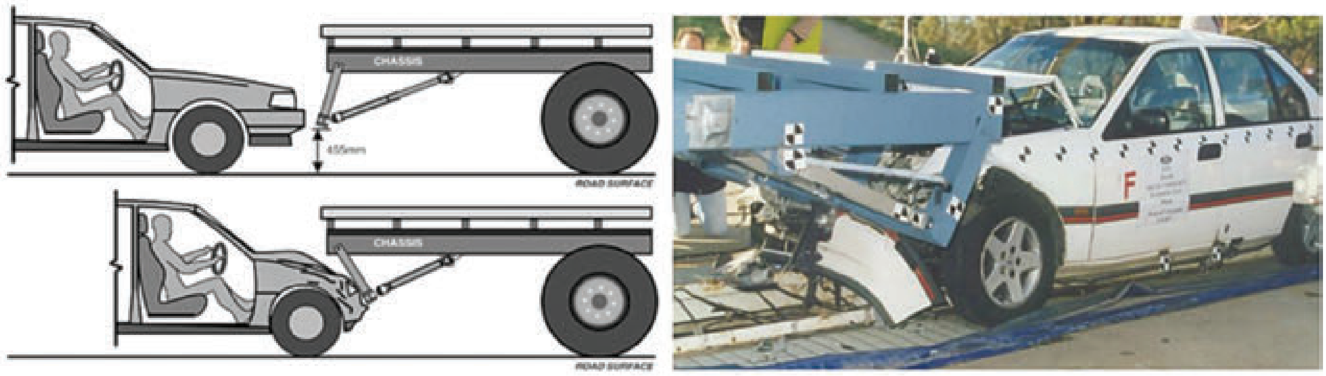


Figure 4. Energy dissipating RUPD barrier design (Rechnitzer, Powell & Sayer, 2001)

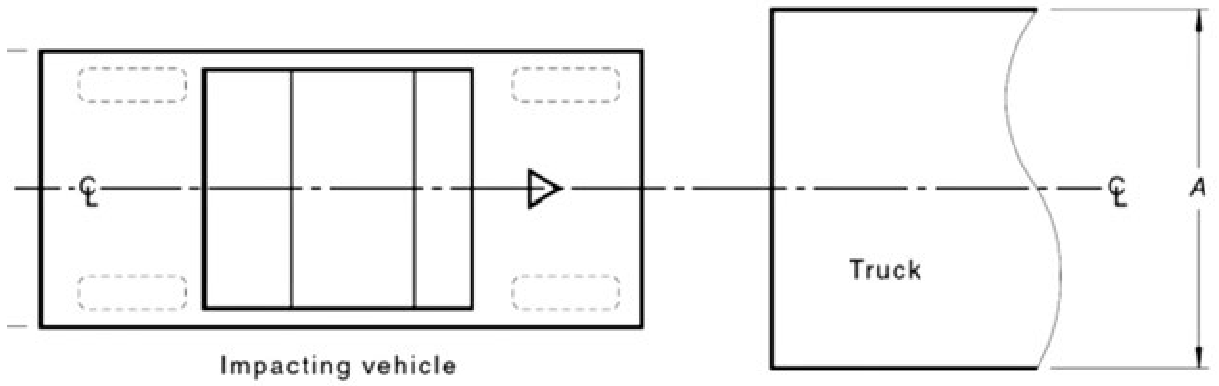
Table 1. Test Matrix For Rear Underrun Protection Devices (Standards Australia, 2017)

Test Level	Feature	Test designation	Impact conditions			Impact point	MASH Evaluation Criteria
			Vehicle	Nominal Speed (km/h)	Nominal Angle deg.		
2	Rear underrun protection device	2-51	2270P	70	0	Fig. 5	C,D,F
		2-52	2270P	70	0	Fig. 5	C,D,F
		2-54	1500A	70	0	Fig. 5	C,D,F
		2-55	1500A	70	0	Fig. 5	C,D,F

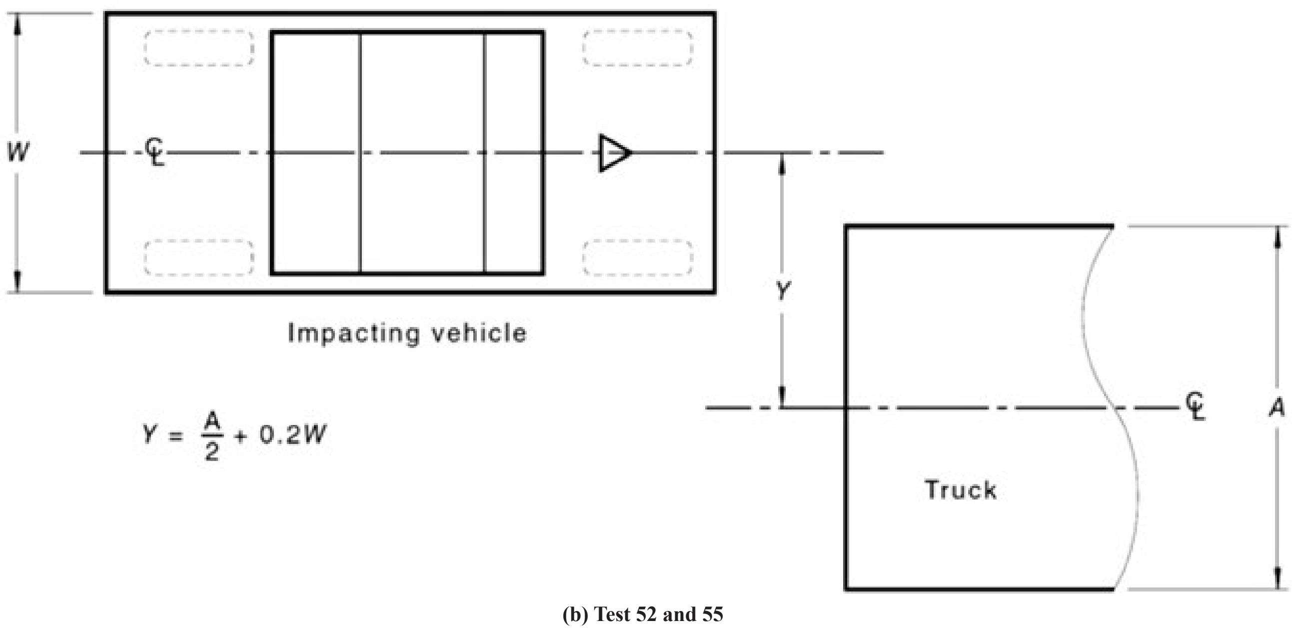
Hardware (MASH) crash test vehicles and testing protocols commonly used in Australia and New Zealand.

Underrun Test Standard

The performance requirements are set out in Section 7 of AS/NZS 3845 for RUPDs. These devices may be equally applied to any truck or trailer of an articulated truck that operates on any public road and are used to protect the occupants in a vehicle that runs into the back of the truck or trailer. RUPDs are permanently fixed to such vehicles. The RUPD usually does not protrude from the rear of the truck or trailer and mostly relies on the impacting vehicle's frontal crash protection system for ride down decelerations for the occupants although some of the impact kinetic energy can be dissipated by the RUPD.



(a) Test 2-51 and 2-54



(b) Test 52 and 55

Figure 4. Impact Conditions For Rear Underrun Protection Devices

Table 1 shows the crash test matrix that underrun devices are required to comply with. Tests are based on the United States (US) Manual for Assessing Safety Hardware (MASH) protocols where a 1500 kg sedan car (1500A) and then a large 2270 kg sports utility vehicle (2270P) are impacted into the RUPD at a speed of 70 km/h in a centred and a 30% offset configuration as indicated in Figure 5 (AASHTO, 2016).

The barrier must meet certain crashworthiness criteria (C, D, F) detailed in MASH (AASHTO, 2016). They are:

C: Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle. Research has demonstrated that if the maximum permitted rearward displacement of the RUPD beyond the face of the rear of the truck does not exceed 500 mm, then survivability is improved. This dimension is to ensure that underrun resulting in hazardous penetration of the vehicle windshield is prevented in most crash situations.

D: Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone.

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

For all tests the RUPD is mounted on a standard MASH 10,000 kg single unit heavy truck test vehicle (designated a 10000S vehicle). During the tests, the test vehicle is placed in second gear and the parking brake set. The RUPD is fixed to the rear of the truck in the same way as it would be installed in service. The RUPD may deform under the impact loading but there cannot be any joint failures or buckling of the RUPDs key support structures or of the support truck structure.

Whilst the RUPD can deform under the impact loading the requirements that there are to be no joint failures or buckling of RUPDs key support structures or of the support truck structure, is to ensure the RUPD has residual load capacity for impacts above 70 km/h. While an impact at 100 km/h would be desirable, this speed is considered too onerous with the current technology.

The research work by the Authors referred to above have established that all criteria can be readily met by well-designed RUPD.

While the performance requirements set out in AS/NZS 3845.2 for RUPDs are intended for trucks servicing work sites and maintenance, the performance criteria can be equally applied to any truck, or trailer of an articulated truck, that operates on any public road and are used to protect the occupants in a vehicle that runs into the back of a truck or trailer. In other words, crashworthy effective RUPDs can now be designed and fitted to any truck that is used within a work or maintenance site or delivering materials to such sites.

In the USA, the IIHS carries out evaluations of the performance of rear underrun guards on semitrailers made by the major manufactures (IIHS, 2017c). The crash tests are described on the IIHS website, and use a mid-sized sedan crashed into a parked semitrailer at 56km/h, in centred 50% offset and 30% offset impacts. Trailers that pass these tests, i.e. prevent underrun (no intrusion into the passenger compartment) qualify for the IIHS TOUGHGUARD Award.

Conclusions

For nearly 30 years the Authors and others have been advocating that the tragic and senseless deaths arising from rear underrun crashes could be largely eliminated by the requirement of effective rear underrun barriers on heavy vehicles. The necessary performance criteria and crash testing for the effective design of truck rear underrun barriers are now finally incorporated in the Australian Standard AS/NZS 3845.2: Road Safety Barrier Systems and Devices.

Although this standard is intended to apply to trucks involved in roadworks and road maintenance, the AS/NZS 3845.2 RUPD requirements are able to be used for all heavy vehicles. This should be promoted to industry, road safety and heavy vehicle regulators.

It would also be appropriate for ANCAP to explore introducing the IIHS type crash test evaluation of the performance of rear underrun barriers on heavy vehicles in Australia, and eventually tests in line with AS/NZS 3845.2:2017 RUPD requirements. This would quickly identify pseudo RUPDs and promote effective properly engineered RUPDS.

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Perspective on Road Safety

It is time to consider a presumed liability law that protects cyclists and other vulnerable road users

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Key findings

- Cycling participation is falling and cyclist hospitalisations are on the rise.
- Motorists are more likely to be at fault in crashes with cyclists.
- A presumed liability law that places the burden of proof on motorists in crashes with cyclists is needed.
- The law would allow better compensation for cyclists and encourage motorists to exert extra care.
- Presumed liability along with other measures are likely to improve safety and cycling participation.

It is widely agreed that cycling is an effective way to promote physical health and mental well-being, reduce congestion on roads and improve the quality of the environment. In recognition of the benefits of cycling, the National Cycling Strategy 2011-2016 set out the objective to double cycling participation by Australians between 2011