TARS Research

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Interface Analysis and Design: Improving Heavy Vehicle Road Safety Barrier Design

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ROAD SAFETY
RESEARCH, POLICING AND EDUCATION
CONFERENCE 2013

Outline

- Introduction
  - Safe system approach and current injury rates
  - Interface Analysis Design (IAD)
  - Heavy vehicle impacts
- Example IAD case
  - Bolte Bridge approach barrier impact
  - High performance bridge barrier analysis
  - Current code requirements
  - Safe System Controls
- Conclusions and Recommendations

Vision Zero and Safe Systems

- Road system designers responsible for the level of safety achieved
- Safe drivers, on safe roads, in safe vehicles

The Safe System approach

- The Safe System approach to road safety recognises the need for responsible road user behaviour, but also accepts that human error is inevitable. It therefore aims to create a road transport system that makes allowance for errors and minimises the consequences: in particular, the risk of death or serious injury.

Interface design

Journal of the Australasian College of Road Safety – May 2009

Contributed Articles

Please note that our November 2009 Journal will have a major focus on motorcycle safety. If you would like to write a 'Letter to the Editor' or submit an article, please send it as a MS Word document to journaleditor@acrs.org.au by 10th September.

Interface Design: The Next Major Advance in Road Safety

By Dr George Rechnitzer, Shane Richardson, Maxwell Shifman & Dr Andrew Short
Delta-V Experts, Melbourne, Australia Web: www.dvexperts.net Tel: (03) 9481 2200.

Interface Design

- Breakdowns in system safety at various interfaces.
- Either causal or increase the risk of injury.
- Focus on interfaces to reduce crash risk, crash severity and injury risk.

Interface Design

- "Interface Design" as a potential catalyst for the next major advances in road safety.
- A holistic approach which encourages all involved in the development of systems to consider all possible interfaces of their project.

1. Behavioural interfaces

- Interface design when applied to the vehicle operator is concerned with vehicle control and crash avoidance by the vehicle operator or independently.
- Interfaces with other road users (pedestrians, cyclists, motorcycles)

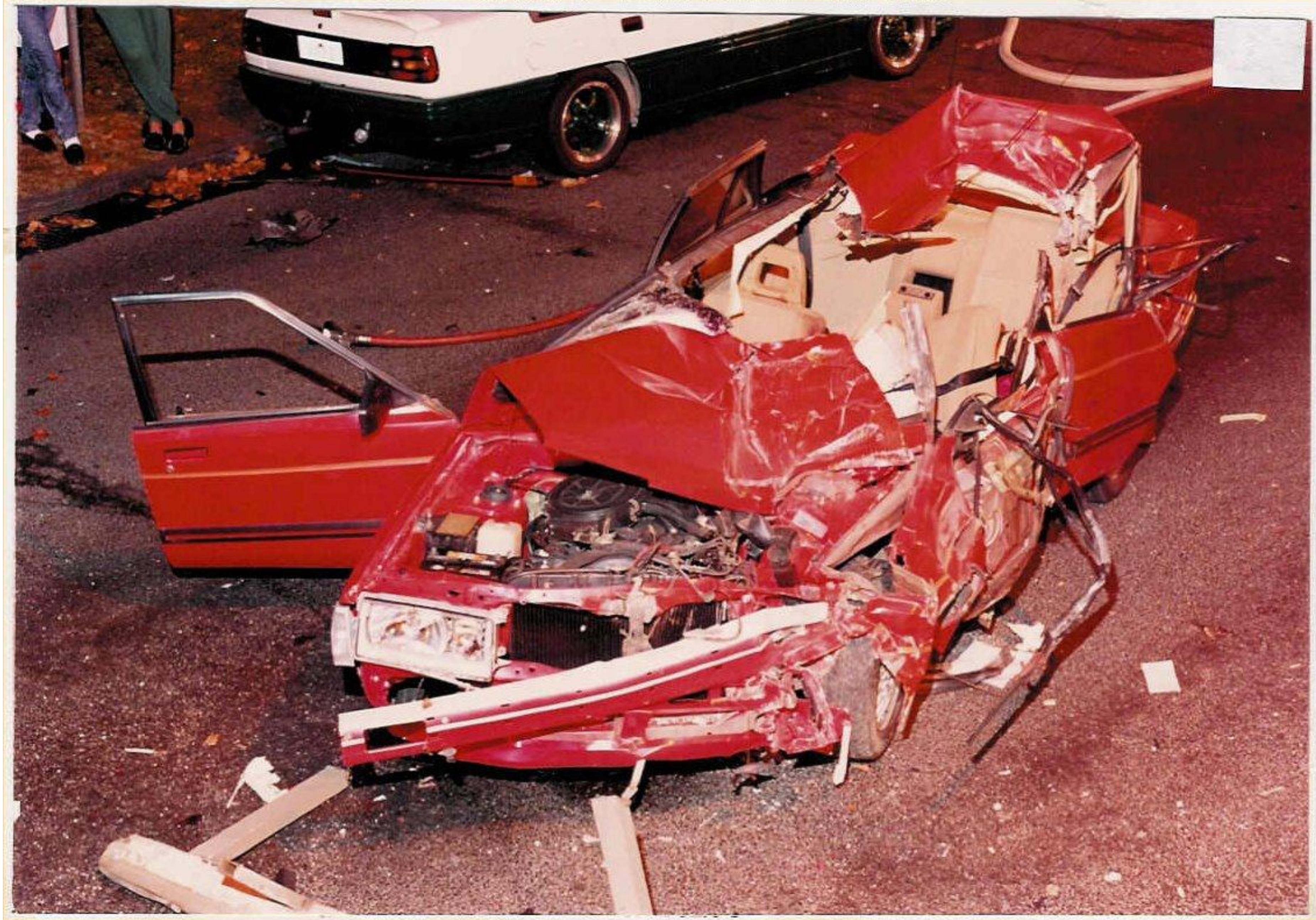
2. Vehicles and Road interfaces

- This relates to the opportunity available in the road transport system for collisions of all sorts.
- Interface design for vehicle crashworthiness includes vehicle-to-vehicle crashes as well as compatibility with heavy vehicles and road infrastructure, level- crossings and so on.

3. Human-impact interface

- Injury prevention in a crash is a function of the interface between the human and whatever is impacted or restrains the human during an impact.

Under –run crashes – fatal interfaces



Truck underrun- Offset incompatibility

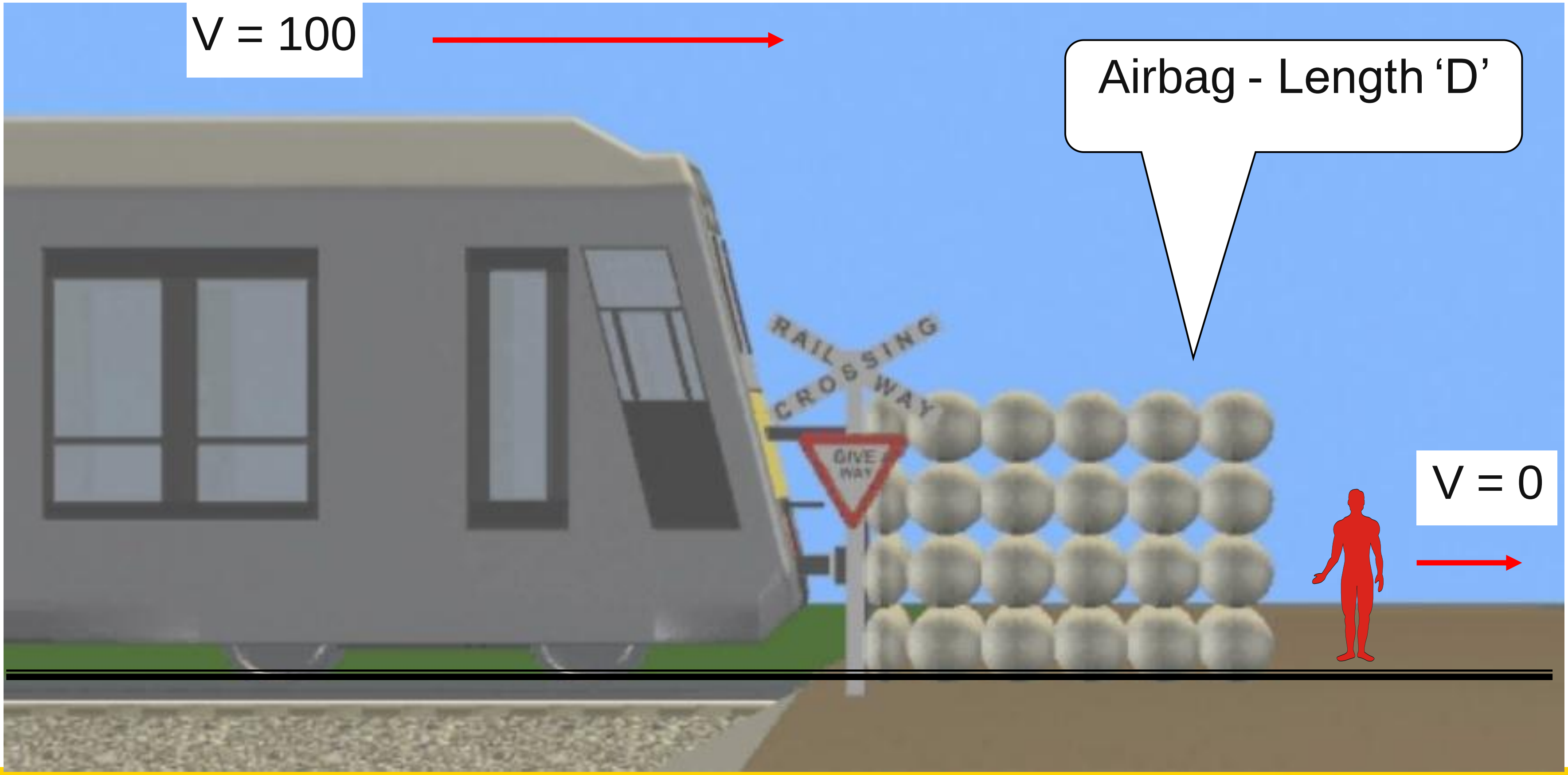
Good interface design: Crash test, energy absorbing, centred, 75 km/hr

Heavy vehicles- safety is a matter of interfaces

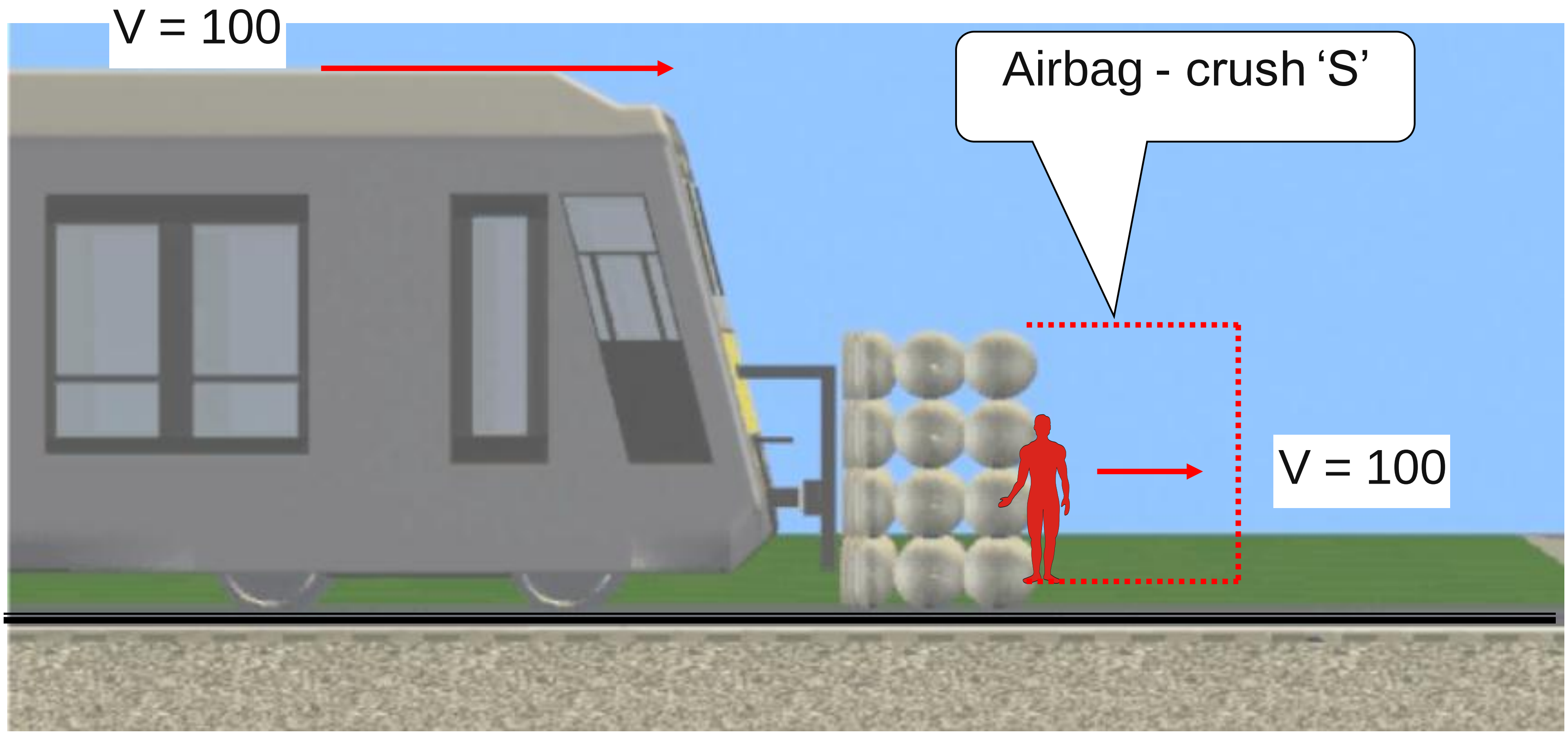
It is not mass difference that determines impact outcomes but interface design!

Can a pedestrian be 'safely' impacted by a 1000t train at a 100km/h?

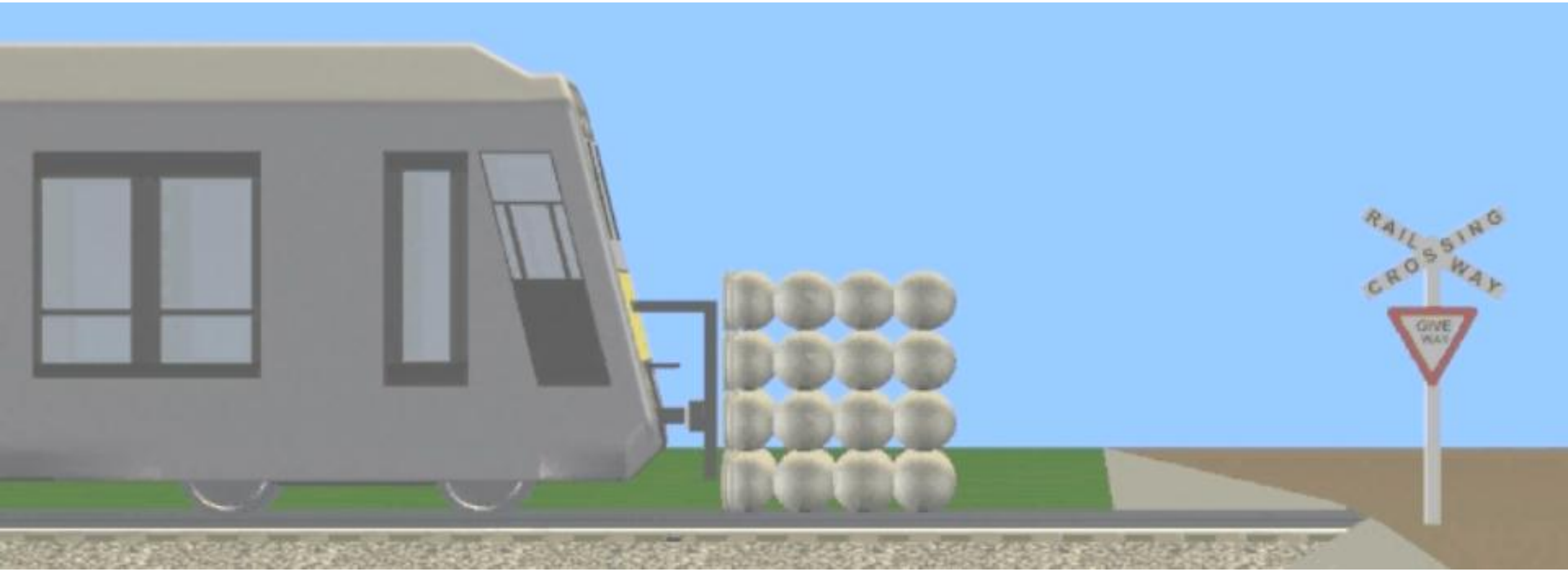
Example 1: Pedestrian - train impact



Example 1: Pedestrian - train impact – post impact



Example 2: Vehicle - train impact - 2



Example 2: Vehicle - train impact - 3

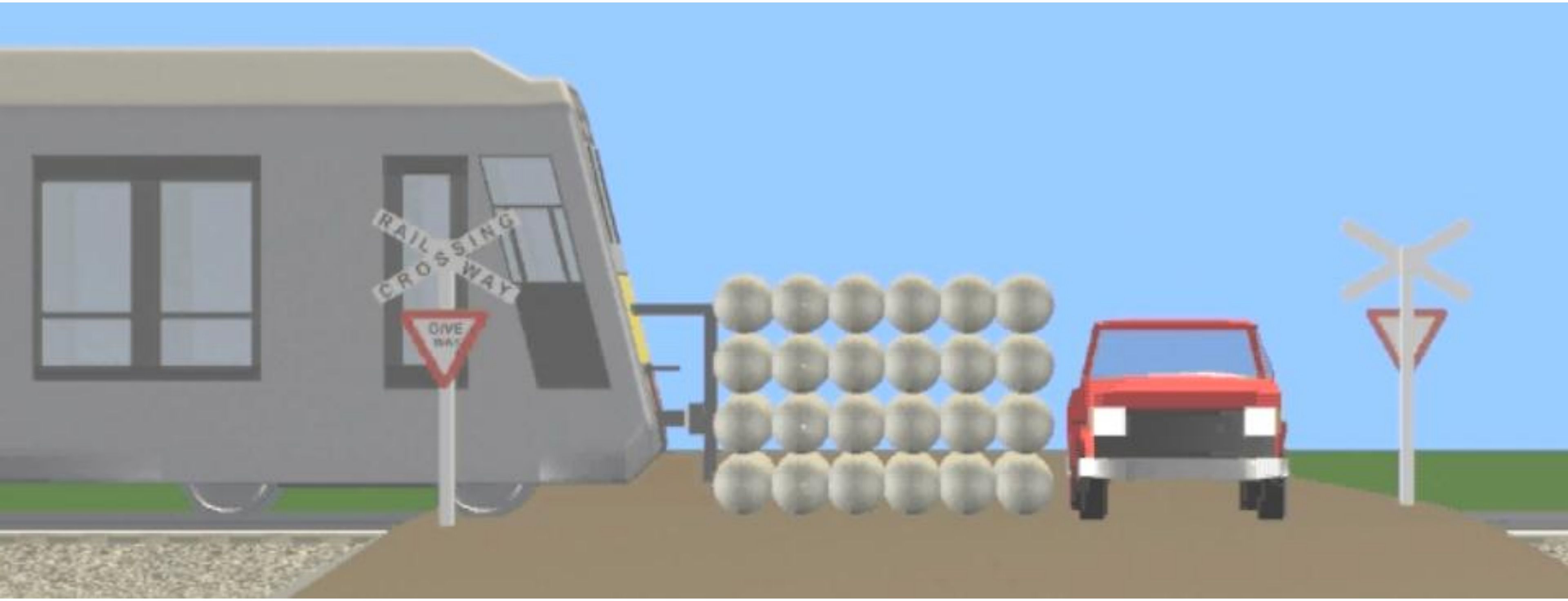


Figure 15: Example of typical W-beam guardrail (manufactured by Armco)

Figure 16: Motorcycle interaction with a typical wire rope barrier. Other interactions involve the motorcyclist sliding or vaulting into the barrier

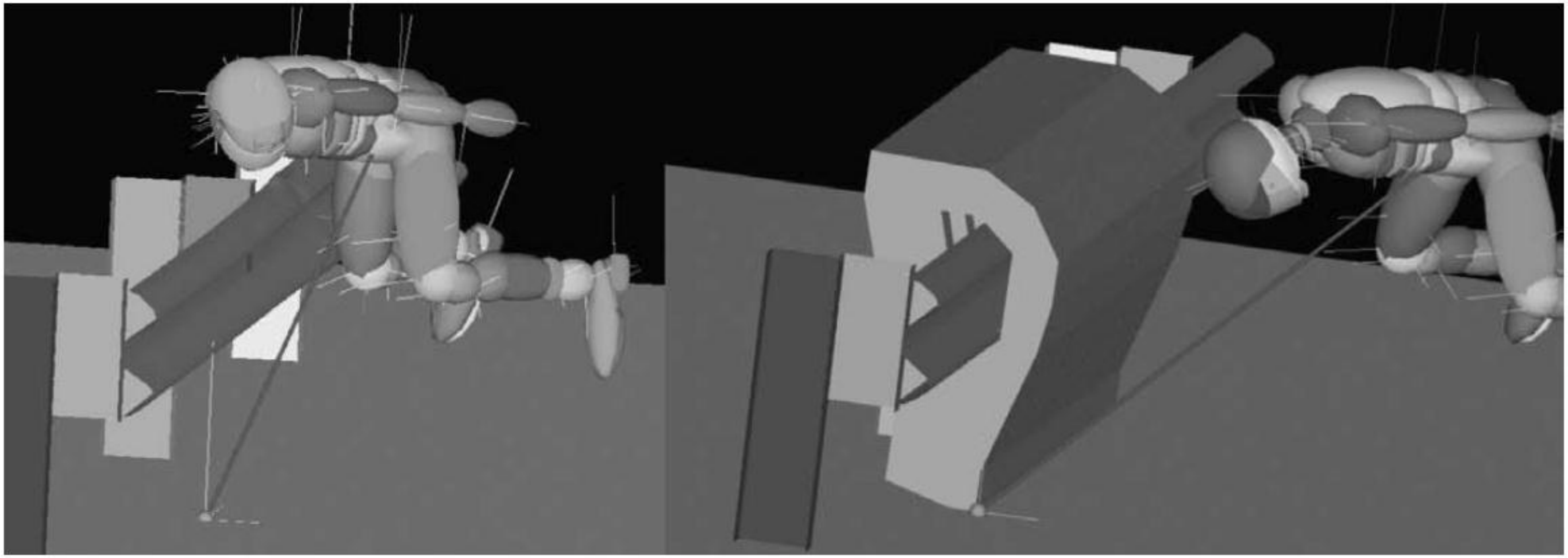


Figure 17: Computer model of a displaced rider impacting a 'W' beam guardrail segment [very hazardous interface], and one fitted with a well design energy absorbing system [low injury risk impact interface].

Diana Crash

No barrier!

She would be alive today if there had been one

We learn our lessons hard!

Ferntree Gully Road, Melbourne (before)

Improved interface

UNSW THE UNIVERSITY OF NEW SOUTH WALES

TARS Research

Monash simulations for determining barrier loads and height (MADYMO)

Objectives:

To simulate the dynamic response of a 44 tonne truck impacting a High Performance Level Bridge Barrier

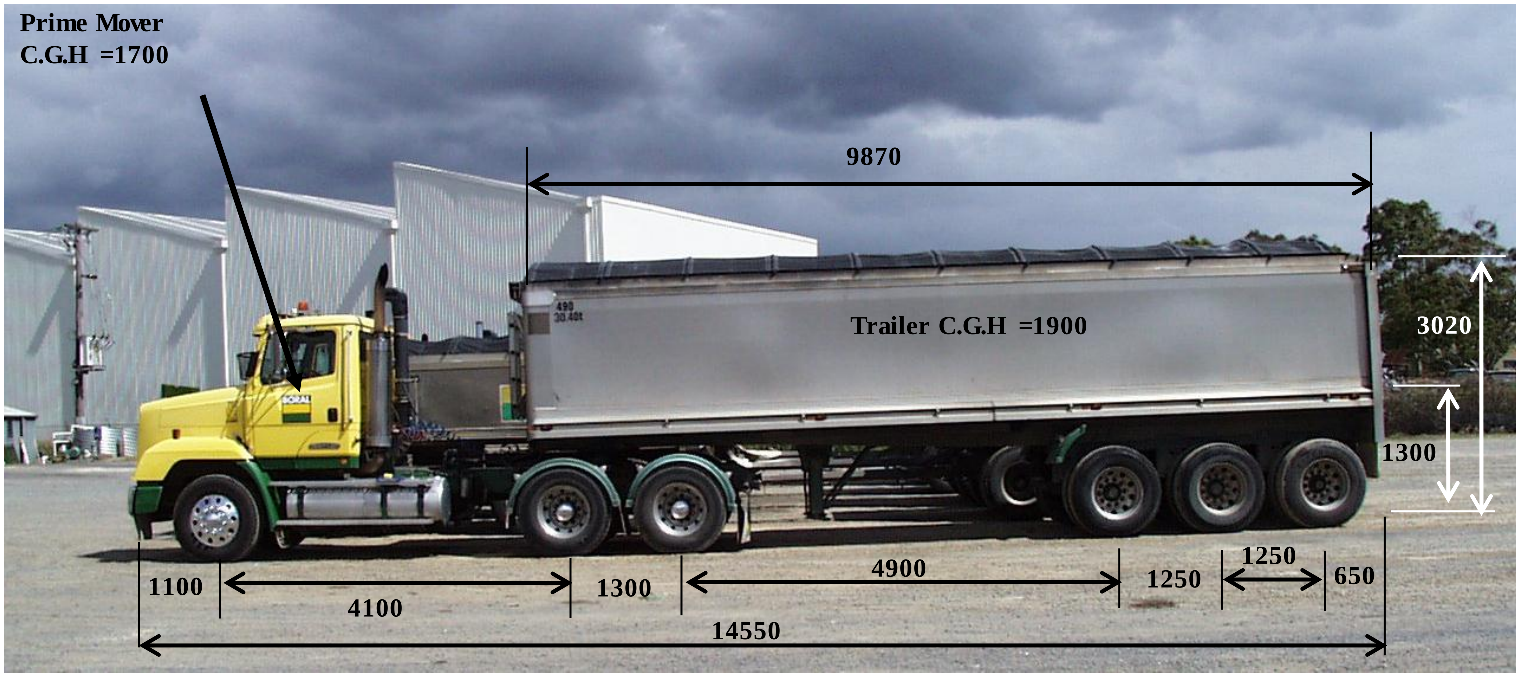
To assess if the safety performance of this barrier would meet the NCHRP 350 Level 6 evaluation criteria

To calculate dynamic loads in the bridge barrier/deck for the case of a 44 tonne truck impact

To provide ultimate load estimation for bridge designers in developing prototype barriers

BRIDGE RAILS

TRUCK BASE MODEL



BRIDGE RAILS

TRUCK BASE MODEL

Truck Models Simulated

Model	Wheel Space (m)	Prime Mover Mass (kg)	Prime Mover CG Height (m)	Trailer Mass (kg)	Trailer CG Height (m)
Base Truck (base model)	4.9	8000	1.7	36000	1.9
Truck01	4.4	12000	1.7	33000	1.2
Truck02	4.4	12000	1.7	33000	2.5
Truck03	10.4	12000	1.7	33000	1.2
Truck04	10.4	12000	1.7	33000	2.5

BRIDGE BARRIER MODEL

Assumptions used to calculate bridge barrier sectional stiffness:

Young's modulus for reinforced concrete 40,000 MPa

Density 2600 kg/m3

The ultimate tensile strength 3 MPa

TRUCK MODEL

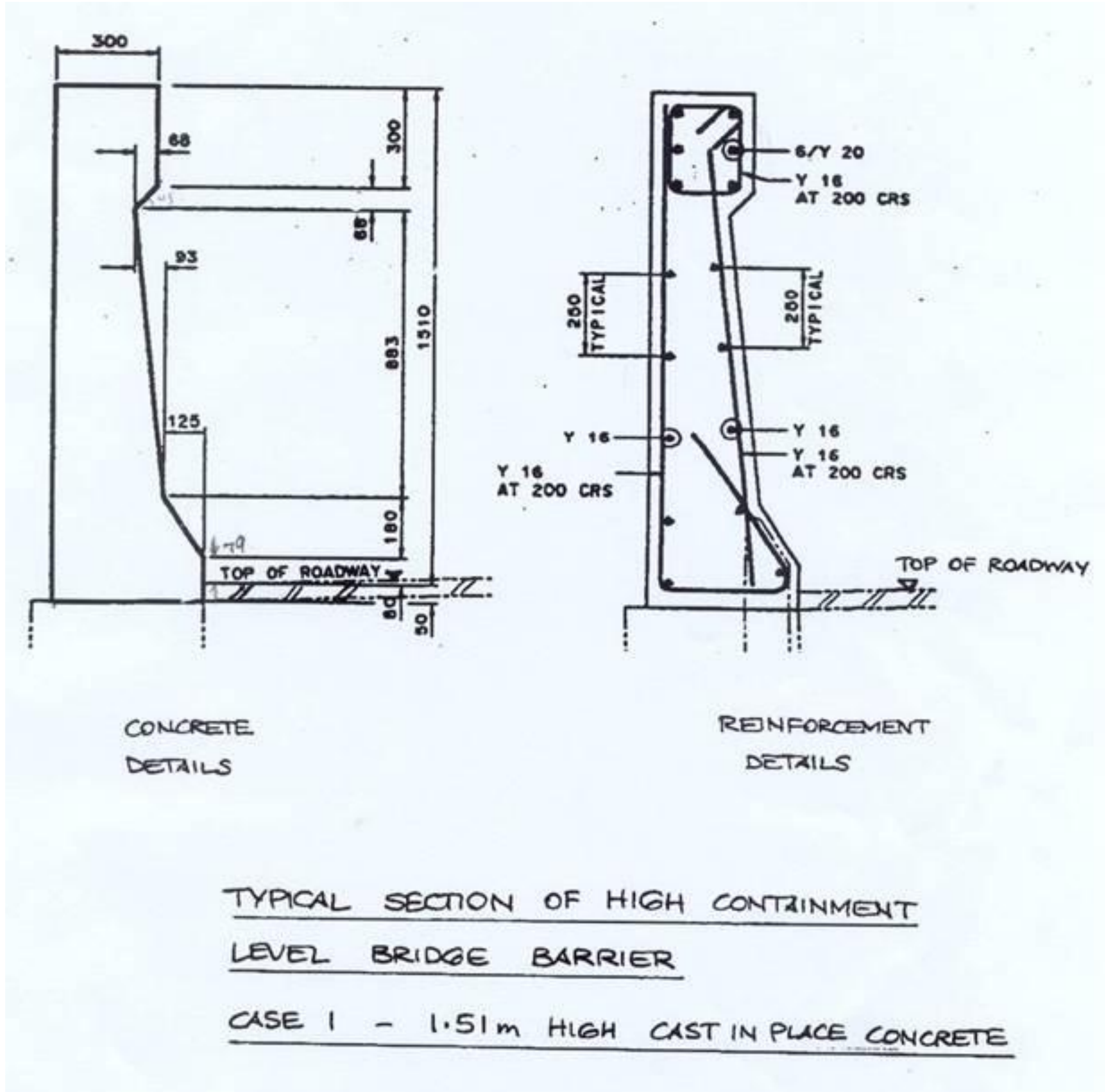
Truck modelled as a multibody system

It consisted of 14 bodies representing the prime mover, the trailer and 12 wheels

The connection between the prime mover and trailer was modelled as a revolution joint

BRIDGE RAILS

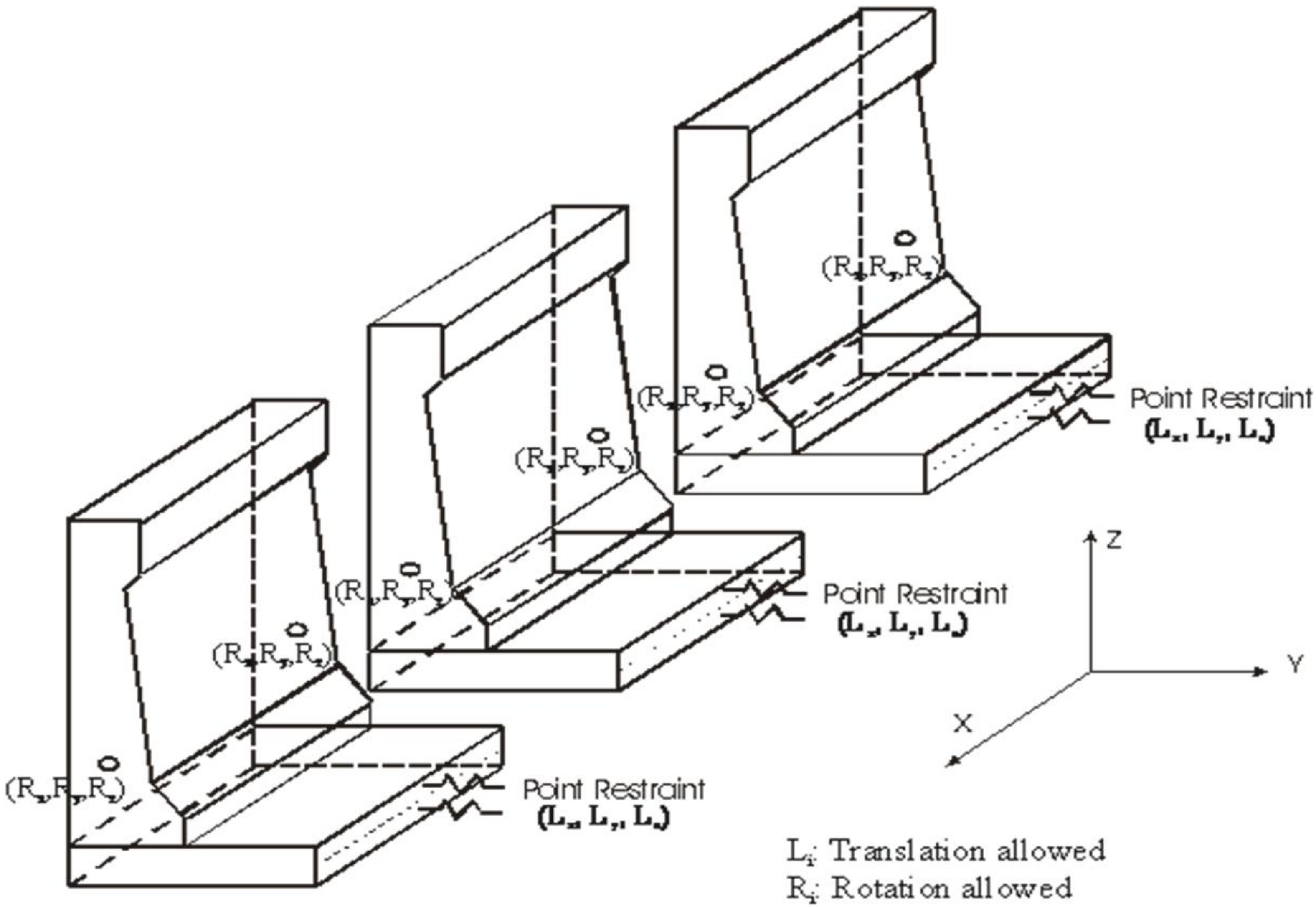
High Performance Safety Bridge Barrier Section



BRIDGE RAILS

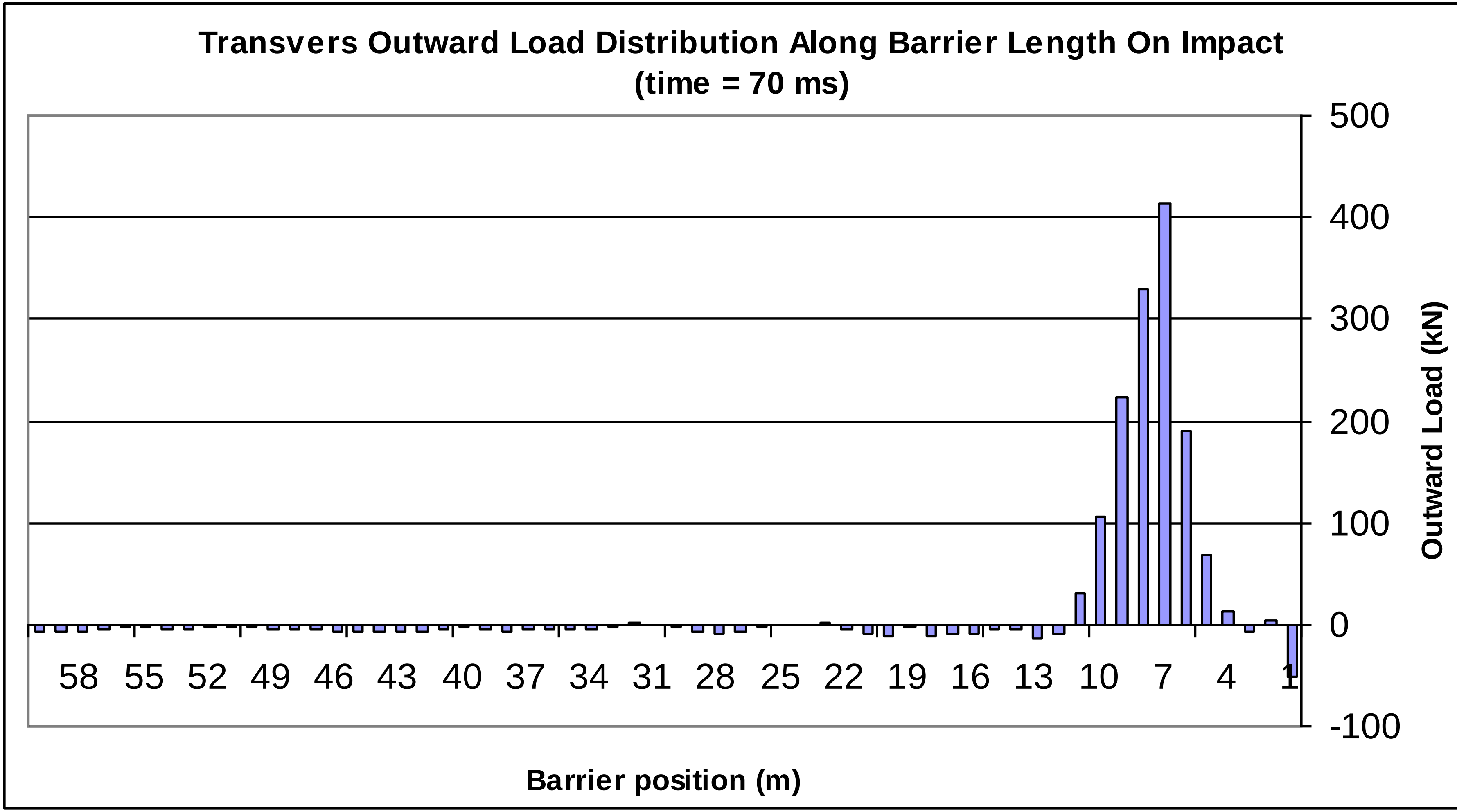
BRIDGE BARRIER MODEL

Multibody model, 60m length @1m each



SIMULATION RESULTS

- Base Model-44Tonne Truck Impact at 100 km/h and 15deg



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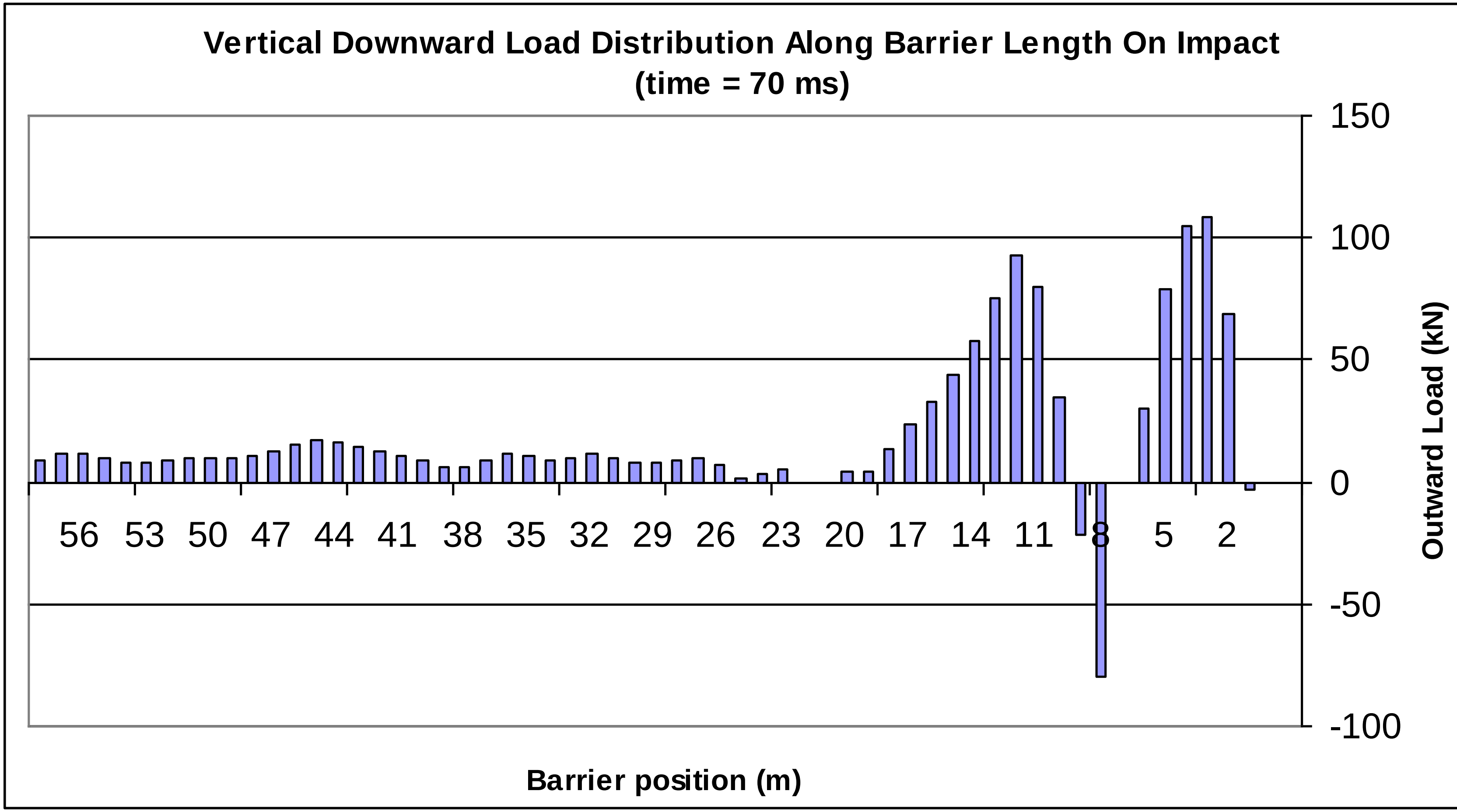
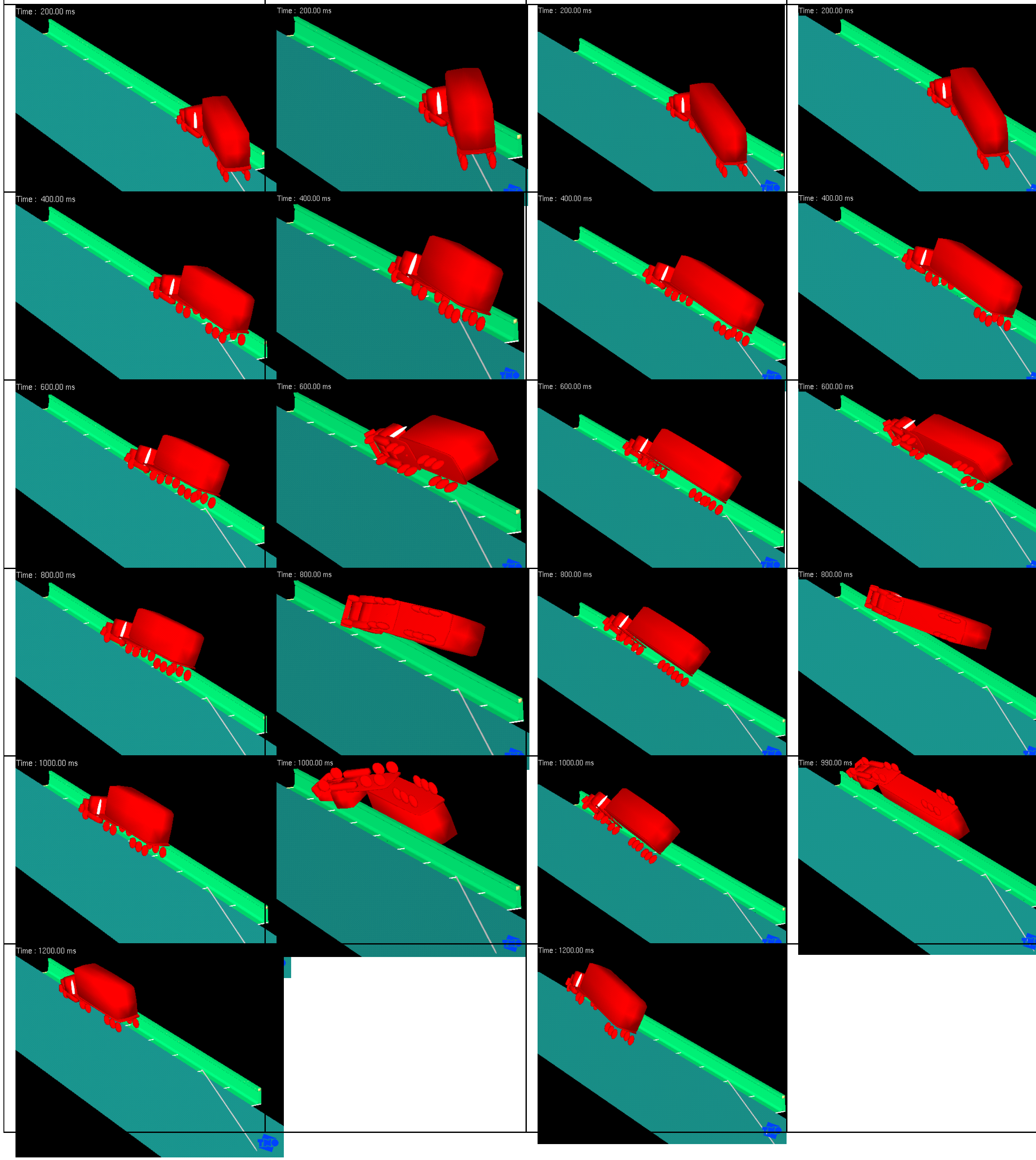


BRIDGE RAILS

SIMULATION RESULTS

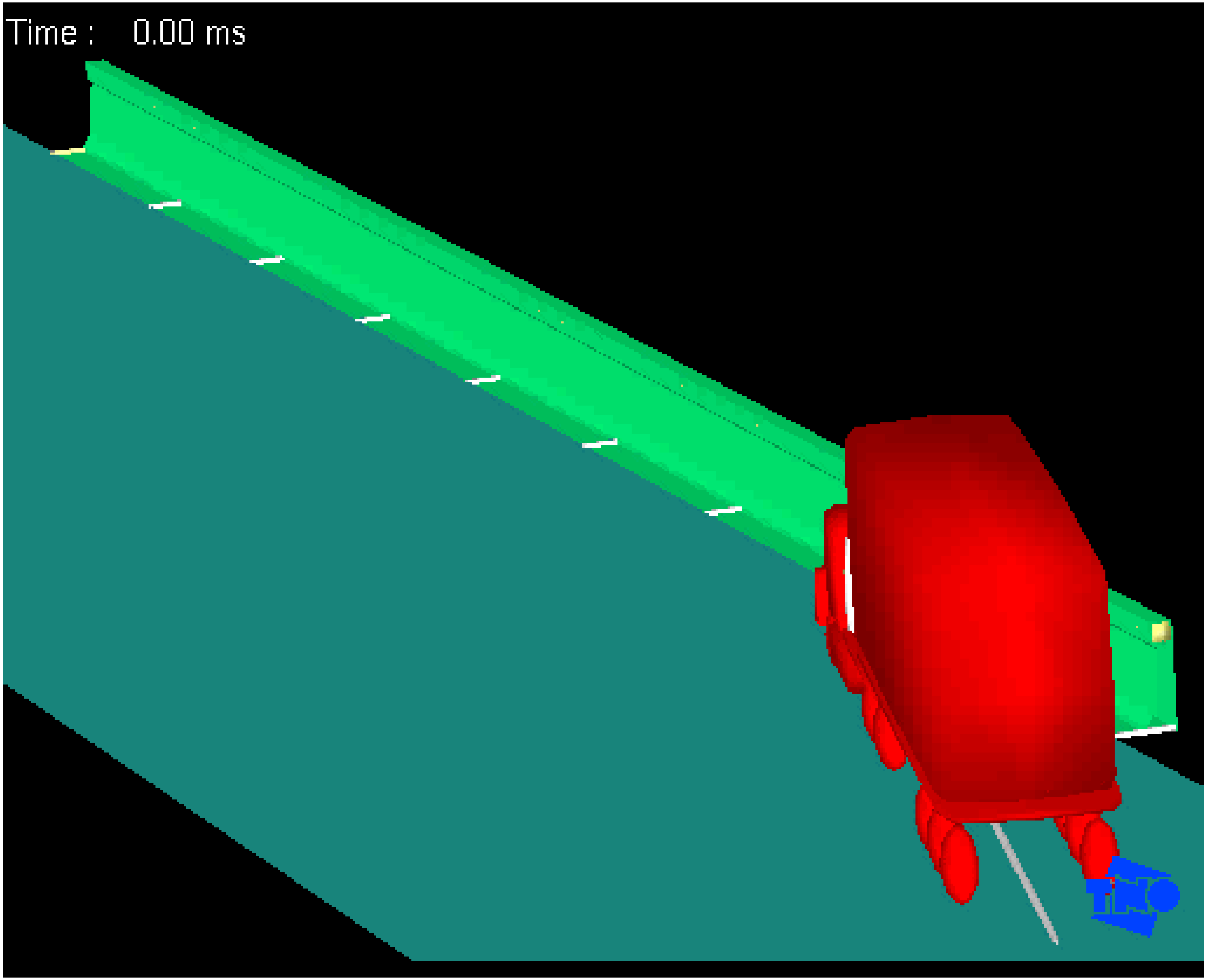
Kinematics

Truck01 @100kph/15deg	Truck02 @100kph/15deg	Truck03 @100kph/15deg	Truck04 @100kph/15deg



SIMULATION RESULTS

Kinematics (PM 12tons, 4.4m, 1.7 CoG; Trailer 33tons, 2.2m CoG)



BRIDGE RAILS

Actual Crash on Bolte Bridge Overpass Victoria (100 km/h at around 30 – 40 deg.)

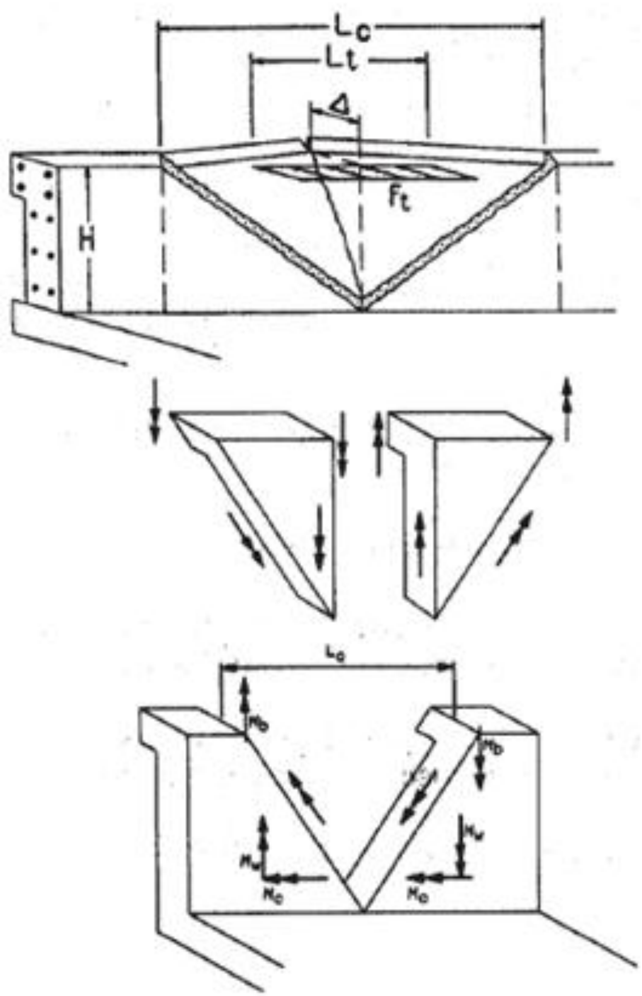
Empty truck (lighter)

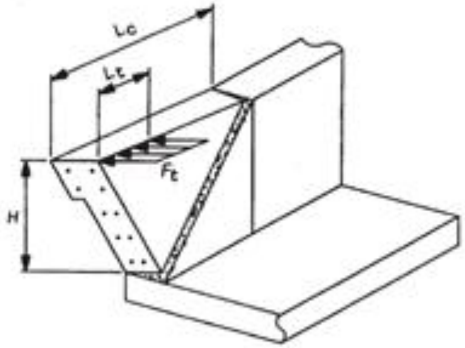
BRIDGE RAILS

Actual Crash on Bolte Bridge Overpass Victoria (100 km/h at around 30 – 40 deg.)

Empty truck (lighter)

Actual Crash on Bolte Bridge Overpass





Plastic failure yield line analysis commonly used for a concrete bridge barrier

AS5100.2-2004 Test Levels match AS/NZS3845:1999 and new standard based on MASH

specified in AS 5100.2-2004, Appendix A, Table A2 for Special Performance Barriers

Barrier Performance Level	Ultimate Transverse Outward Load (kN)	Ultimate Longitudinal or Transverse Inward Load (whichever larger) (kN)	Vehicle Contact Length for Transverse and Longitudinal Loads (m)	Ultimate Vertical Downward Load (kN)	Vehicle Contact Length for Vertical Loads (m)
Greater than Test Level 6* (44 t articulated van)	1000	330	2.5	380	15
Test Level 6 (36 t articulated tanker)	750	250	2.4	350	12
Computer Simulation Results (44 t articulated truck)	830	200	2.5	650	15

* Test Level 6 is the highest crash test severity level adopted in AS/NZS 3845:1999 which in turn is based on the US NCHRP 350 crash test procedures. The US has a set of six crash test levels, TL1 to TL6 developed as part of the National Cooperative Highway Research Program, published in Report 350 (NCHRP, 350, 1993). The crash test procedures required by AS/NZS 3845:1999 are based on the Federal Highway Administration (FHWA) NCHRP 350 (1993) report and Australian jurisdictions generally require compliance with NCHRP 350, or other equivalent procedures.

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AS5100.2-2004 Test Levels match AS/NZS3845:1999 and new standard based on MASH

Recommended design loads specified in AS 5100.2-2004, Table 11.2.2 and Appendix A, Table A1.

Barrier Performance Level	Ultimate Transverse Outward Load (kN)	Ultimate Longitudinal or Transverse Inward Load (whichever larger) (kN)	Vehicle Contact Length for Transverse and Longitudinal Loads (m)	Ultimate Vertical Downward Load (kN)	Vehicle Contact Length for Vertical Loads (m)
Medium (informative)	500	170	2.4	350	12
Regular (normative)	250	80	1.1	20	5.5
Low (normative)	125	40	1.1	20	5.5

Road Safety Simulations – now with LSDYNA

- ❑ Concrete bridge rail (Tractor-Trailer)
  - ➢ NCHRP-350 5-12 (82.7 km/h, 16.2 deg.)

Road Safety Simulations – now with LSDYNA

http://tractor-trailer.model.ntrci.org/download/download.cgi

National Transportation Research Center, Inc

FEM Models for Semitrailer Trucks

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Download models and reports

Here you can download the FEM models and reports for the project. The available FEM models are:

1. standalone models for tractors and trailers
2. crash scenario models

The standalone models for tractors and trailers have different wheelbases and lengths as needed for simulations of the tests. The standalone models are documented in the Model section of the web site. The line numbers in the files correspond to the lines shown in the documentation.

Crash scenario models include tractor, trailer, ballast, barrier and coupling between the tractor and the trailer. These models also can have large initiatialization files for accounting for gravity initialization.

Conclusions & Recommendations

- Interface Analysis and Design:
    - Bolte Bridge crash highlighted incompatibilities in the interface analysis and design of the bridge barrier–road-traffic system design..
    - To reduce impact loads, for example, trucks should be limited to a top speed of 60 km/h and kept to the left lane with no overtaking in the case of bridge barriers where only Low or Regular barriers have been installed. ……

Conclusions & Recommendations

- Interface Analysis and Design:
  - On bridges truck speed needs to be reduced significantly and the trucks kept close to the barrier to reduce the impact angle to less than 15 degrees if possible.
  - What speeds and what angles should be determined from further research simulating typical crashes, using current validated Finite Element programs that are now freely available via the internet.

Conclusions & Recommendations

- Interface Analysis and Design:
  - In Interface Design we explicitly recognise that failures in our road safety system occur because of breakdowns in system safety at various interfaces.
  - By paying due attention to interface design we open up our thinking to an increased range of countermeasures possibilities, and provide opportunities for improving road safety and reducing risk. ……

Questions?

DECADE OF ACTION FOR ROAD SAFETY 2011-2020

Together we can save lives.