FINAL REPORT

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ZONE OF INTRUSION STUDY

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DISCLAIMER STATEMENT

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

METRIC CONVERSION TABLE

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
in	inches	25.4	millimeters	mm
in	inches	0.0254	meters	m
ft	feet	0.305	meters	m
lb	pounds	0.454	kilograms	kg
mi	miles	1.61	kilometers	km
mph	miles per hour	1.61	kilometers per hour	km/h
mph	miles per hour	0.447	meters per second	m/s

TECHNICAL REPORT DOCUMENTATION PAGE

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16. Abstract

The Midwest Roadside Safety Facility (MwRSF) performed an analysis using LS-DYNA simulation to investigate the zone of intrusion (ZOI) of an NCHRP Report No. 350 2000p pickup truck when impacting a 40-in. high F-shape parapet. The ZOI for the 40-in. F-shape concrete barrier impacted by the 2000p vehicle at 62 mph at an angle of 25 degrees (equivalent to TL-3) is predicted to be 5 inches. The ZOI for the 40-in. F-shape concrete barrier impacted by the 2000p vehicle at 45 mph at an angle of 25 degrees (equivalent to TL-2) is predicted to be between 1.8 and 2.5 inches, depending on the impact conditions simulated. The variations in this relatively small ZOI are attributed to the mesh quality of the model and to the system geometry. The 2000p pickup truck front hood geometry is such that it will extend over a 40-in. high F-shape parapet during impact conditions examined in this study. Thus, some ZOI is inevitable at almost all impact speeds. However, compared to a 32-in. parapet, the amount of structure extending over the 40-in. barrier is possibly inconsequential. That is, with a 32-in. parapet a significant amount of vehicle structure will overhang the barrier and potentially cause problems within the ZOI. With the 40-in. parapet, the amount of vehicle structure overhanging the barrier is limited to the front corner of the hood and possibly a little bit of the fender. This limited amount of structure in the ZOI may not cause any problems during an impact event.

17. Key Words	18. Distribution Statement		
Zone of Intrusion, LS-DYNA Simulation, NCHRP Report 350, 40-in. F-shape concrete barrier	No restrictions.		
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EXECUTIVE SUMMARY

The Midwest Roadside Safety Facility (MwRSF) performed an analysis using LS-DYNA simulation to investigate the zone of intrusion (ZOI) of an NCHRP Report No. 350 2000p pickup truck when impacting a 40-in. high F-shape parapet.

The ZOI for the 40-in. F-shape concrete barrier impacted by the 2000p vehicle at 62 mph at an angle of 25 degrees (equivalent to TL-3) is predicted to be 5 inches. The ZOI for the various conditions simulated was very consistent.

The ZOI for the 40-in. F-shape concrete barrier impacted by the 2000p vehicle at 45 mph at an angle of 25 degrees (equivalent to TL-2) is predicted to be between 1.8 and 2.5 inches, depending on the impact conditions simulated. The variations in this relatively small ZOI are attributed to the mesh quality of the model and to the system geometry.

The 2000p pickup truck front hood geometry is such that it will extend over a 40-in. high F-shape parapet during impact conditions examined in this study. Thus, some ZOI is inevitable at almost all impact speeds. However, compared to a 32-in. parapet, the amount of structure extending over the 40-in. barrier is possibly inconsequential. That is, with a 32-in. parapet a significant amount of vehicle structure will overhang the barrier and potentially cause problems within the ZOI. With the 40-in. parapet, the amount of vehicle structure overhanging the barrier is limited to the front corner of the hood and possibly a little bit of the fender. This limited amount of structure in the ZOI may not cause any problems during an impact event.

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INTRODUCTION

The Midwest Roadside Safety Facility (MwRSF) performed an analysis using LS-DYNA simulation to investigate the zone of intrusion (ZOI) of an NCHRP Report No. 350 2000p pickup truck when impacting a 40-in. high F-shape parapet; this report documents that study.

SCOPE OF SERVICES

The Florida Department of Transportation has requested that MwRSF perform a computer simulation analysis to investigate the zone of intrusion (ZOI) of an NCHRP Report No. 350 2000p pickup truck when impacting a 40-in. high F-shape parapet. This impact will be simulated at speeds of 62 mph and 45 mph at an angle of 25 degrees. The results of this analysis will be documented and submitted to the Florida Department of Transportation.

ZOI SUMMARY

The ZOI for the 40-in. F-shape concrete barrier impacted by the 2000p vehicle at 62 mph at an angle of 25 degrees (equivalent to TL-3) is predicted to be 5 inches. This prediction is based on LS-DYNA nonlinear finite element analysis using the best available c2500 pickup truck model. The ZOI for the various conditions simulated was very consistent. The simulation parameters varied had little influence on the ZOI. Their influence did affect the overall kinematic behavior of the vehicle, but the differences were observed primarily after the ZOI had already occurred.

The ZOI for the 40-in. F-shape concrete barrier impacted by the 2000p vehicle at 45 mph at an angle of 25 degrees (equivalent to TL-2) is predicted to be between 1.8 and 2.5 inches, depending on the impact conditions simulated (explained below). The variations in this relatively small ZOI are attributed to the mesh quality of the model and to the system geometry.

The 2000p pickup truck front hood geometry is such that it will extend over a 40-in. high F-shape parapet during impact conditions examined in this study. Thus, some ZOI is inevitable at almost all impact speeds. However, compared to a 32-in. parapet, the amount of structure extending over the 40-in. barrier is possibly inconsequential. That is, with a 32-in. parapet a significant amount of vehicle structure will overhang the barrier and potentially cause problems within the ZOI. With the 40-in. parapet, the amount of vehicle structure overhanging the barrier is limited to the front corner of the hood and possibly a little bit of the fender. This limited amount of structure in the ZOI may not cause any problems during an impact event.

IMPORTANT PROJECT DETAILS

Impacts into concrete barriers are influenced by several phenomena. Of significance for this study, that includes the tire-barrier friction, the air out of the tires when high pressures are reached, and the failure of suspension joints when extreme forces are reached.

The tire-barrier friction helps determine how the vehicle rides up the barrier during the impact. In general, the higher the friction, the higher the front end rides up the barrier during the early portion of the impact.

If a tire airs out, there is an immediate loss of load between the vehicle and the barrier. This relaxation of load can affect the vehicle riding up the barrier and the amount of front crush of the vehicle.

Suspension failure affects the loading into the vehicle and can significantly affect the overall kinematic behavior of the vehicle throughout the event. For all full-scale test investigations, it was observed that if the suspension components had failed, then the tire had also aired out. However, a tire may air out without causing suspension joint failures.

These three phenomena cannot be accurately simulated for prediction with today's state-of-the-art simulation techniques. Thus, a parameter study is done by varying each of these phenomena so that the ZOI can be bracketed regardless of which event was to occur on a specific crash test. The model used for this study is shown in Figure 1.

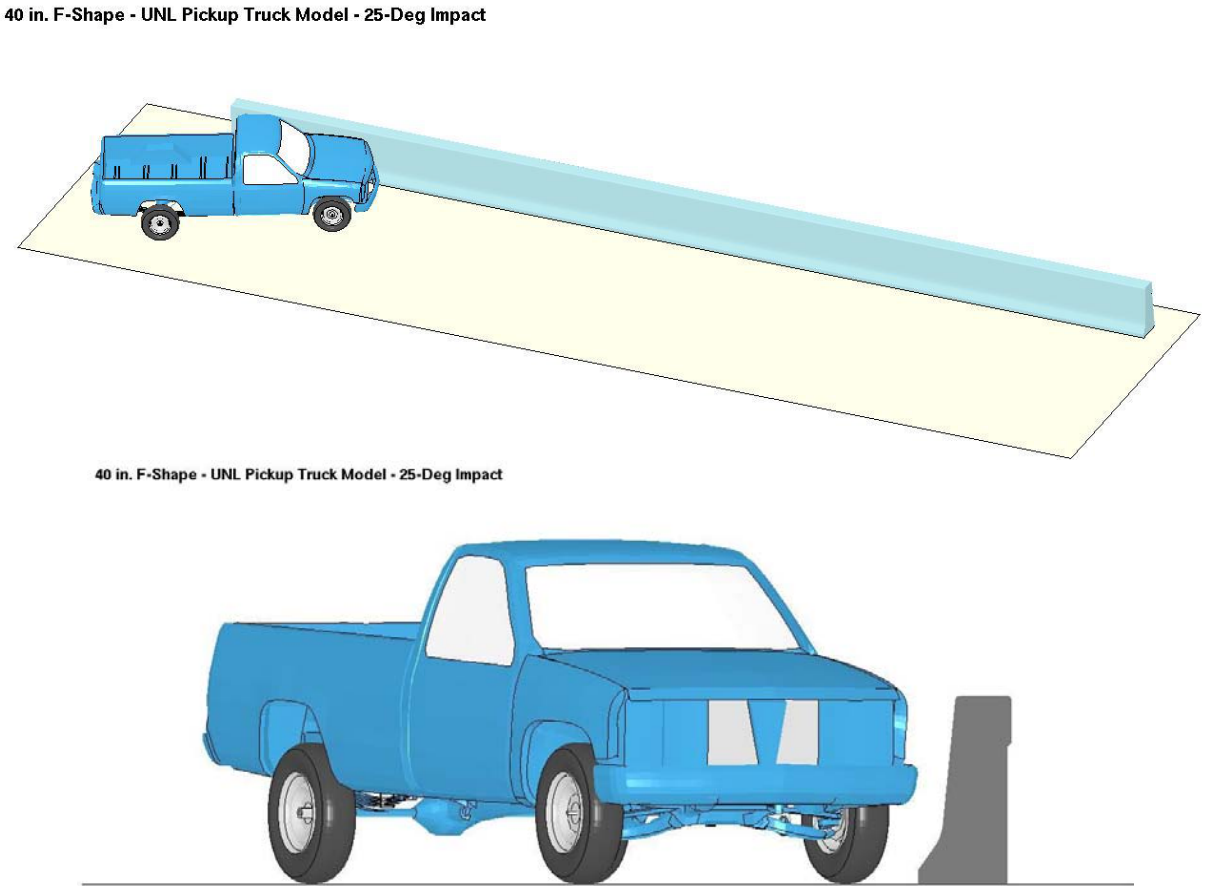
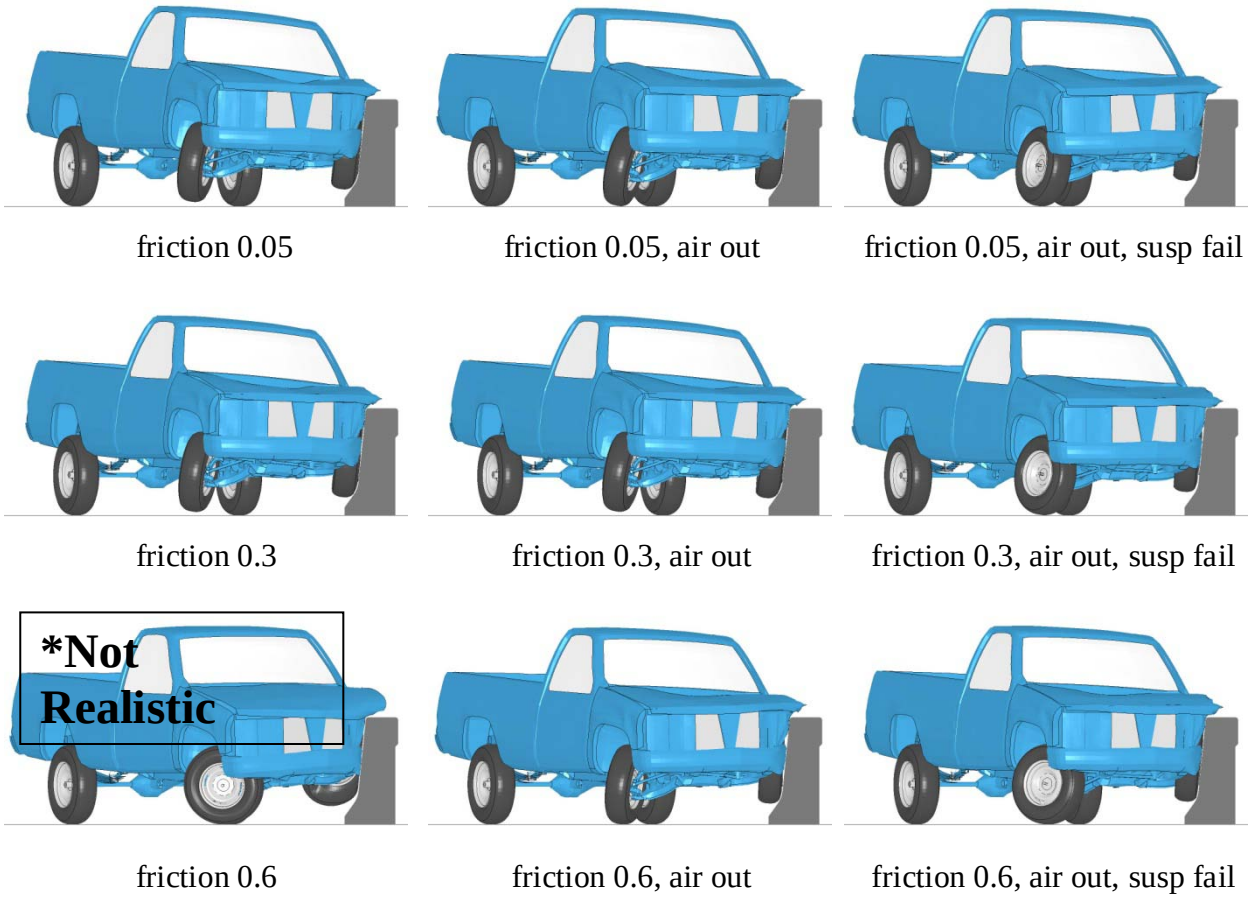


Figure 1. Simulation Model – Initial Condition

ZOI SIMULATION RESULTS FOR 62 MPH

Images at maximum ZOI for the 9 cases simulated at 62 mph are shown in Figure 2.

Definitions used in Figure 2 captions:
friction – friction coefficient defined between tire and barrier
air out – tire airs out when pressure reaches a failure pressure
susp fail – wheel tears off suspension when suspension joints reach failure forces



friction 0.05 | friction 0.05, air out | friction 0.05, air out, susp fail

friction 0.3 | friction 0.3, air out | friction 0.3, air out, susp fail

friction 0.6 | friction 0.6, air out | friction 0.6, air out, susp fail

Figure 2. Maximum ZOI for 62 MPH, 25 degree impact into 40-in high F-shape parapet

*Not Realistic – in this case, with such a high friction and no tire air out or suspension failure defined, the vehicle did not yaw as seen in all physical testing of concrete barrier testing. Instead the vehicle basically bounced off the barrier after jamming the tire/wheel into the wheel well. Thus, this case was deemed unrealistic.

For all eight realistic simulations shown in Figure 2, each one had a phenomenon that was neglected in determining the ZOI. That phenomenon is identified by the arrow in Figure 3. That area is the result of two elements in the model kinking and distorting in a local area. This was the result of the coarseness of the hood mesh in that area. Thus, this local distortion was not considered when determining the ZOI.

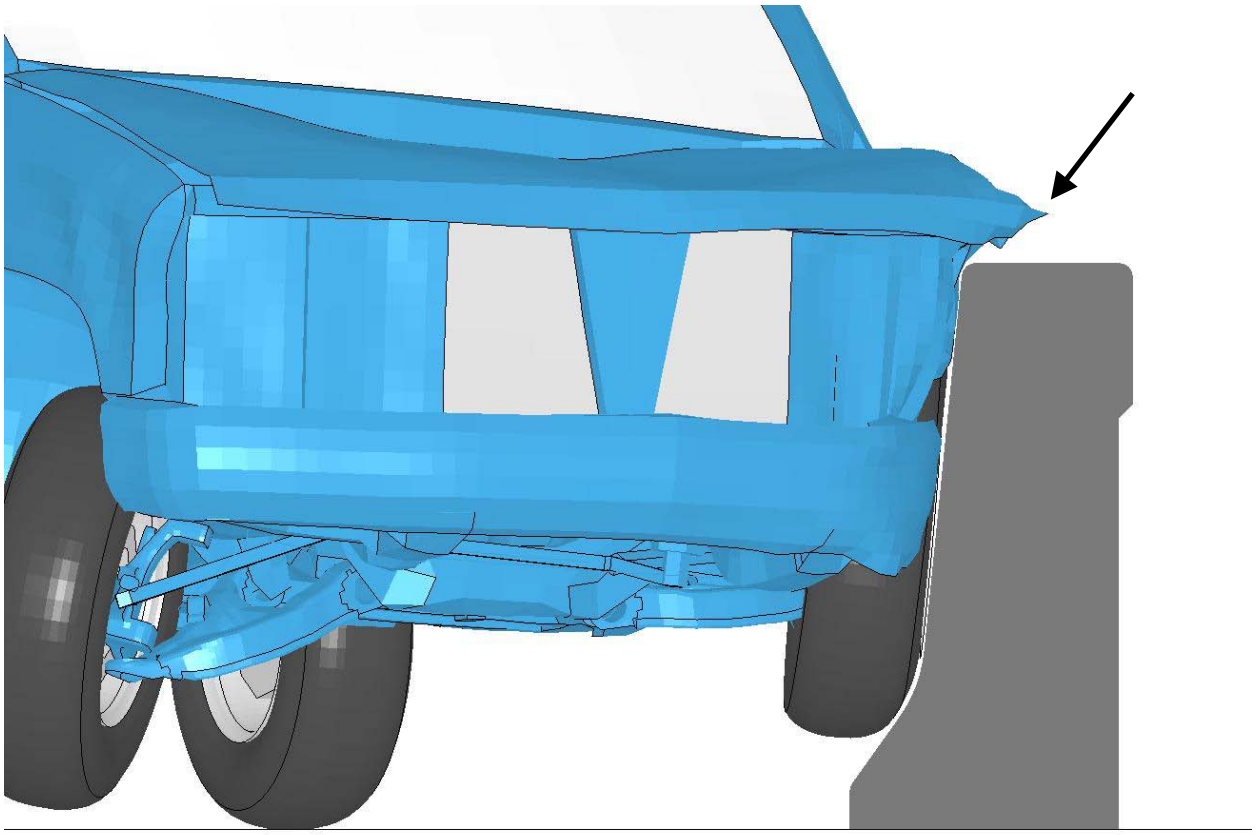
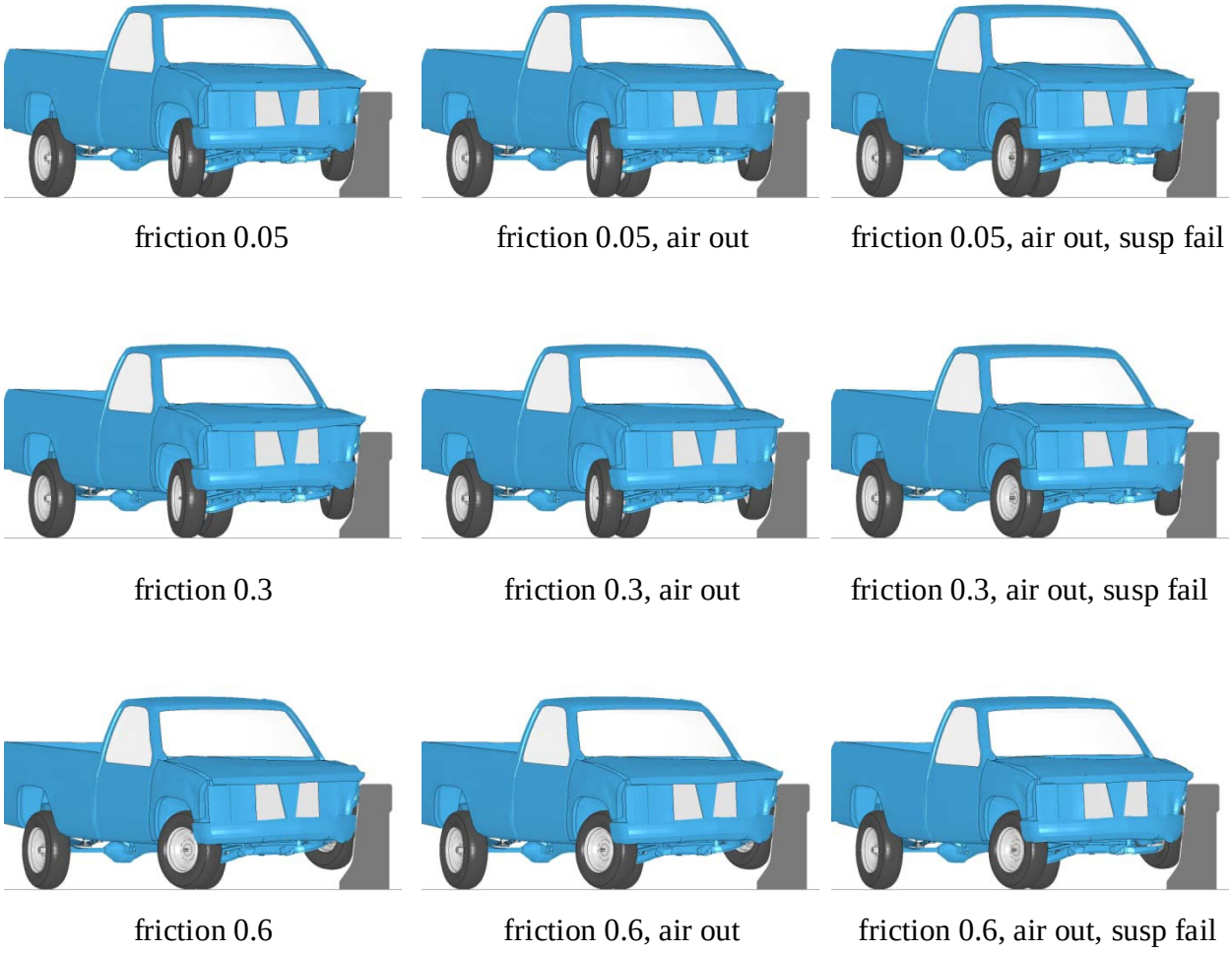


Figure 3. Local deformation due to coarse mesh

ZOI SIMULATION RESULTS FOR 45 MPH

Images at maximum ZOI for the 9 cases simulated at 45 mph are shown in Figure 4.

Definitions used in Figure 4 captions:
friction – friction coefficient defined between tire and barrier
air out – tire airs out when pressure reaches a failure pressure
susp fail – wheel tears off suspension when suspension joints reach failure forces



friction 0.05 | friction 0.05, air out | friction 0.05, air out, susp fail

friction 0.3 | friction 0.3, air out | friction 0.3, air out, susp fail

friction 0.6 | friction 0.6, air out | friction 0.6, air out, susp fail

Figure 4. Maximum ZOI for 45 MPH, 25 degree impact into 40-in high F-shape parapet

ZOI BETWEEN 45 AND 62 MPH

Extrapolating ZOI between 45 and 62 mph cannot be done with precision or confidence; reasons for this are as follows:

1. The coarseness of the mesh in the vehicle model can exhibit the local deformations, as discussed previously and shown in Figure 3, at unpredictable impact conditions when the speed is increased over 45 mph. That is, the local deformations do not occur at 45 mph, do occur at 62 mph, and sometimes do and do not occur at speeds in-between when varying the impact conditions.
2. The region of the vehicle that determines the ZOI is a relatively small area of the vehicle, as shown in Figure 5. Small parameter changes in the impact conditions can affect this local region on the order of 1 or 2 inches of deformation.
3. As an example of the complexity of extrapolating, the ZOI for the case with a friction coefficient of 0.3 and allowing the tires to air out is slightly higher for 50 mph than it is for 55 mph.

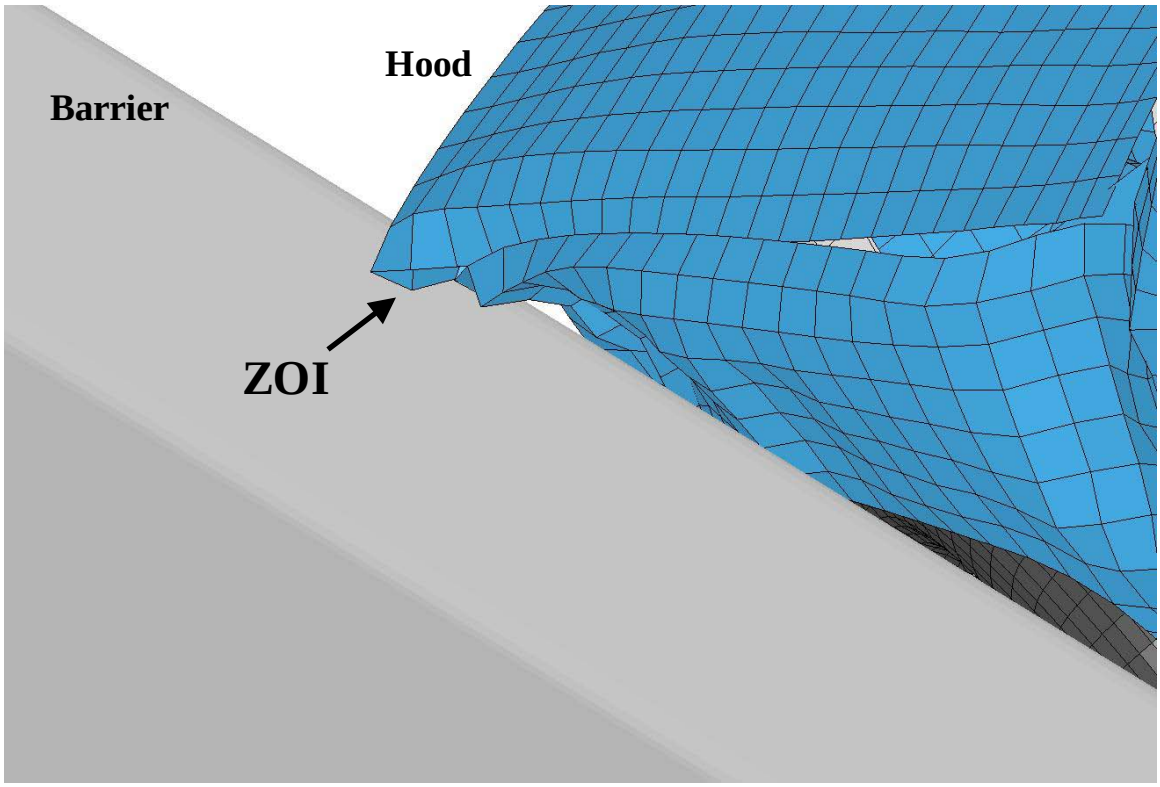


Figure 5. ZOI for 50 mph, Friction 0.3 and Tire Air Out