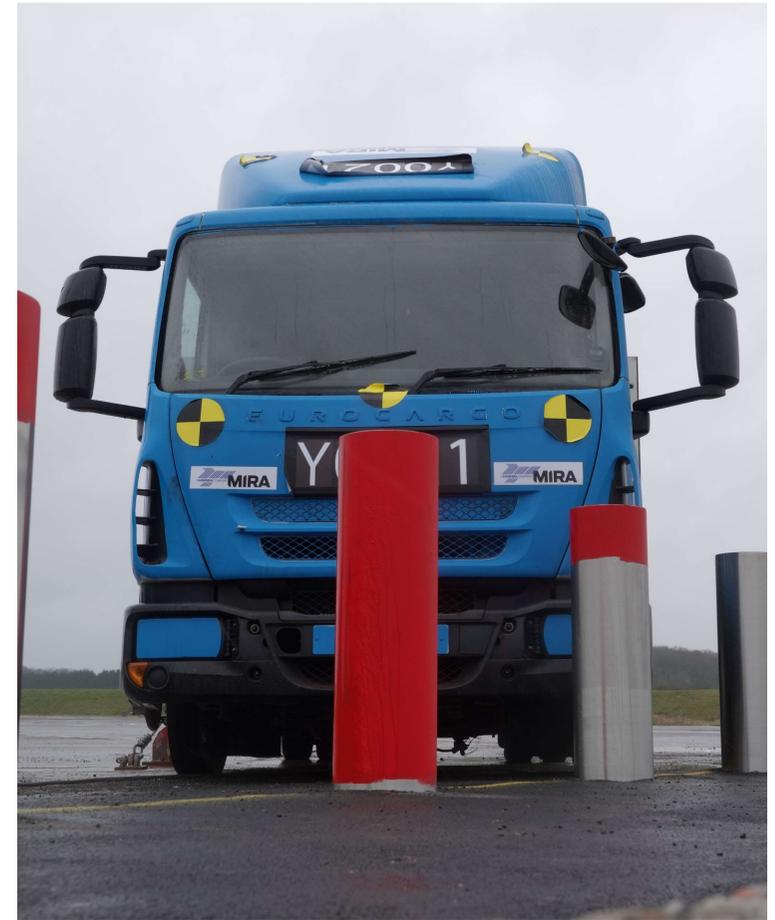


Simulation and Physical Testing of an Innovative ‘floating’ Shallow Mount Hostile Vehicle Barrier

Arup



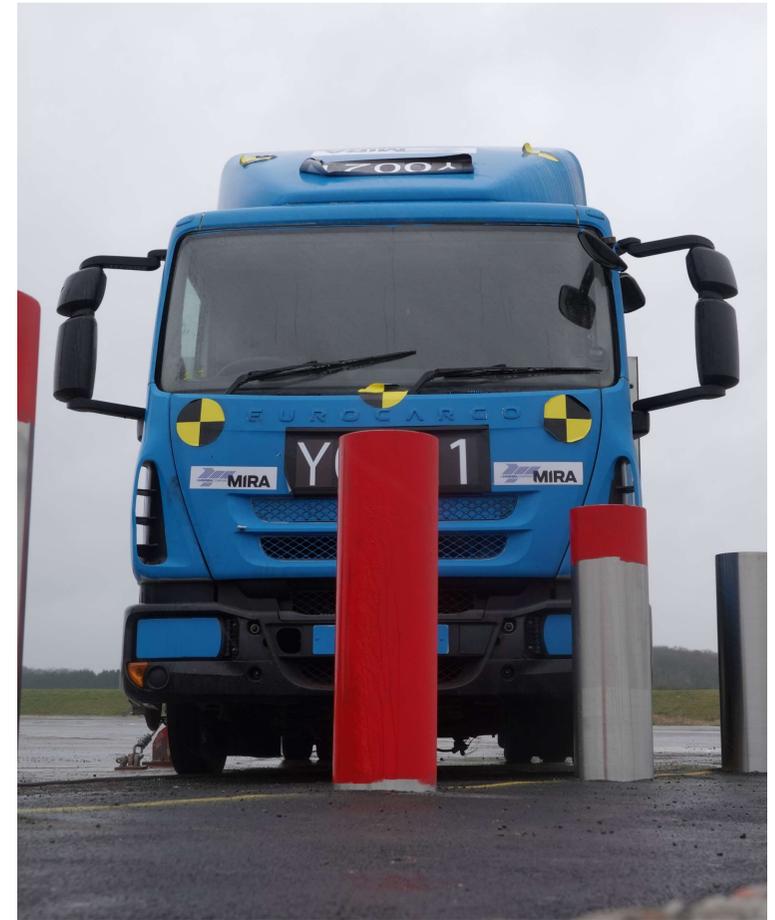
Dr Jon Farley, Arup Australia | Joel Smith, Arup Australia | Dr Dan Aggromito, Arup USA | Luke Pascoe, Arup Australia

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October 2022

Presentation Overview

- Vehicle as a Weapon attacks
- Test standards
- Vehicle barrier development history
- Problem statement: Protection of bridges
- Development of new product
- Physical testing results

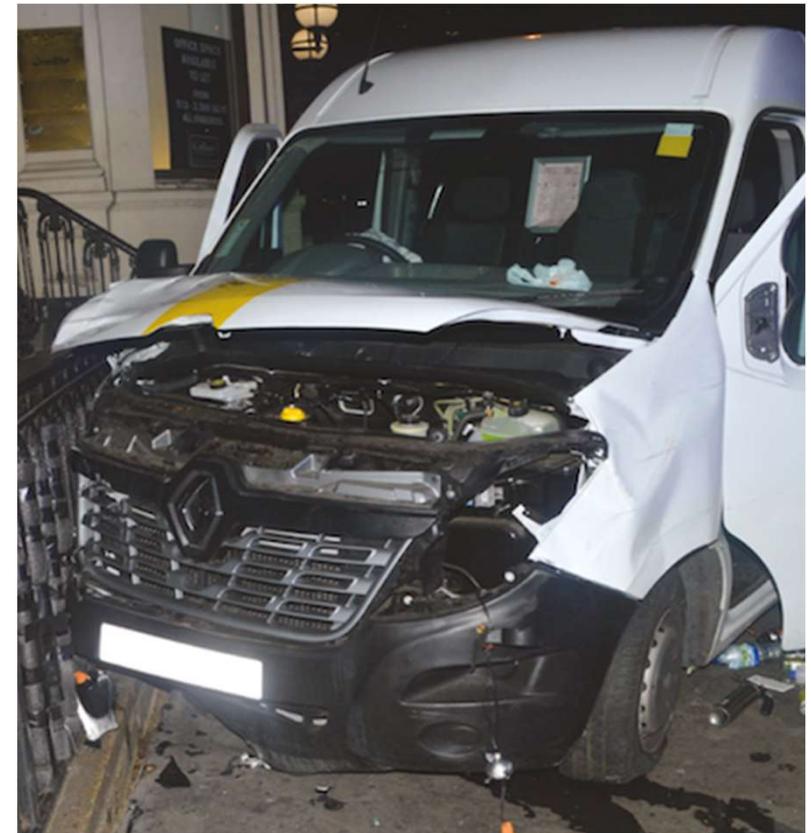


Vehicle As a Weapon

Vehicle As a Weapon attacks are a subset of vehicle borne threats – a threat where the use of a vehicle is the primary tool:

Three subsets of Vehicle Threats:

1. Kinetic delivery mechanism (VaW)
2. To deliver an explosive payload (VBIED)
3. To enable a layered attack



JUST TERROR TACTICS

TRUCK ATTACKS

The Ideal Vehicle

- Slightly Raised Chassis and Bumper
- Fast in Speed or Rate of Acceleration
- Double-Wheeled Load-Bearing Truck



How to Acquire a Vehicle

- Buying
- Renting
- Taking from a Kafir by Force or Deception
- "Borrowing" from a Kafir or Mujahid

Large in Size
Heavy in Weight

Ideal Targets

- Large Outdoor Festivals, Conventions, Celebrations, and Parades
- Pedestrian-Congested Streets (High/Main Streets)
- Outdoor Markets
- Outdoor Rallies



JUST TERROR TACTICS

Vehicle Attacks

Though being an essential part of modern life, very few actually comprehend the deadly and destructive capability of the motor vehicle and its capacity of mowing large numbers of casualties if used in a premeditated manner. This was expertly demonstrated in the attack launched by the brother Mahmud Labaniyya Rashedi who, while traveling at the speed of approximately 90 kilometers per hour, plowed his 17-ton load-bearing truck into a crowd celebrating Bastille Day in Nice, France, barreling through his attack the shoulders of 60-Corridor citizens and injuring 241 men.

The method of such an attack is that a vehicle is plowed at a high speed into a large congregation of people, smashing their bodies with the vehicle's strong outer frame, while advancing forward - crushing their heads, necks, and backs under the vehicle's wheels and chassis - and leaving behind a trail of carnage.

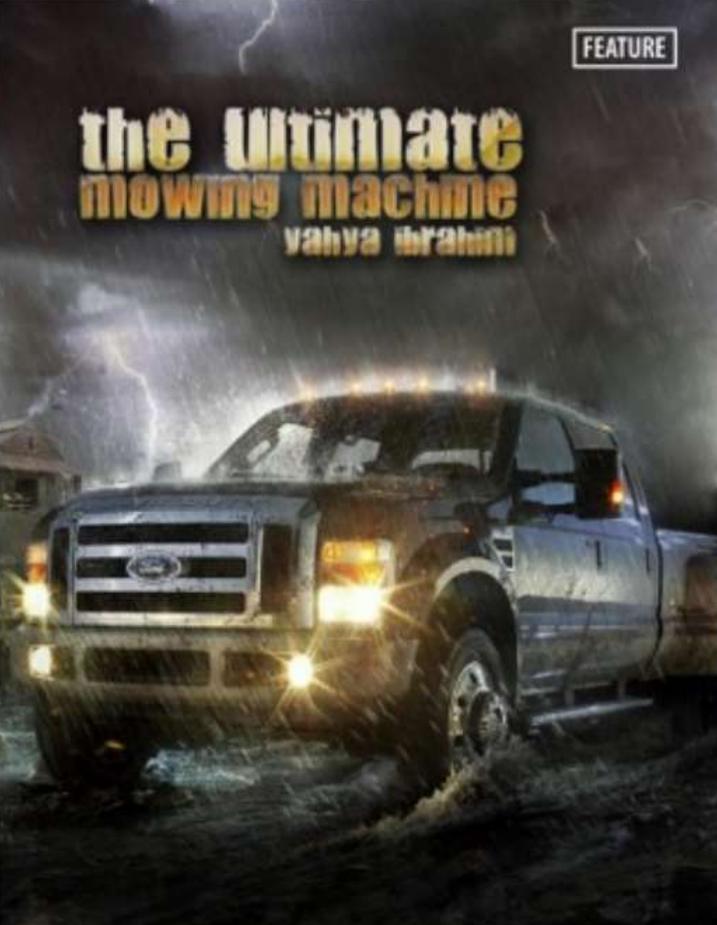
Such an attack may be so heinous a large kill count. It may be aimed at disrupting the financial stability of a specific nation. It may simply be aimed at intimidating the masses of Allah and depriving them of a peaceful sleep. Accordingly, in the execution of the attack mission, the mujahid must choose a method that best suits the operation at hand.



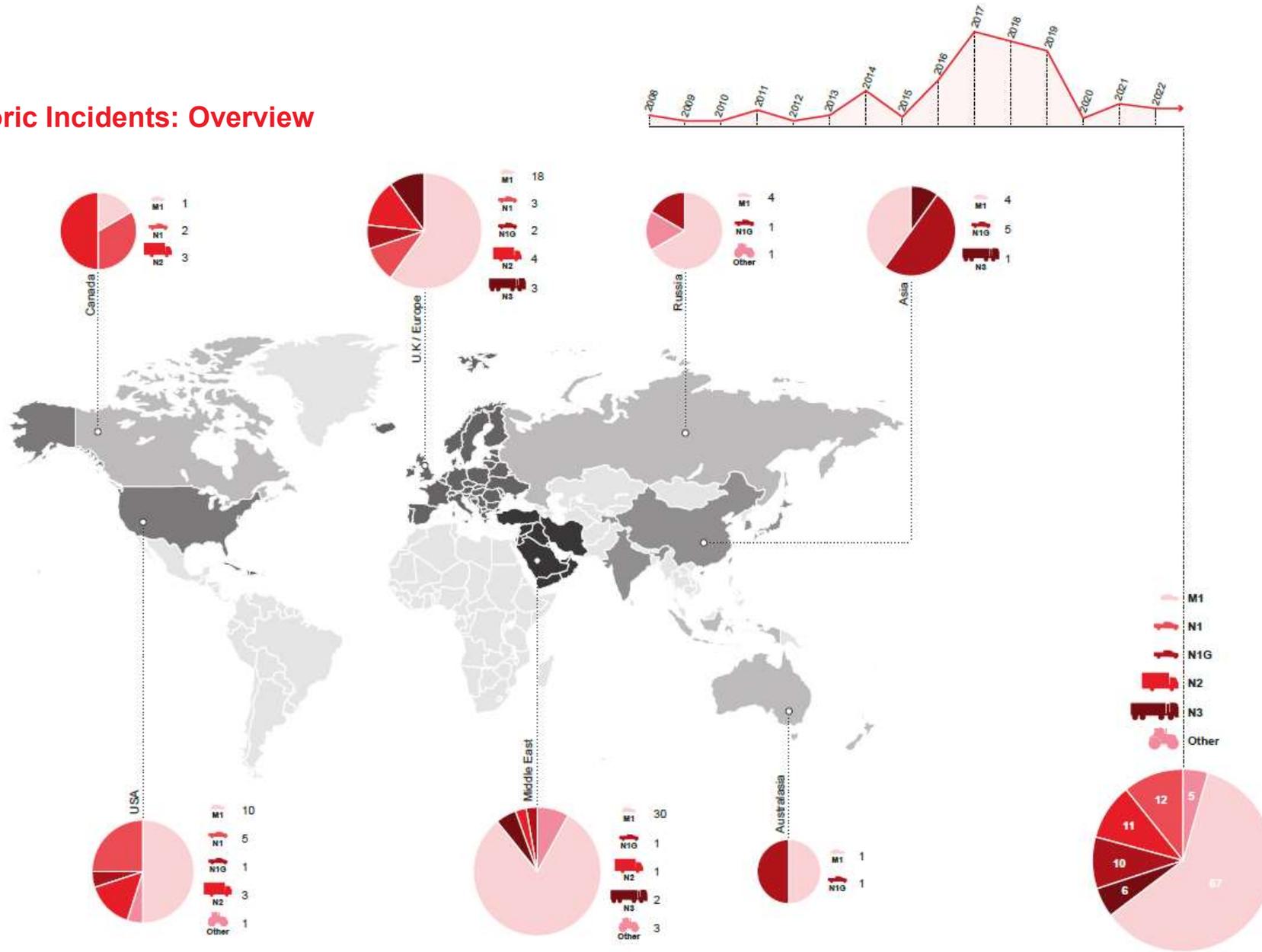
the Ultimate mowing machine

vahya ibrahimi

FEATURE



Historic Incidents: Overview



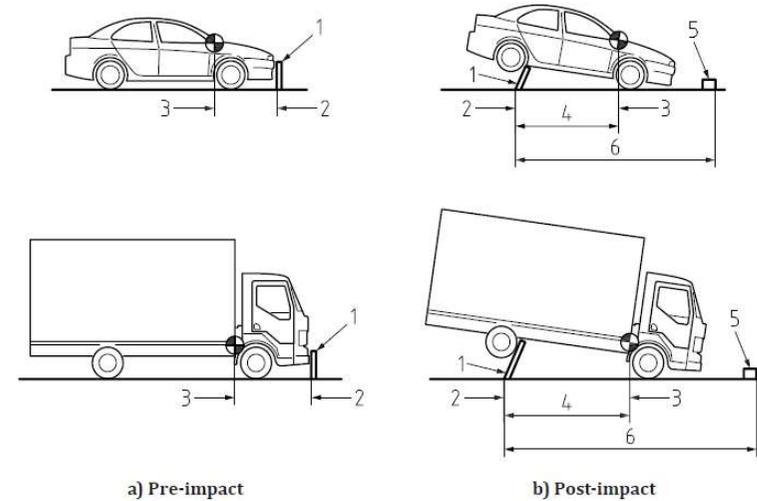
Testing Standards

Three Primary Standards:

- IWA 14-1 – Europe
- PAS68 – UK
- ASTM F2656 – USA

Key Features:

- Physical vehicle test (roadworthy)
- Impact at set speeds (30mph, 40mph 50mph)
- Specific vehicle classes and parameters
- Data measurement on post impact penetration
- Tests remain expensive – 50,000GBP



- Key
- 1 VSB (e.g. bollard)
 - 2 VSB datum line
 - 3 vehicle datum point
 - 4 vehicle penetration distance
 - 5 major debris
 - 6 major debris distance

Figure 6 — Vehicle penetration distance and major debris distance – Side view

Table 1 — Test vehicle specification

Vehicle classification	M1	N1G	N1	N2A	N2B	N3C	N3D	N3E (1)		N3F (1)
								3-axle rigid	4-axle rigid	
Type of test vehicle (A)	Car	4x4 crew cab pick-up	Day cab vehicles (B)							
			Flat bed (D)	2-axle rigid	2-axle rigid	2-axle rigid	2-axle rigid	3-axle rigid	4-axle rigid	
Test vehicle mass (kg)	1 500	2 500	3 500		7 200		12 000	24 000	30 000	
Minimum unladen mass (kg)	1 235	1 700	1 675	3 575	5 200	6 100	6 200	9 750	10 500	
Maximum ballast (kg)(C)	265	800	1 825	3 625	2 000	1 100	5 800	14 250	19 500	
Maximum secured	265	800	1 825	3 625	2 000	1 100	5 800	1 000	1 000	
Maximum unsecured	50	50	75	100	100	100	100	14 250	19 500	
Tolerance (kg)	±50	±50	±50	±50	±50	±50	±50	±50	±50	
Test vehicle mass (kg)	1 500	2 500	3 500	7 200	7 200	7 200	12 000	24 000	30 000	
Tolerance (kg) (D)	±75	±75	±100	±400	±400	±400	±400	±400	±400	
Vehicle length (mm)(E)	4 500	5 200	6 200	7 610	8 340	9 560	8 900	7 640	9 600	
Tolerance (mm)	±360	±600	±380	±1 520	±1 670	±1 910	±1 900	±1 200	±1 000	
Vehicle width (mm)(F)	1 760	1 850	2 100	2 400	2 400	2 500	2 500	2 400	2 500	
Tolerance (mm)	±150	±200	±175	±200	±200	±225	±225	±200	±225	
Wheel base (mm)(G)	2 700	3 200	3 805	4 310	5 275	5 910	5 450	5 600	6 800	
Tolerance (mm)	±540	±500	±710	±830	±1 100	±1 250	±1 250	±500	±500	
Height from ground to lowest edge of the chassis rail at the front (mm)	n/a	435	440	515	630	750	845	750	810	
Tolerance (mm)		±75	±120	±175	±175	±200	±225	±200	±200	

Vehicle Barriers Design

- Historic development: lots of steel and concrete
 - Very stiff – vehicle does the deforming
 - Unyielding (elastic methods)
 - Deep foundations to transfer load to ground
- Recently: lighter, shallower, operable
 - Growing need for retrofit (protection of existing infrastructure)
 - Complex ground conditions (services, structures)
 - Vehicle barrier ‘absorbs’ impact



© Heald



© GPS

Problem Statement – Bridge footpath protection

- In 2017 London Bridge attacks occurred
- Bridges were identified as a higher risk (threat deflection)
- Historic structures (+100 years)
- Limited load capacity
- Very limited foundation depths
- Movement / expansion joints

Very few products exist in the market

London Bridge van & knife attack June 3 2017



1 10.07pm
Van driven by attackers hits **Xavier Thomas**, who falls into River Thames. His body is found three days later, two miles downstream

2 **Christine Archibald** struck and killed by van

3 Van crashes into railings outside Barrowboy & Banker pub. Attackers stab and kill **James McMullan** and **Sara Zelenak**

4 Attackers enter courtyard in Borough Market, stabbing **Sebastien Belanger** and **Alexandre Pigeard**. Belanger dies on the scene

5 Pigeard dies outside Southwark Cathedral. **Kirsty Boden** stabbed while trying to help Mr Pigeard. She dies later that night

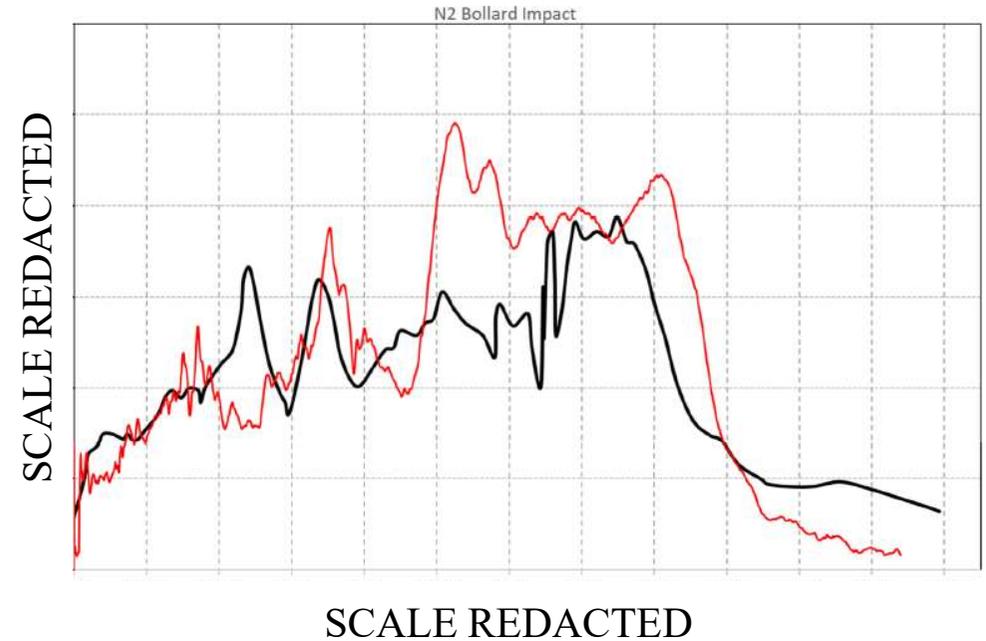
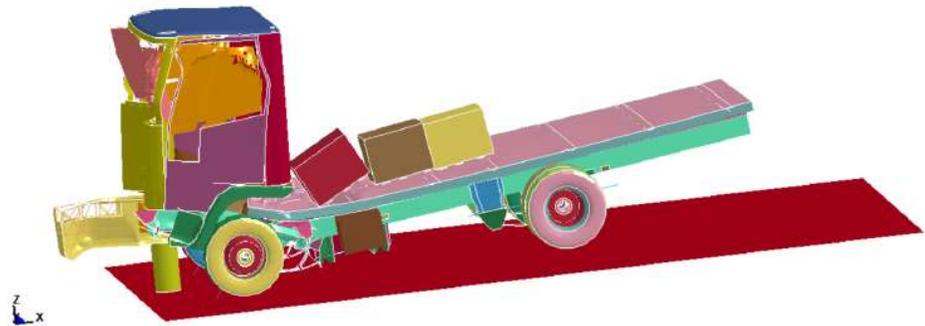
6 **Ignacio Echeverria** knifed on Borough High Street trying to fight off attackers. He dies later while being carried by a doctor across London Bridge

7 10.16pm
Police surround attackers outside Wheatsheaf pub, shooting them dead

PA graphic

Vehicle Model Validation

N2A Vehicle Validation



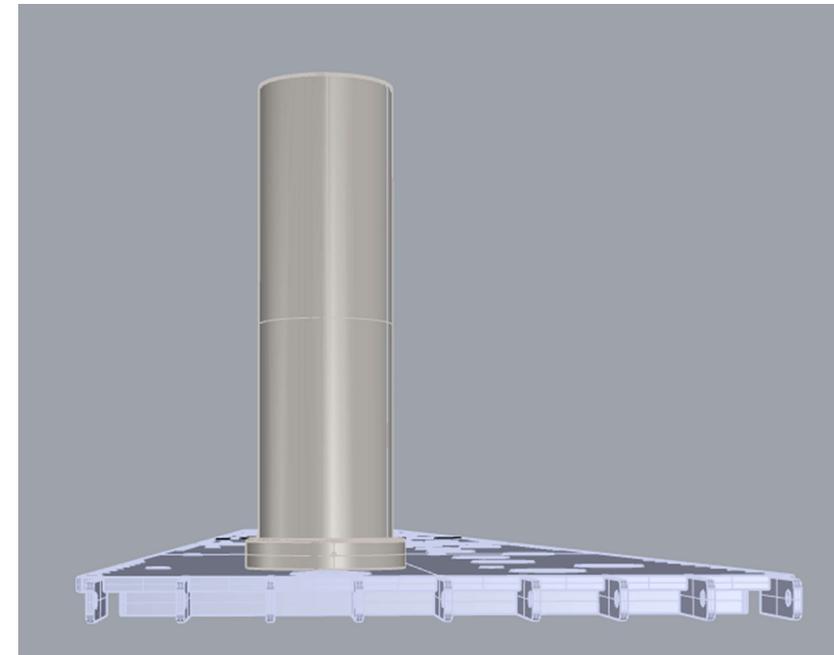
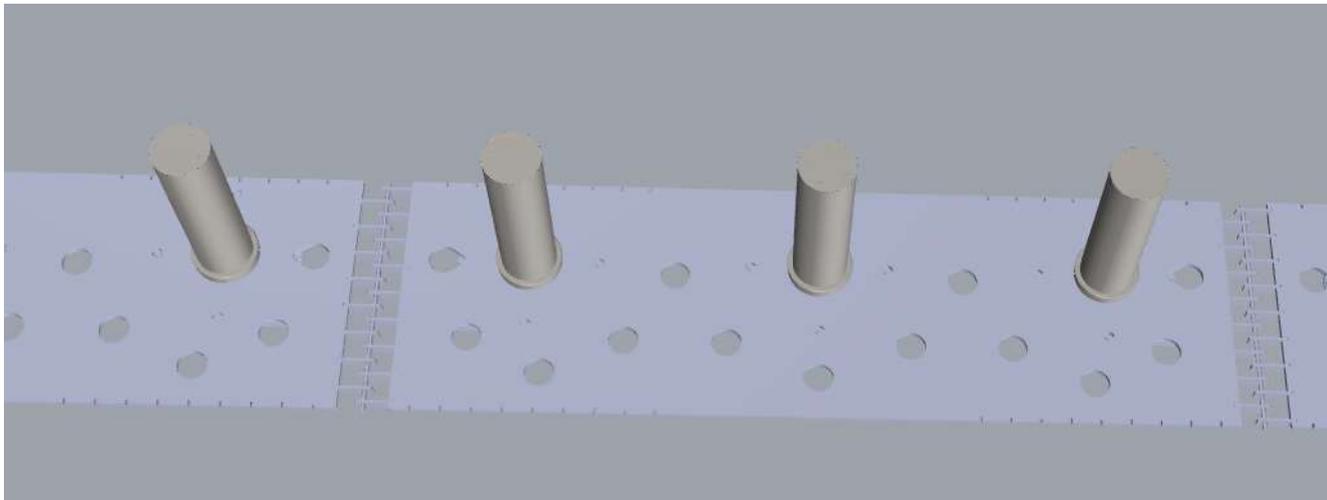
Typical Values at 48kmh impact:

Peak Force: 1250kN

Impact Duration: 180ms

Impulse: 100kNs

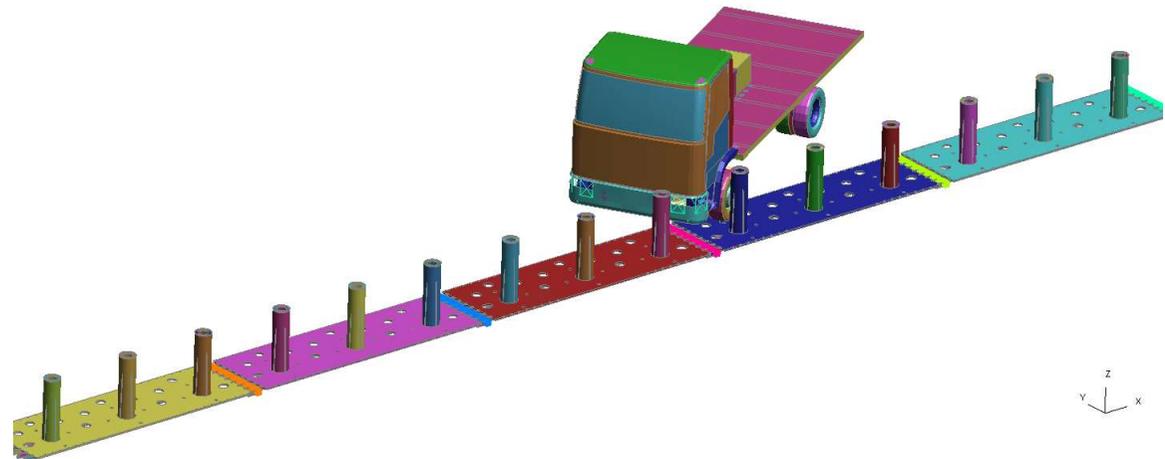
Developed Solution



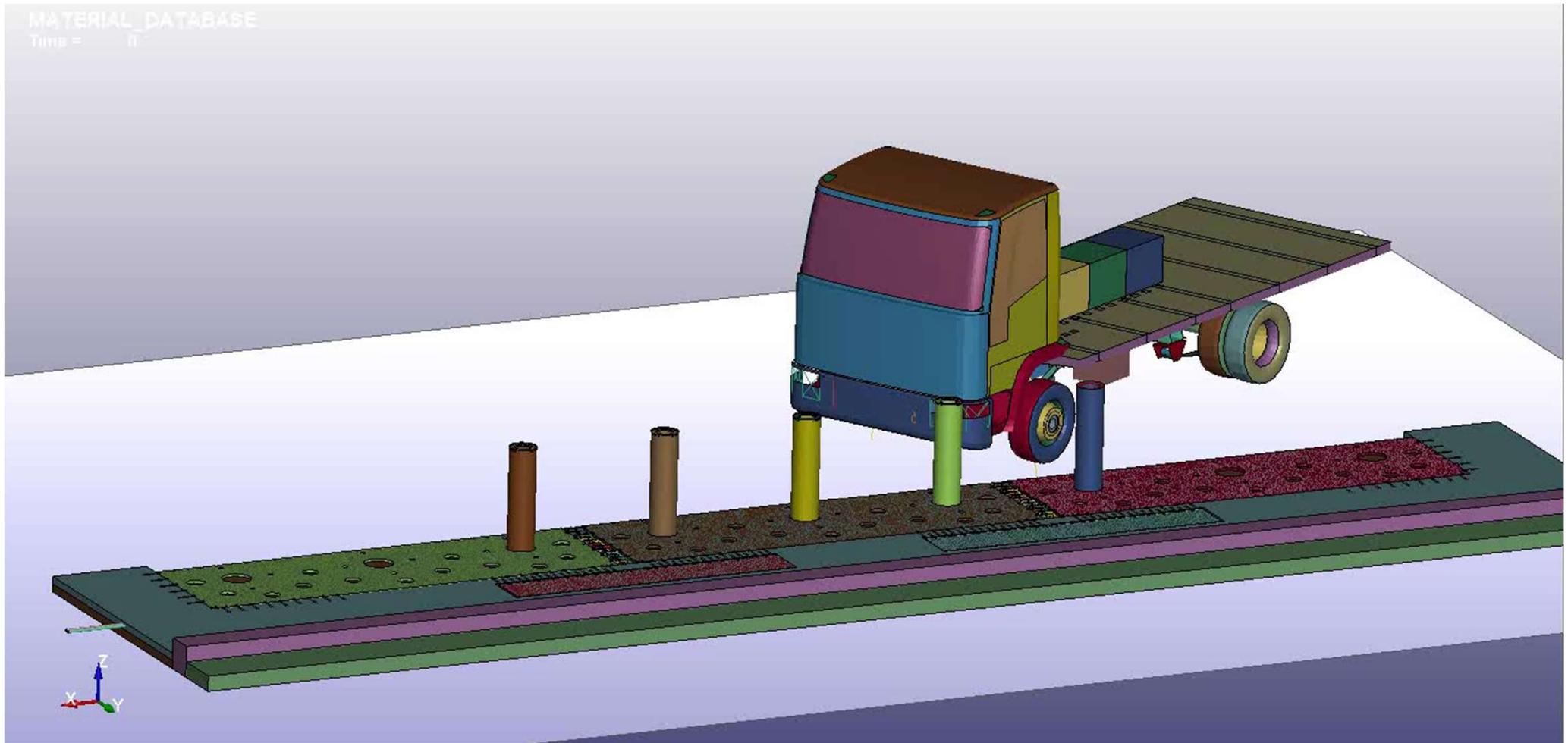
- Linear array of bollards connected through base plate
- Bollards designed with internal absorption structure
- Base plates connected via tabs and reo-bar

Barrier Simulation

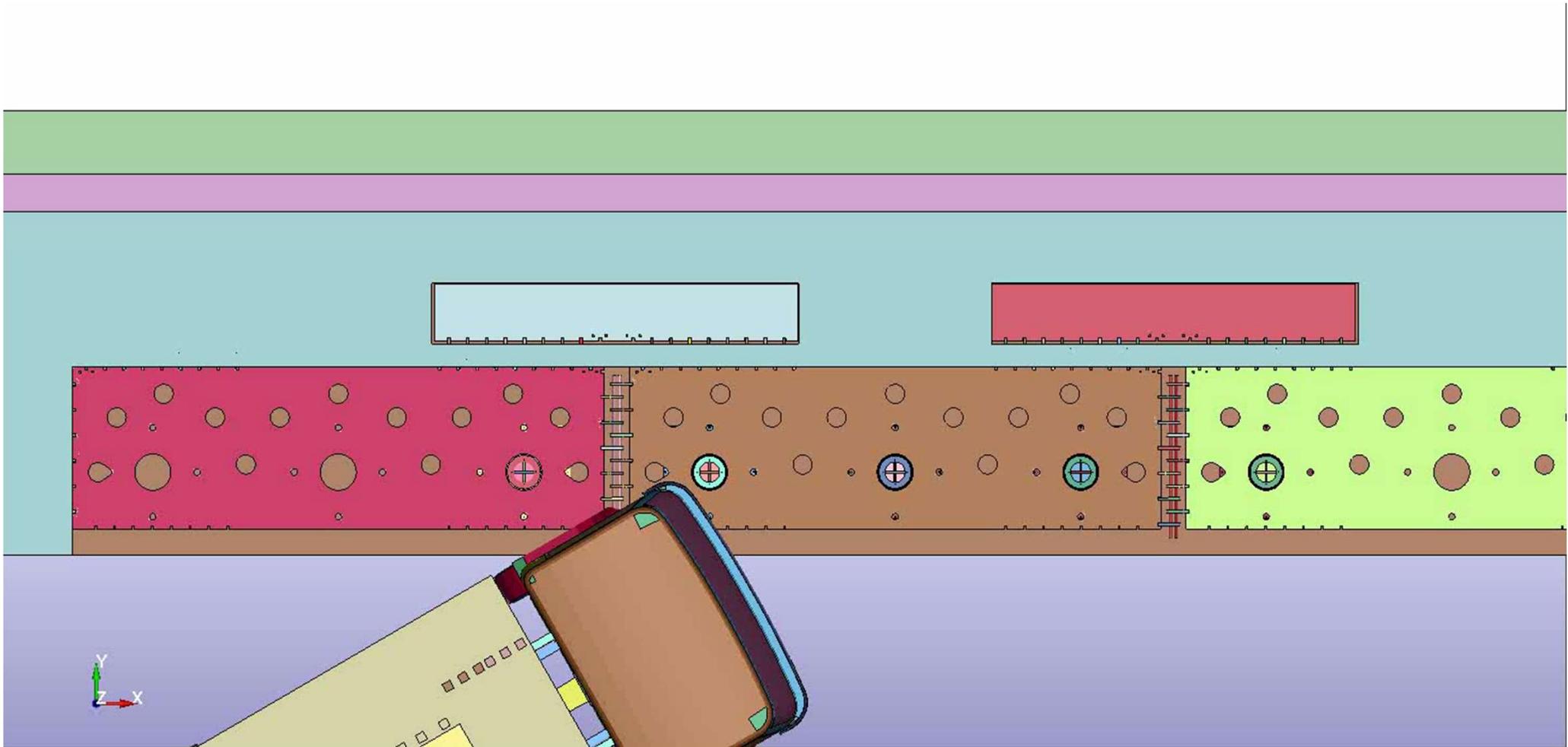
- Linear Bollard Setup:
 - 5 x Base Plate Assembly
 - 15 x Bollard Assembly
 - 15 x Internal Stiffener Assembly
- N2 Vehicle:
 - Speed: 48 km/hr
 - Mass: 7.5 tonne
 - Angle: 30 degrees from x-axis (about z-axis)



Barrier Simulation



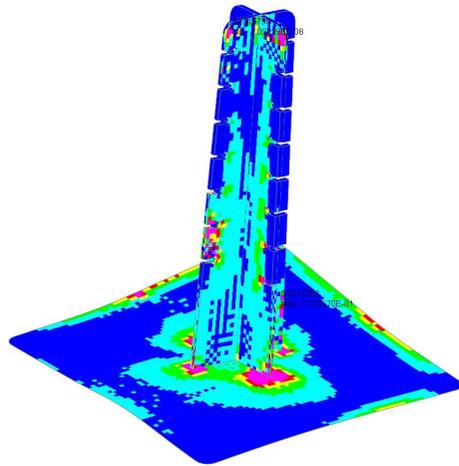
Barrier Simulation



Barrier Simulation

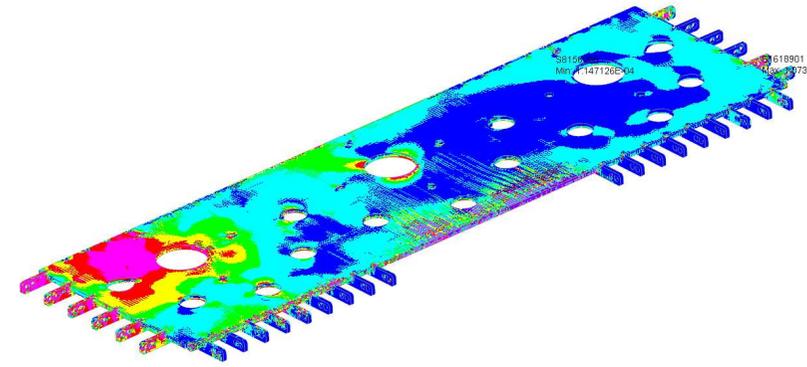


D3PLOT: MATERIAL_DATABASE
1: Max S2019783: 7.273670E-01, Min S2015790: 1.022290E-08



ARUP

D3PLOT: MATERIAL_DATABASE
1: Max S1618901: 1.073323E+00, Min S8156055: 1.147126E-04



MAX Princ Stress
(Mid surface)
(Maximum Value)

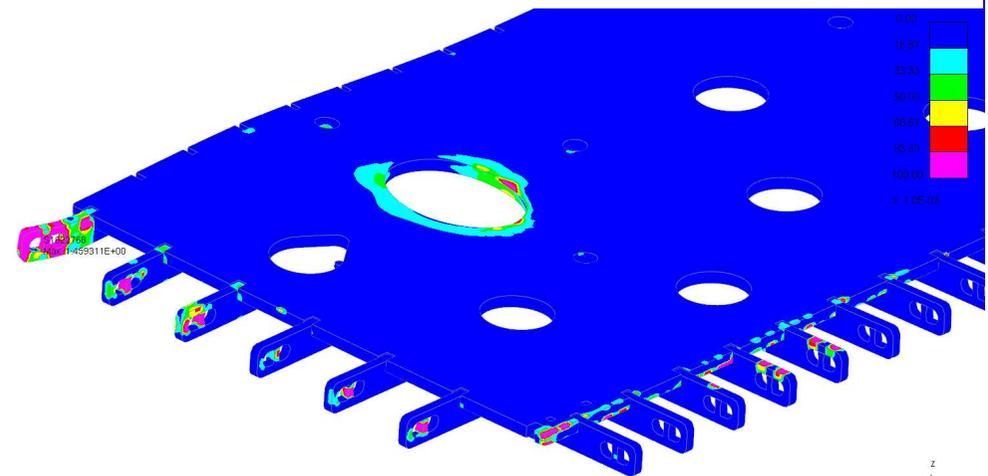
0.00
83.33
166.67
250.00
333.33
416.67
500.00

x 1.0E-03

MAX Princ Stress
(Mid surface)
(Abs Max Value)

0.00
83.33
166.67
250.00
333.33
416.67
500.00

x 1.0E-03



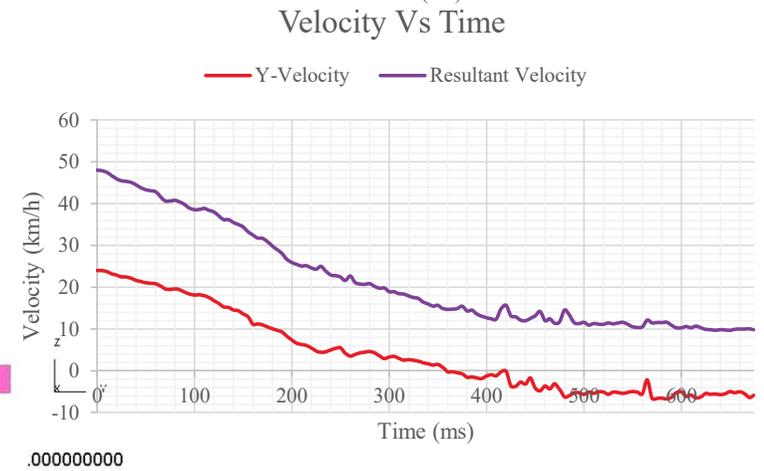
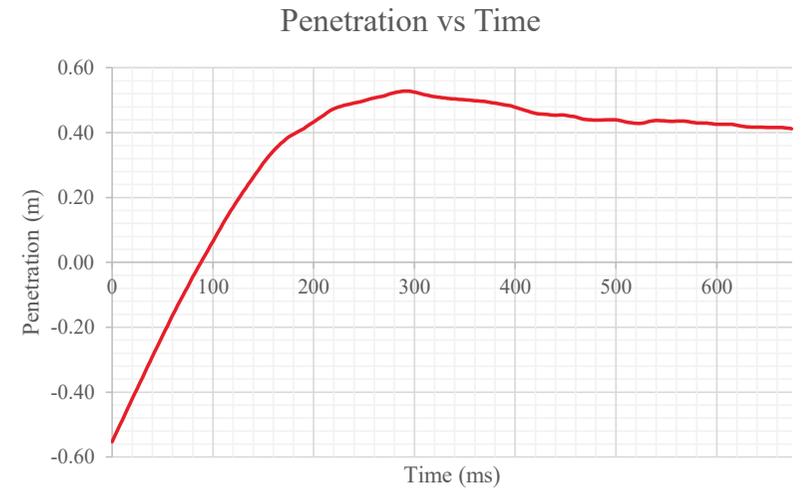
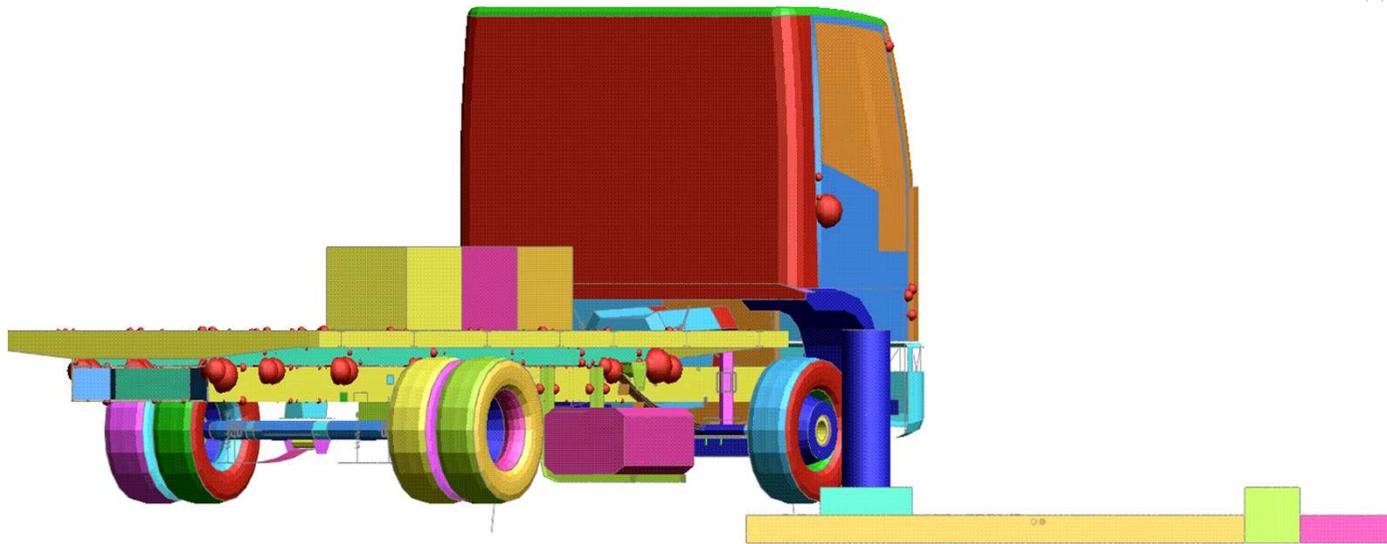
MAX Princ Stress
(Mid surface)
(Maximum Value)

0.00
83.33
166.67
250.00
333.33
416.67
500.00

x 1.0E-03

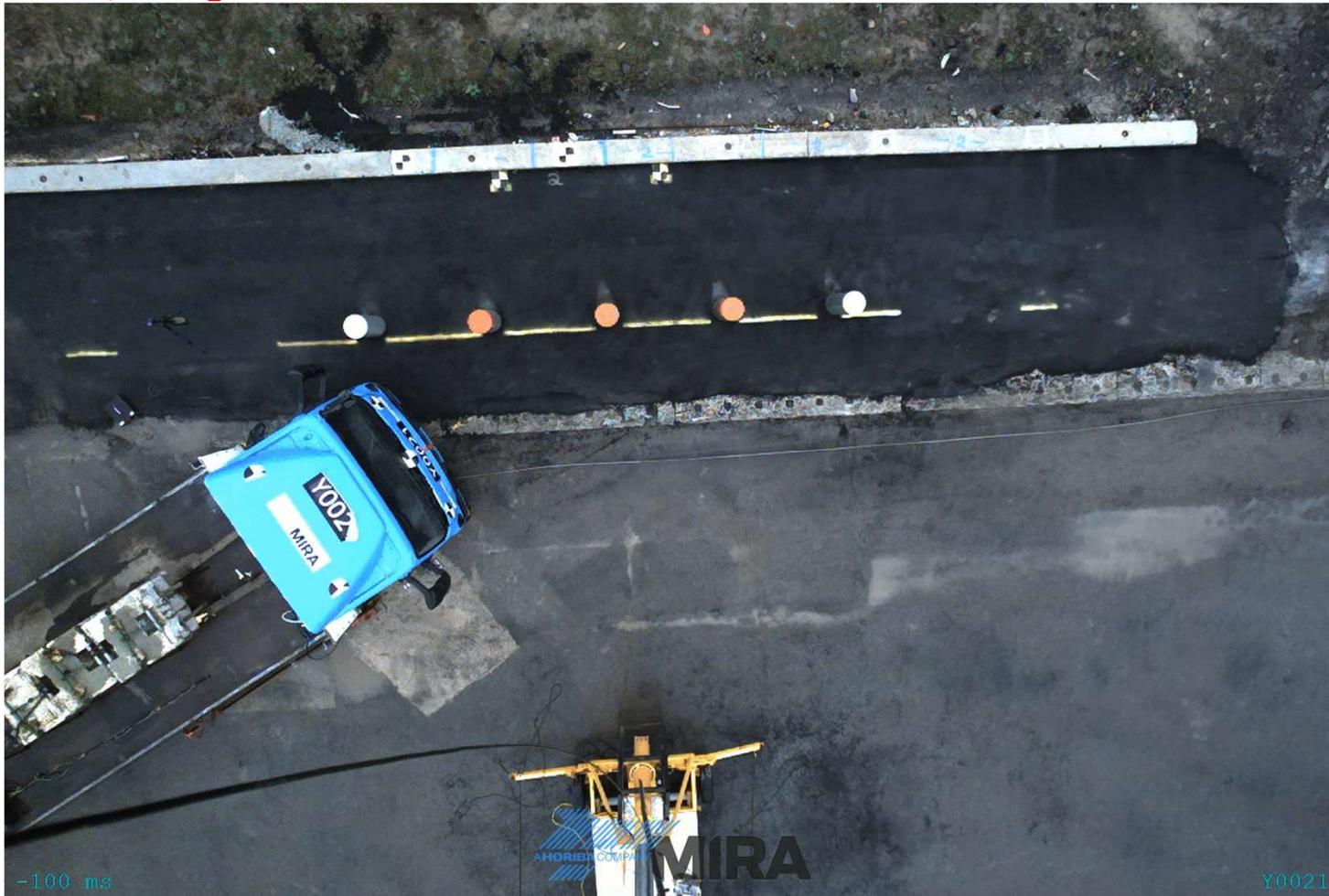
Barrier Simulation

D3PLOT: MATERIAL_DATABASE



Physical test results – Vehicle Bollards

IWA 14-1 | N2A, 48kmh, 30degs



Physical test results – Vehicle Bollards

IWA 14-1 | N2A, 48kmh, 30degs



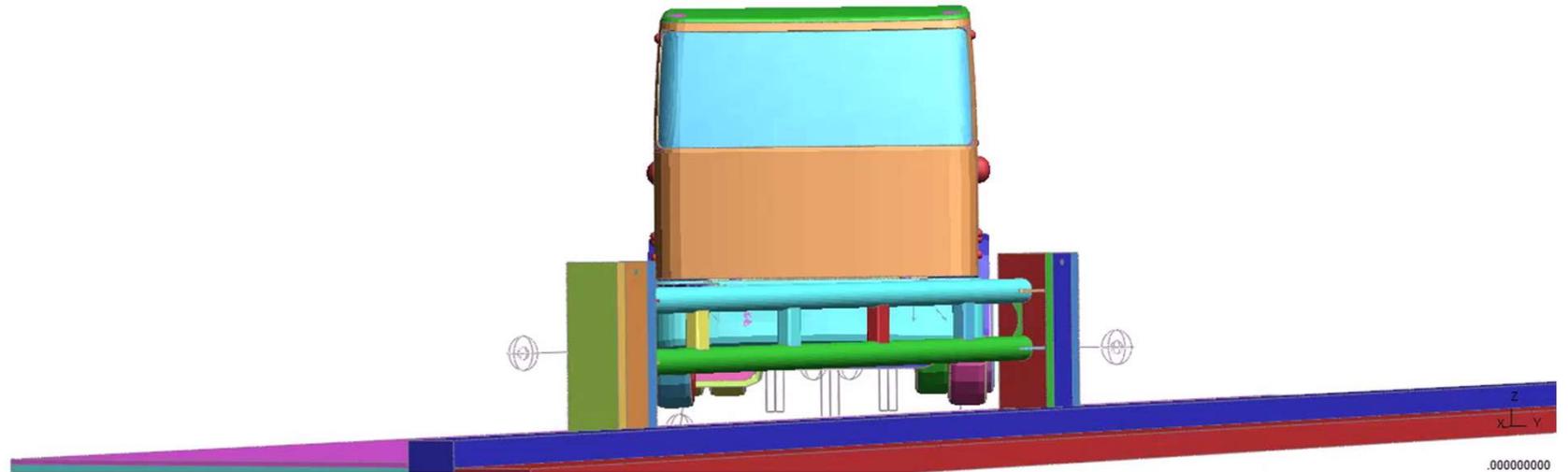
Physical test results – Vehicle Bollards

IWA 14-1 | N2A, 48kmh, 30degs



Test Results – Vehicle Barrier

D3PLOT: CPNI BOLLARD - GATE R005



Lessons Learnt

- Simulation work enabled both products to achieve a test pass first time
- Validation set remains very small!
- Global model response is reasonable
- BUT detail lacking for systems response (cab, suspension failure)
- Product sales numbers are small, development budgets are tight



Thanks

Quick thankyou to collaborators:

Nigel Buckley – AVS Elli (Designer & Manufacturer)

Dr Dan Aggromito – Arup San Francisco

Joel Smith – Arup Melbourne

Luke Pascoe – Arup Melbourne

ARUP