WP # 2004-4

Computerised simulation of car and 4WD impacts into alternative median barrier profiles using the DyMesh collision algorithm within the HVE simulation environment

Grant Johnston, Iwan Parry
TRL Limited

Clint Bradley
Grant Johnston Consulting Engineers Pty Limited

ABSTRACT

This paper presents a cost effective alternative to repetitive finite element modelling of vehicle to barrier impacts using Engineering Dynamics Corporation's HVE 3D Simulation system. Whilst it is not claimed this system is suitable for full NCHRP compliance testing it was found to provide a cost effective and fast alternative for preliminary testing of alternative barrier profiles. A pre-beta release of the DyMesh Collision Algorithm was used to simulate a series of vehicle to barrier impacts for a blackspot location in Sydney's north. An alternative barrier profile had to be considered due to road width limitations preventing the footprint of a standard "New Jersey" profile barrier. A further concern was the barrier height preventing vision of lead vehicle brake lights through the tight reverse curves at this location. As a result of this analysis a recommendation was made to install a barrier of the British VCB profile.

INTRODUCTION

This paper presents the results of investigations undertaken on behalf of the New South Wales RTA into identification and preliminary simulation testing of suitable alternative barrier systems to be installed along the median island of Spit Road between Medusa Street and Pearl Bay Road, Mosman. The software used was the HVE 3D Simulation system produced by Engineering Dynamics Corporation. It is not suggested this software provides a fully validated simulation suitable for NCHRP certification. It does however provide a rapid and cost effective method to run different vehicle types into different barrier profiles and achieve indicative dynamic and inertial responses. Following this initial testing selected finite element simulations or full scale testing can be undertaken. Following the simulations undertaken in this report it was intended to run a full scale test and if necessary NCHRP certification testing.

The reason an alternative barrier profile was required was that the footprint of current barrier designs could not be accommodated within the existing road reserve without major utility relocation. The prevalence of articulated buses on this section of road prevented any further narrowing of the existing lane widths. A concern was also raised with respect to existing median barrier heights blocking the view of a forward vehicle's brake lights through the outside radius of the reverse curves. This paper concentrates on the methodology used in the completion of this project rather than the actual results.

This location has raised community concerns with respect to road safety following a fatal head-on collision and a moderate historical pattern of crashes. Of particular concern to the community is the frequency of cross median type crashes on the reverse curves adjacent to Upper Spit Road and Ida Avenue.

A preliminary data analysis was undertaken which included crash data for this section of roadway between 1995 and the third quarter of 2000, summary speed data from counting stations either side of the study area and a survey of the actual mounting height of vehicle brake lights. A review of the our own crash database was also conducted to identify crashes investigated for the purpose of litigation along this section of roadway. Three such crashes were identified including the previously mentioned fatal crash. Whilst this provided only a small sample it did provide much more detail relating to each crash than the form data from the RTA database. This data was particularly important for the fatal crash as it gave additional information relating to issues such as the precise types of vehicles involved and the actual incident angle of the errant vehicle as it crossed the centre median.

An international literature search was conducted to identify any other similar type treatments which may have been trialed, tested or implemented internationally. The significant part of this literature search was conducted at TRL (Transport Research Laboratories) in the United Kingdom, as part of an international study tour by Grant Johnston in May 2001.

PRELIMINARY DATA ANALYSIS

RTA Crash Data

Data was provided from the RTA database for the period January 1995 to December 2000 for the section of Spit Road between Bickel Road and Spit Bridge. This was slightly longer than the specific area of the study brief. As a first pass this data was plotted by type and severity onto a transparent overlay with the Central Mapping Authority 1:2000 Orthophoto as a base plan.

From this data two significant clusters of cross median crashes were identified. The first of these appeared to involve northbound (downhill) vehicles failing to negotiate the first left horizontal curve adjacent to Upper Spit Road, crossing the central median where a total of 8 head-on crashes were recorded, including 4 injury and 0 fatal crashes. The second major cluster is for southbound (uphill) vehicles failing to negotiate the first uphill left horizontal curve adjacent to Ida Avenue, crossing the median where a further 9 head-on crashes were recorded with 4 injury and 1 fatal crashes. Other small isolated sets of cross median crashes including single vehicle loss of control to the opposite side of the road were also recorded. The crash plot for this section, taken from the larger drawing is shown in Figure 1.

A subset of 33 cross median crashes were identified and isolated for further analysis to determine the stereotypical crash types. This subset included all crashes coded as DCA 201 head-on, DCA 702 and 704 which are the off straight road to right codings and the DCA's in the 800 range with an R subscript which are the off road on curve crashes to the right. A second level of analysis was then conducted on this subset.

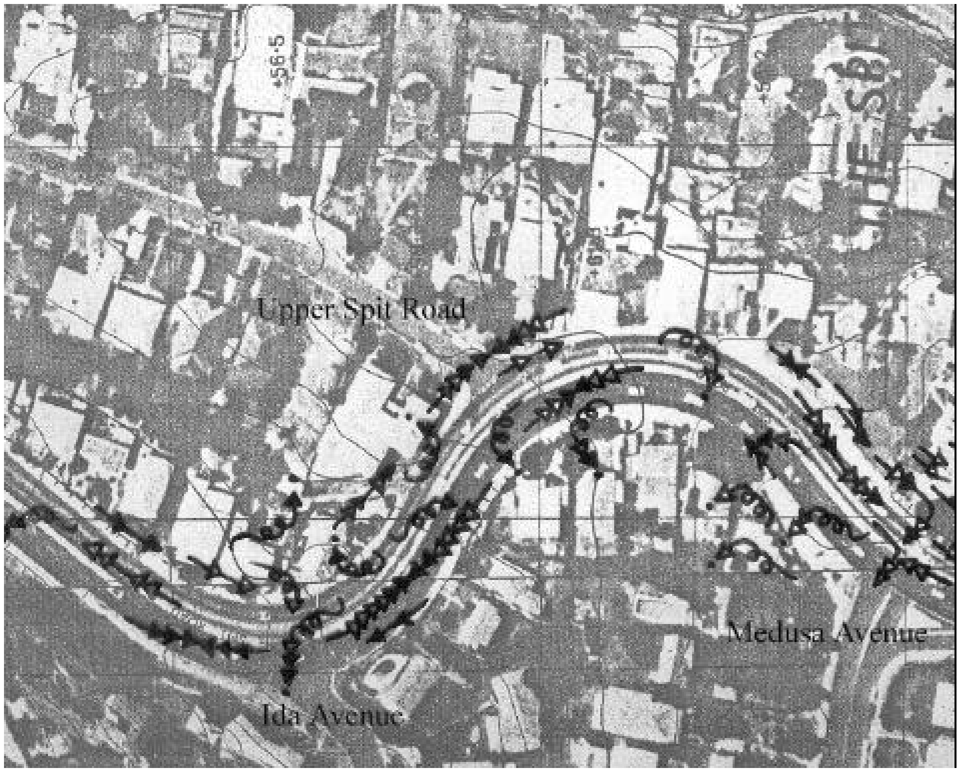


Figure 1 ***Crash plot of reverse curve showing clusters of cross median crashes***

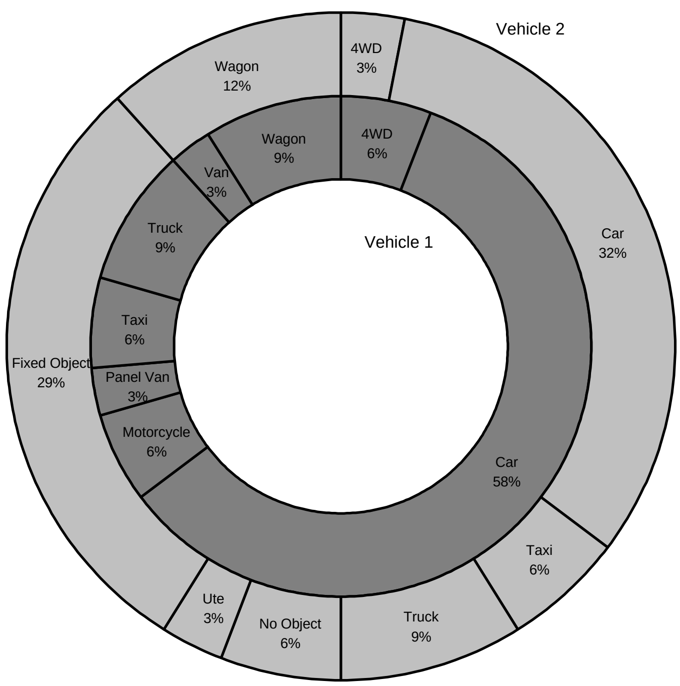


Figure 2 *Distribution of vehicle types*

Day of Week versus Time of Day

Interesting highlights were that from Sunday to Friday there is an almost equal spread between day and night crashes, noting of course that the volume data suggests very small night time compared to day time volumes. However on a Saturday there is a clear concentration of evening crashes. Alcohol information was not available though it would have been interesting to test the data for any alcohol involvement in the Saturday evening crashes.

Road Surface Condition

The frequency of wet road crashes at this location is less than the state average of around 25% wet road crashes (1998 Statistical Statement). This therefore suggests no major contribution to crash rates at this location from a wet road pavement.

Vehicle Type

Figure 2 shows that the majority of involved vehicles were car or car derivative type vehicles. Current trends in the logging of crashes suggest that those vehicles coded as wagons may be 4WD type vehicles. It was therefore important in the simulation to consider both a car and a 4WD type vehicle into the subject barrier. Trucks account for 9% of vehicle 1 (typically the errant vehicle) and therefore whilst not over represented they were considered in final recommendations. People mover type vehicles do not appear to be involved in any significant percentage of the cross median crashes and hence were not one of the key vehicle groupings, but were considered in one simulation run into the final recommended barrier profile. A bus simulation was also prepared even though they were not identified as a key vehicle group.

Recorded Speed of Vehicle 1

The recorded speed for vehicle one separated into north and southbound loss of control was also analysed. This data suggests an upper limit for the speed of a southbound vehicle hitting the barrier as being around 80 km/h and a northbound vehicle of around 70 km/h. These values are also consistent with the values derived from the provided speed data.

Litigation Crash Data

A total of three crashes were identified of which one was relevant to the current study. This crash involved a southbound 4WD vehicle travelling up the hill and crossing the median near Ida Avenue. A fatal head-on impact then ensued with a northbound sedan. This crash is the fatal crash discussed in the introduction and listed in the provided crash data.

The relevant parts of this event are that it involved a southbound 4WD crossing the central median allegedly as a result of swerving to avoid an unidentified pedal cycle. Speed did not appear to be an issue. The angle of the vehicle upon crossing the median was measured to be between about 25 and 35 degrees based on marks reportedly collected by the attending police officer.

Summary Speed Data

Summary speed data was provided for Spit Road obtained from two counting stations, one 500 metres north of the study area and the second around 200 metres south. These stations therefore reasonably span the area of this study.

This data generally suggests a reasonably consistent average and 85thile speed at these locations independent of day of week and time of day.

The northern location suggests an average free speed for northbound vehicles of around 66 km/h and southbound vehicles of around 64 km/h. The corresponding 85th%ile speeds are around 74 km/h for northbound vehicles and 73 km/h for southbound.

The second location presents slightly lower values with average free speeds of around 59 km/h for northbound vehicles and 56 km/h for southbound. The corresponding 85th%ile speeds are 67 for northbound and 64 for southbound.

The raw data was requested to check the upper limit of recorded speeds for maximum ranges at which the barrier may be called upon to perform. This data was unfortunately not available.

Mounting Height of Vehicle Brake Lights

Part of the background to this project was that a lower barrier profile would need to be selected than the standard height New Jersey type barriers due to the relative radius of these curves and the need to observe lead vehicle's brake lights.

There was little information available on the current frequency of vehicles on the road with the (now) mandatory high level brake lights (see ADR 60/00). Since the ADR relating to these lights does not give a minimum mounting height but rather one relative to the lower rim of the rear windscreen there is also little information available on the actual height of these lights on the NSW car fleet. The RTA road design guide gives design heights for the standard brake light but no data for the high level brake light.

A small survey was therefore undertaken of some 54 cars parked in a local shopping centre carpark on the evening of Thursday 7 June 2001. The results of this survey are shown plotted in Figure 3.

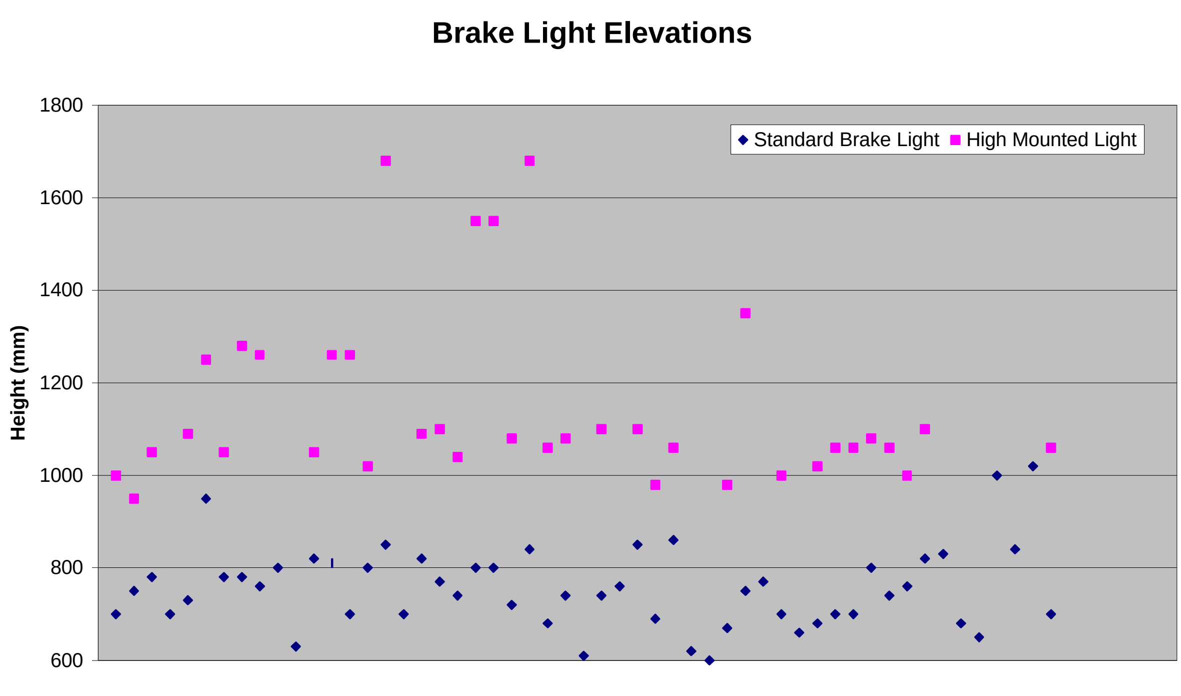


Figure 3 *Mounting Height Distribution of Vehicle Brake Lights*

It was found that some 70% of vehicles had a high level brake light fitted with a general minimum height of around 1 metre. Of those vehicles without a high level brake light, 7 of 16 vehicles had its primary brake lamps above 750 mm (the height of a standard VCB profile barrier). This therefore means that 17% of vehicles would have had all of its brake lamps below this median barrier. The lowest set of brake lamps identified without a supplementary high level lamp were a Hillman Hunter at 600 mm followed by a Mercedes 280SE at 610 mm and an early model Hyundai Excel at 620 mm.

INTERNATIONAL LITERATURE REVIEW

The RTA Road Design Guide provides guidance on the selection of safety barriers. The latest version of the barrier design section is 1996, suggesting that literature and tests on barriers up to then had been reviewed and assessed with regard to suitability for the Australian vehicle fleet.

Research on alternative or modified barrier types/shapes since 1996 are generally in unpublished research work, much of which has been undertaken by TRL in the UK.

The literature reviewed for this project has focused on the factors relating to barrier design, rather than attempting to find a “new” barrier type suitable for the “Spit Hill” road environment.

As a result of this literature review three barriers were identified for use in the simulations. These barrier profiles are shown in Figure 4. The first two of these were contained within the RTA brief for consideration while the most appropriate barrier identified internationally which appeared to meet the desired criteria was the British VCB barrier.

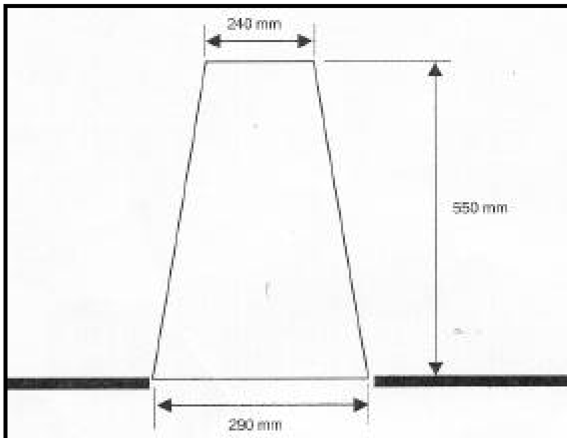
Impact Angle and Impact Speed

The British VCB has been tested successfully at impact speeds of up to 115 km/h and impact angles of 20 degrees. However an 18 tonne rigid truck rolled on the barrier at an impact speed of about 80 km/h and an impact angle of 15 degrees. The height of the VCB is 750 mm. Higher barrier heights of about 1.2 metres are considered necessary to successfully “contain” heavy vehicles. These are not feasible at this location due to the issues concerning the visibility of lead vehicle brake lights.

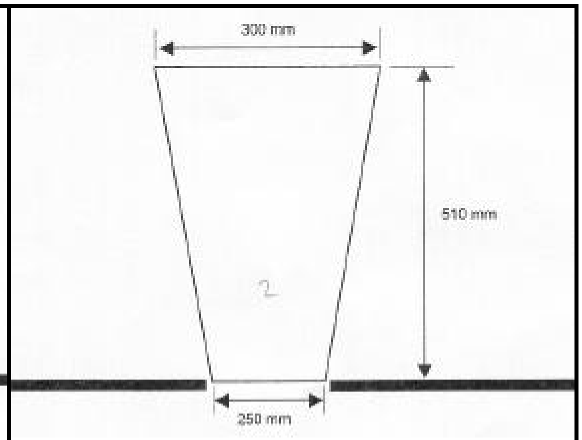
Simulations undertaken at SWOV in The Netherlands (Schoon) using VEDYAC suggests that safety barriers are successful in terms of injury risk for impact angles of 20 degrees at 100 km/h, 25 degrees at 80 km/h, and 30 degrees at 60 km/h. The measure of serious injury risk was the Acceleration Severity Index (ASI). An ASI below 1.6 indicates a high chance of no serious injury for belted occupants; an ASI below 1.0 indicates a high chance of no serious injury for unbelted occupants.

These criteria are for head-on impacts. For barrier impacts Schoon considered that these criteria could be set too low, but could not reliably indicate how much higher to set them.

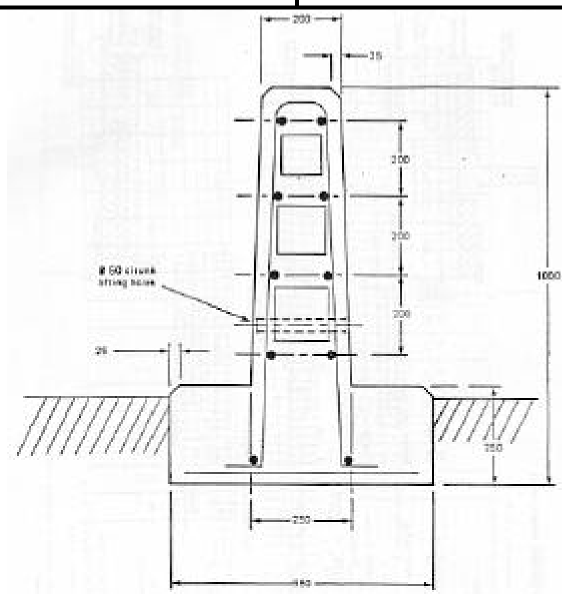
The likely impact speeds on Spit Hill were expected to be below 80 km/h, indicating that a barrier should not result in serious injury to vehicle occupants at impact angles at or below 25 degrees. The VEDYAC modelling showed that for a rigid barrier at an impact speed of 80 km/h, and an impact angle above about 15 degrees, the avoidance of serious injury requires the use of a seat belt. At 60 km/h or less, the serious injuries should be avoided even if the occupants are not wearing a belt.



RTA Barrier Profile



RTB Barrier Profile



VCB Barrier Profile

Figure 4 *Proposed barrier profiles*

An INRETS (France) study by Quincey and Vulin, showed that for a DBA type concrete barrier (similar to a General Motors profile but with a steeper face – the sloped step on the GM profile is higher than on the NJ profile, but has the same angle) provided an ASI of 1.3 for a 30 degree impact at 72 km/h. At 31 degrees and 84 km/h, the ASI was 1.7. The stopping distance of the car in the latter case was 26 metres, and in the former was 70 metres.

Given the winding alignment, high angle impacts with the barrier are likely. However, given the high seat belt wearing rates of front seat occupants in Sydney, the use of a rigid barrier on Spit Hill should not create any undue risk to vehicle occupants in a car which hits the barrier at less than 25 degrees. The risk may also be low for impact angles at or below 30 degrees, depending on the speed profile on Spit Hill. If the 85th percentile speed is around 70 km/h, then the 30 degree angle impacts are unlikely to produce serious injuries to most occupants. If the ASI criteria are conservative, then 30 degree impacts at 80 km/h, could also have a high chance of not producing serious injuries.

Vehicle Type, Ride-up Height and Rollover

The literature (Macdonald, 1992) showed that a small front wheel drive car, (e.g. Morris Mini) rode further up the face of a New Jersey barrier than did a larger car. In one TRL test a Mini impacting at 20 degrees and at 112 km/h rolled over. The reason for the higher ride-up and therefore rollover was considered to be, relative to the US experience with New Jersey barriers, the stiffer suspension and shorter front overhang of the Mini compared with typical US cars, and the higher impact speed.

It should be noted that the sloped face on the lower part of the NJ profile was to dissipate some of the impact energy into the car's suspension. This could occur where the suspension was soft and the car had a large front overhang.

The problems with smaller cars were overcome with the development of the near vertical face of the VCB.

Climbing height data of the front wheel of the impacting vehicle for a VCB profile was not in the literature reviewed. Given the near vertical profile, the front wheel of the impacting car does not appear to be in a position to contact the barrier, and so no, or very little climbing occurs. This limits vehicle roll to a very low level for passenger cars.

Therefore, for a typical urban Australian car fleet, which includes lots of small to medium front wheel drive cars, the VCB profile would appear to be appropriate. It would also appear that the VCB profile could be reduced in height, without serious consequences for passenger car impacts, and this was one aspect of the modelling for this project.

However, the standard VCB height of 750 mm could be too low to prevent rollover of heavy vehicles. In one TRL test, an 18 tonne truck rolled onto the barrier at an impact angle of 15 degrees and a speed of 79 km/h. In the INRETS tests, one truck and three buses with 10 to 12 tonne tare masses, were successfully contained at impact angles of 20 degrees and impact speeds of 65 to 72 km/h. The INRETS barriers were 800 mm high.

Barrier Face Friction

VEDYAC modelling showed that by reducing the friction of the face of a NJ barrier the climbing height of the front wheel was reduced substantially from 800 mm at 60 km/h and 25 degrees to 600 mm for the same speed and angle. The modelling also showed that the ASI was reduced substantially, especially at 100 km/h and impact angles above 20 degrees. At 60 km/h, friction slightly lowered ASI, although ASI at 60 km/h was less than at 100 km/h.

The effect of friction at 80 km/h would appear to be between the effects at 60 km/h and at 100 km/h. The effect of friction on a VCB barrier was not modelled. Friction on a VCB would appear to be irrelevant to climbing height, but could have an effect on ASI, at higher speed impacts such as around 70 to 80 km/h. Therefore it was considered prudent to provide a low friction face for this project.

DESCRIPTION OF SOFTWARE USED IN THIS PROJECT

HVE 3D Software

The simulations were undertaken utilising HVE (Human, Vehicle, Environment)-3D simulation software produced by Engineering Dynamics Corporation, Beaverton, OR, USA. This software is a recent three dimensional extension of the company's long established suite of two dimensional accident reconstruction software, known commercially as EDVAP (Engineering Dynamics Vehicle Analysis Package). This original software has been used in over 40 countries by more than 1500 users for the primary purposes of forensic accident reconstruction and road safety research. Primary users include forensic accident investigators, various Police agencies, road safety research organisations, government road agencies (such as the National Transport Safety Board (NTSB), USA) and motor vehicle manufacturers.

HVE is in itself simply a three dimensional interface purpose built for the study of the interaction between humans, motor vehicles and the operating environment. Add on physics modules are actually employed with the three dimensional HVE environment to model the event itself. This event may take on a number of forms including a single vehicle simulation, a multi-vehicle collision, a vehicle / pedestrian crash or a study of an occupant's response and the operation of the restraint systems. Different purpose built physics products are available with different programs most suitable to different types of events to be analysed. The range of physics programs currently available include:

SIMON	—	Vehicle simulation model
EDCRASH	—	Reconstruction of single and two-vehicle accidents
EDSMAC4	—	Simulation of simultaneous multiple vehicle collisions
EDVSM	—	Passenger Vehicle Simulator
EDVDS	—	Commercial Vehicle (tractor with up to 3 trailers) Simulator
EDHIS	—	Human Impact Simulator (Occupant or Pedestrian)
EDGEN	—	Kinematics Spreadsheet
GATB	—	Graphical Articulated Total Body Human Simulator

SIMON Simulation Module

The physics module used for the purpose of the barrier impacts is the SIMON simulation model, a new model completely developed by EDC specifically for use with the HVE operating system. All other models have been previously ported from some other simulation program to operate in HVE.

SIMON is a physics module used to study the dynamic response of one or more vehicles to driver inputs, factors related to the environment (e.g. terrain, atmosphere) and inter-vehicle collision(s). *SIMON* uses a new, general purpose 3-D vehicle dynamics engine developed and patented by Engineering Dynamics Corporation. The dynamics engine allows a sprung mass with six degrees of freedom and unsprung masses with up to five degrees of freedom per axle. Each vehicle model may have up to three axles (six axles for full trailers) and single or dual tires. Independent and solid axle suspension types are allowed.

DyMesh (Dynamic MEchanical SHell) Collision Simulation Module

DyMesh is a computer model for 3-D dynamic simulation of motor vehicle crashes. DyMesh uses a 3-D vehicle mesh with mechanical properties as input and produces vehicle-fixed collision forces and moments as output. DyMesh employs methods from finite element technology for collision detection, and stress-strain relationships for force calculation. Using the *HVE* simulation environment, vehicle deformation is visualized as it is calculated during collision or rollover simulations.

In a forensic investigation this would usually involve comparing the simulated damage against actual damage from staged collisions or real world crashes as a means to validate their simulation results. Because the vehicle mesh typically includes several thousand nodes, *HVE* displays the resulting damage with great resolution down to the level of individual nodes. So if a vehicle contained say a 15 centimeter mesh, the damage is visualised down to a 15 cm segment of the vehicle and its interaction with its neighbouring nodes.

DyMesh can be used for all types of collision simulations. It is however especially useful for crashes involving complicated rollover, severe underride, or any crash where three-dimensional collision dynamics are present, such as in the current low height barrier simulations. A complete discussion of DyMesh can be found in SAE Technical Paper 1999-01-0104,

DETERMINATION OF SIMULATIONS TO BE UNDERTAKEN

The range of simulations to be undertaken as part of the project was based on the preliminary data analysis, two preliminary loss of control simulations for a vehicle rounding each of the subject left horizontal curves, a consideration of the alternative barrier types as defined within the RTA brief and identified within the literature search component of the project and consideration of a range of the seemingly dependent variables also identified within the literature search.

Loss of Control Simulations

A number of preliminary simulations were conducted involving both an uphill and downhill vehicle failing to negotiate what was found to be the first of its series of horizontal curves, in both cases a left horizontal curve. It was found from these simulations that an expected approach angle to the median barrier could be around 30 degrees. Due to the width associated with the three lanes and the reasonably tight radius of these curves in some cases an impact angle of up to 45 degrees could be attained. This presents a conservative upper limit at which the basic simulations were tested.

It was therefore decided that all base simulations would be conducted at a 30 degree angle to the barrier which check simulations at 15 and 45 degrees.

Barrier Profiles

Based on the results of the literature search and the RTA brief it was decided to consider the three different barrier types. These are the two profiles given in the RTA brief and the British VCB barrier but constructing the base as flush with the road pavement so as to allow full lane width up to the edge of the barrier. The profile of each of these barriers is shown in Figure 4. In order to visually discriminate between barriers in the simulation runs a convention was adopted where the impacting vehicle for all simulations involving the RTA barrier is red, for RTB it is yellow and for VCB it is dark blue.

Final Simulations to be Undertaken

On the basis of these combinations of variables a total of 46 simulations were undertaken to cover each possible combination of variables. These simulations involved a car and a 4WD into each of the three barriers at 15, 30 and 45 degrees at 80 km/h, at 30 and 45 degrees at 60 km/h and at 30 degrees and 80 km/h but with the vehicle barrier friction turned up to 0.70. Three additional simulations of the recommended barrier profile were undertaken for a bus, van and a truck at 15 and 30 degrees at 80 km/h. "Do nothing" collision pulses were also obtained for comparison. Two vehicle following simulations looking over the recommended barrier height to consider the issue of visibility of the lead vehicle's brake lights were also undertaken.

RESULTS

Head-on Simulations

Two "do nothing" head on crash scenarios were simulated both involving a moderate to high angle crossing of the central median by a 4WD type vehicle impacting a passenger sedan travelling in the opposite direction.

These scenarios suggest base collision pulses for the sedan of 38 to 40 g and for the 4WD of around 28 to 37 g. This therefore presents the base "do nothing" case where each incident has potentially two car loads of occupants sustaining these type of decelerations. Any barrier pulses need to be considered in the context of the base values. It is worth noting however that rollover of either vehicle would not be expected and therefore would not expect the potentially more harmful effect of direct intrusion into the occupant's headspace.

Car Following Simulation

This simulation was prepared based on a Toyota Corolla (small and therefore lower driver's eye height type vehicle) following a Volkswagon Beetle which was identified in the survey as having one of the lowest set of brake lamps. The vehicles are both assumed to be travelling at about 60 km/h and the intervehicle spacing is a little more than 2 seconds.

It is apparent from this video that under these conditions the left rear brake lamp of the Volkswagon is intermittently visible probably to the degree that it would be acceptable at this level of spacing. If the vehicles were actually closer, which would not be unusual based on the operating conditions on Spit Road, then the lamp would become progressively more visible to the following driver. It is noted that opposing vehicles within the median lane could temporarily obscure the sight lines across the corner to the lead vehicle's brake lights, however this would then be independent of whichever median was used. A clip from one of these simulations is shown in Figure 5.

Barrier Simulations

It should be emphasised that it is not suggested that the results of any individual simulation should be relied upon as a discrete or exact simulation of what may occur in the real world event. The indicators represented by each crash type can be relied upon as to what type of behaviour and what approximate magnitude of deceleration forces one may expect. The results of each individual simulation will not be discussed. Rather an examination of each set of simulations for a particular vehicle class and barrier profile is undertaken. Each barrier type is discussed in sequential order summarising the overall findings and the main advantages and disadvantages of each barrier.

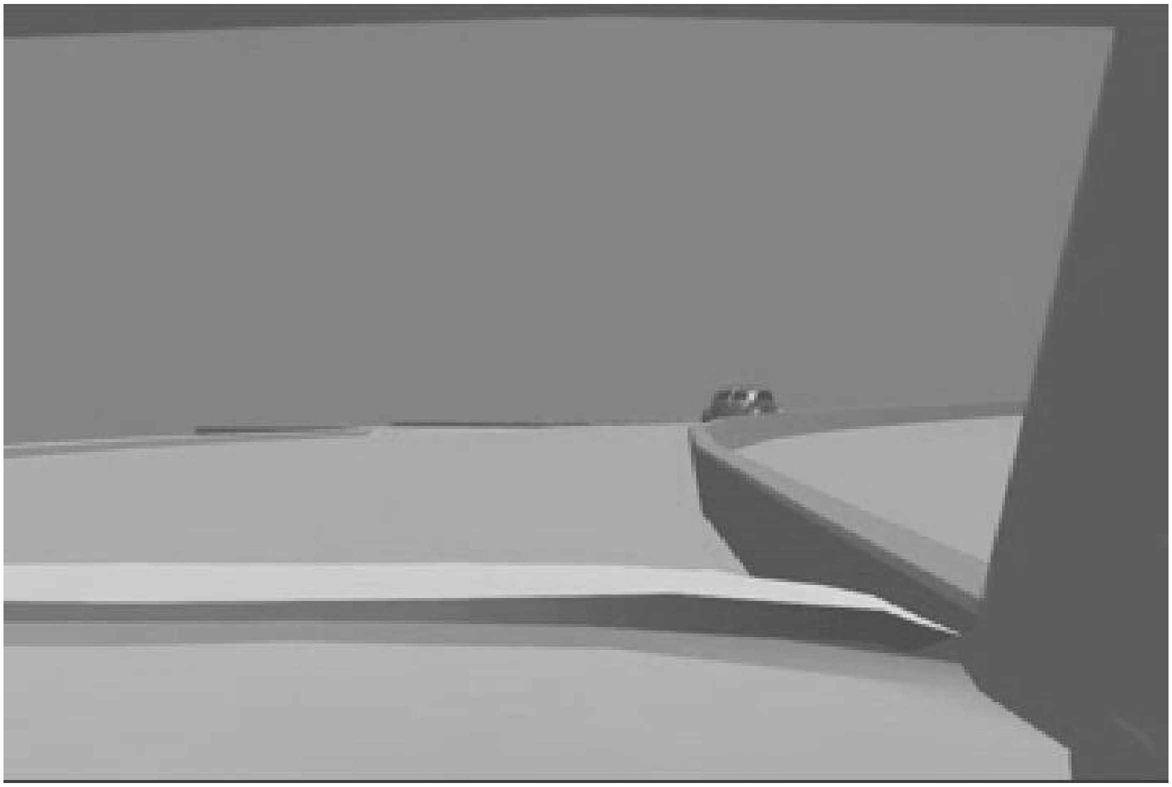


Figure 5 *Clip from car following simulation*

RTA Type Barrier
This barrier presented reasonable results for the car series of tests and actually presented the lowest deceleration values for the 45 degree car impacts. As these were however considered for contingency purposes only as a worse case scenario this is not considered a large advantage in the choice of a final barrier type. This barrier would be acceptable if only cars were to be considered.

This barrier did not perform well in the 4WD impacts with a number of runs "nosediving" at the front right wheel at initial impact and the inertia of the vehicle then causing the rear to lift resulting in a possible rollover or in some cases possibly breaching the barrier. Analysis of the mechanisms operating suggests that the primary reason this barrier was not suitable for the 4WD type vehicles is the lack of any suitable contact patch between the vehicle and the barrier. Measurement on one of the author's vehicles which is a Toyota Prado 4WD, with no modified ground clearance, provides only a small contact patch actually well below the centre line of the bumper.

It should be noted that the runs are also conducted without any dynamic instability or initial roll of the impacting vehicles. In a loss of control situation this may not be the case, hence the actual contact patch may be even smaller than that assumed in these simulations. There may also be additional forces already operating on the vehicle rather than the essentially static forces assumed at the start of each simulation.

This barrier does present an acceptable height to remain below brake lights but this presents a minimal trade-off compared to its lack of suitable containment for 4WD type vehicles.

Figure 6 *Clip from RTA barrier simulation for a 4WD at 80 km/h and 30 degree approach angle*

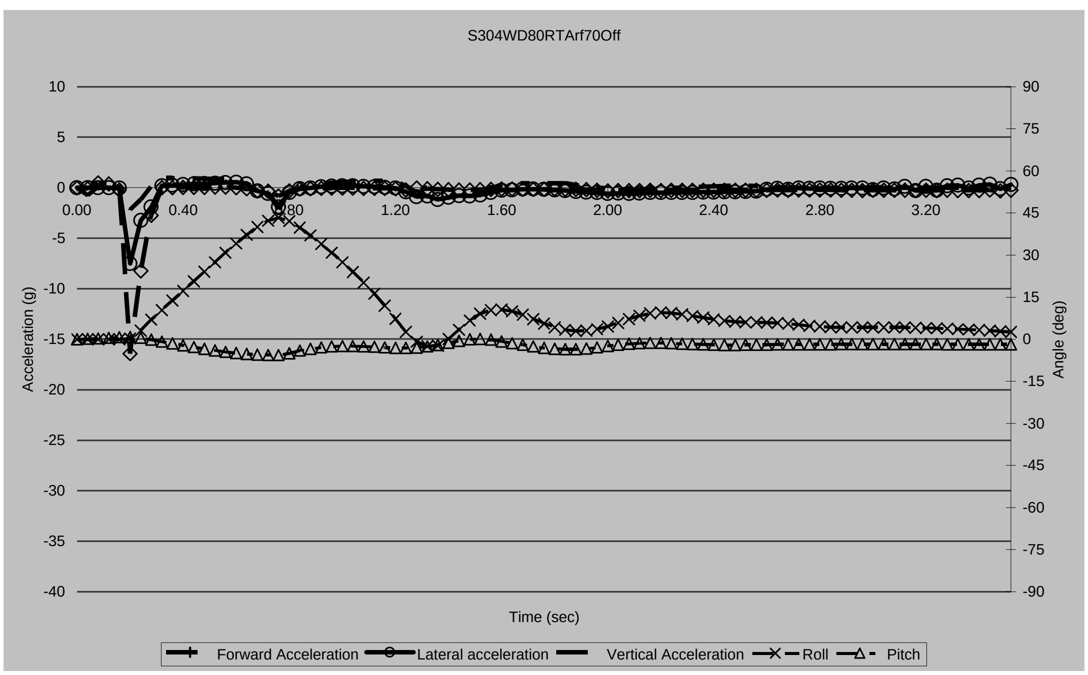


Figure 7 *Results derived from simulation shown in Figure 6*

This barrier is unacceptable for 4WD type vehicles and may actually exacerbate the situation for the occupants of this type of vehicle by inducing rollover in a moderate speed moderate angle impact. As the simulations also suggest that the barrier may be breached it may not prevent problems for opposing vehicles associated with errant vehicles.

An example of the numerical simulation results obtained from this particular impact is shown in Figure 7 including both acceleration traces and positional traces of roll yaw and pitch angles. The top lines show the acceleration plots generally peaking at a forward acceleration peak of around 17 g and a lateral peak of around 6g. Of more concern in this example however is the peak rollover value of around 45 degrees with only the presence of the barrier seeming to prevent the vehicle rolling over in this scenario.

RTB Type Barrier

This barrier was actually 40 mm lower than the RTA type barrier and also provided insufficient containment for 4WD type vehicles. It was found that the 4WD vehicles may tend to overrun the barrier despite the idea behind this barrier being that an outward facing slope may tend to apply a small force deflecting the impacting vehicle downwards.

The simulations however suggested that a different mechanism to the downward deflecting force may in fact operate similar to what has been observed during some testing in the USA on pickup type vehicles where the impacting corner actually “nosedives” and the inertia of the rear of the vehicle causes the rear to ride up into or perhaps over the barrier. This appears to be a case of simple physics that if the barrier can effectively stop the vehicle at this height then it is so far below the vehicles centre of gravity that the vehicle attempts to vault, rotating from the rear about the pivot point at the barrier / vehicle interface.

This phenomenon was particularly apparent in the higher impact angle simulations. The car also displayed a similar tendency although the retarding force is close enough to the centre of gravity height of this vehicle that excessive vaulting did not occur. It should be noted however that the vehicle used was a smaller type vehicle, being a Toyota Corolla sedan such that larger sedans may also experience unacceptable levels of lift. A clip from one of 4WD simulations is shown in Figure 8.

VCB Barrier

There was no significant difference in the magnitude of decelerations forces for any of the barrier profiles but the VCB type barrier was the only one which provided acceptable containment of 4WD type vehicles. The accompanying videos show that for all of the 4WD scenarios the vehicle was successfully redirected or stopped without any possibility of rollover or breaching the barrier. Although the forces were high for the higher incident angle impacts there is no way of significantly reducing these values if a rigid barrier is used as the only deceleration distance available is the crushing of the impacting vehicle. An example of the identical simulation to those shown in the previous simulation clips using the VCB barrier is shown in Figure 9.

Figure 8 *Clip from RTB barrier simulation for a 4WD at 80 km/h and 30 degree approach angle*

Figure 9 *Clip from VCB barrier simulation for a 4WD at 80 km/h and 30 degree approach angle*

CONCLUSIONS

This paper documents the results of investigations undertaken on behalf of the RTA into suitable barrier systems to be installed along the median island of Spit Road between Medusa Street and Pearl Bay Road, Mosman. The nature of these investigations involved computerised crash simulations of various barrier profiles for both a passenger sedan and a 4WD type vehicle.

As a result of these investigations three alternative barrier profiles were considered, two of which were contained within the RTA brief as possible considerations and the third is the British style VCB Barrier identified as a result of the literature search and as part of a recent study tour to the UK by Grant Johnston where preliminary investigations for this project were undertaken at TRL. It should be noted however that the VCB Barrier is also listed in the RTA Road Design Guide as a suitable barrier.

A series of identical simulations were then run for each of the three barrier types. As a result of these simulations it was determined that the two RTA proposed barriers both performed poorly with insufficient containment for 4WD type vehicles. This was principally due to an unacceptably small contact patch at the front right corner of the impacting vehicle. The simulations have suggested that in the majority of cases this results in the vehicle "nosediving:" at the front right corner. As the retarding force is applied much lower than the centre of gravity of the 4WD vehicle it then tends to attempt to vault with very significant lifting of the rear of the vehicle occurring as it pivots about its contact region at the wall. The VCB barrier did not replicate these results and was considered to provide an acceptable level of containment for both cars and 4WD's.

Concern was raised in relation to the ability to observe lead vehicles brake lights over a median barrier of any significant height through the right horizontal curves. A simulation of a drivers eye view in a following vehicle over the VCB profile barrier was undertaken and this suggested that it probably presented an acceptable trade off for its increased crash benefits. The actual problem of observing the lead vehicles brake lights was found to be minimal.

It was therefore a recommendation of the project team that a VCB profile barrier be installed at this location to prevent future incidences of cross median crashes.

Disclaimer

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