



# INDIANA UNIVERSITY

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## ON-SITE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION INVESTIGATION

CASE NUMBER - IN-05-025  
LOCATION - WISCONSIN  
VEHICLE - 2004 MAZDA 6S  
CRASH DATE - July 2005

Submitted:

September 13, 2006  
Revised: April 1, 2008



Contract Number: DTNH22-01-C-07002

Prepared for:

U.S. Department of Transportation  
National Highway Traffic Safety Administration  
National Center for Statistics and Analysis  
Washington, D.C. 20590-0003

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

**Technical Report Documentation Page**

1. <i>Report No.</i> IN-05-025		2. <i>Government Accession No.</i>		3. <i>Recipient's Catalog No.</i>	
4. <i>Title and Subtitle</i> On-Site Side Impact Inflatable Occupant Protection Investigation Vehicle - 2004 Mazda 6s Location - Wisconsin			5. <i>Report Date:</i> September 13, 2006		
			6. <i>Performing Organization Code</i>		
7. <i>Author(s)</i> Special Crash Investigations Team #2			8. <i>Performing Organization Report No.</i>		
9. <i>Performing Organization Name and Address</i> Transportation Research Center Indiana University 222 West Second Street Bloomington, Indiana 47403-1501			10. <i>Work Unit No. (TRAIS)</i>		
			11. <i>Contract or Grant No.</i> DTNH22-01-C-07002		
12. <i>Sponsoring Agency Name and Address</i> U.S. Department of Transportation (NPO-122) National Highway Traffic Safety Administration National Center for Statistics and Analysis Washington, D.C. 20590-0003			13. <i>Type of Report and Period Covered</i> Technical Report Crash Date: July 2005		
			14. <i>Sponsoring Agency Code</i>		
15. <i>Supplementary Notes</i> On-site side impact air bag investigation involving a 2004 Mazda 6s with manual safety belts, dual front driver and front right passenger air bags, seat back-mounted side impact air bag and side curtain air bags.					
16. <i>Abstract</i> This report covers an on-site investigation of a side impact air bag deployment crash that involved a 2004 Mazda 6s (case vehicle), which ran-off-road and rolled over. This crash is of special interest because the case vehicle was equipped with side curtain air bags and front seat back-mounted side impact air bags. The case vehicle was also equipped with Advanced Occupant Protection System (AOPS) features, and the case vehicles' driver (33-year-old, female) sustained a police reported "A" (incapacitating) injury as a result of the crash. The case vehicle was traveling south in the outside lane of a six-lane, divided U.S. highway. The driver stated that a car swerved into her lane from the middle lane. The driver steered right in an attempt to avoid a crash and the case vehicle began rotating clockwise, departed the road, tripped and rolled over driver side leading. The case vehicle rolled over at least two full rolls (i.e., 8 quarter rolls). The left side curtain air bag and driver's seat back-mounted side impact air bag deployed during the rollover. The case vehicle came to rest on its wheels in a field heading northeast. The driver was restrained by her manual, three-point, lap-and-shoulder safety belt. She sustained several minor left rib fractures due to contact with her door and her left arm impacted her seat back-mounted side impact air bag causing an abrasion to her left upper arm. She also strained her right shoulder. She was transported by ambulance to a local hospital, treated and released.					
17. <i>Key Words</i> Side Impact Air Bag Deployment, Rollover			Motor Vehicle Traffic Crash Injury Severity		18. <i>Distribution Statement</i> General Public
19. <i>Security Classif. (of this report)</i> Unclassified	20. <i>Security Classif. (of this page)</i> Unclassified		21. <i>No. of Pages</i> 9	22. <i>Price</i>	

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This investigation was brought to NHTSA's attention on or about July 26, 2005 by a firefighter with the local fire department involved in the rescue activities related to this crash. This crash involved a 2004 Mazda 6s (case vehicle) that ran-off-road and overturned. The crash occurred in July, 2005, at 10:24 p.m., in Wisconsin and was investigated by the applicable city police department. This crash is of special interest because the case vehicle was equipped with side curtain air bags and front seat back-mounted side impact air bags. The case vehicle was also equipped with Advanced Occupant Protection System (AOPS) features, and the case vehicle's driver (33-year-old, female) sustained a police reported "A" (incapacitating) injury as a result of the crash. This contractor inspected the case vehicle and scene on August 23, 2005, and interviewed the case vehicle's driver on September 22, 2005. This summary is based on the police crash report, scene and vehicle inspections, driver interview, occupant kinematic principles and this contractor's evaluation of the evidence.

## SUMMARY

The case vehicle was traveling south in the outside lane of a six-lane, divided U.S. highway at a driver estimated speed of 97 km.p.h. (60 m.p.h.). The driver stated that a car swerved into her lane from the middle lane. The driver steered right in an attempt to avoid a crash and the case vehicle to began rotating clockwise, departed the road, tripped and rolled over driver side leading. The case vehicle rolled over at least two full rolls (i.e., 8 quarter rolls) across a distance of approximately 25 meters (82 feet). During the last portion of the rollover, the case vehicle impacted a wire fence. The left side curtain air bag and driver's seat back-mounted side impact air bag deployed during the rollover. The case vehicle came to rest on its wheels in a field heading northeast. The driver remained in the case vehicle and was removed by rescue personnel. At the time of the crash the light condition was dark, the atmospheric condition was clear, and the roadway pavement was dry, level, traffic polished bituminous.

The CDCs for the case vehicle were determined to be: **00-TDDO-3** for the rollover and: **00-TYLS-1** and **00-LYEW-1** for damage from the fence that occurred during the rollover. The WinSMASH reconstruction program could not be used on this crash because rollovers are out-of-scope for the program. Based on the extent of roof crush, the rollover severity was determined to be moderate. The case vehicle was towed due to damage.

Immediately prior to the crash sequence the case vehicle's driver was seated in an upright position with her back against the seat back, her left hand on the steering wheel, right arm on the center armrest, left foot on the floor and right foot on the accelerator pedal. The driver's seat track was located between its forward and middle position, the seat back was slightly reclined and the tilt steering column was adjusted to between its center and full up position. The driver was wearing contact lenses at the time of the crash and was restrained by her manual, three-point, lap-and-shoulder safety belt system.

During the rollover, the driver's left chest impacted her door causing several minor rib fractures and her left arm impacted her seat back-mounted side impact air bag causing an abrasion to her upper left arm. She also strained her right shoulder. The contact source for this injury was

not determined. The driver's use of her safety belt system and the deployment of her left side curtain air bag and seat back-mounted side impact air bag during the rollover most likely prevented the driver from sustaining more serious injury.

### CRASH CIRCUMSTANCES

**Crash Environment:** The trafficway on which the case vehicle was traveling was a six-lane, divided U.S. highway traversing in a north and south direction. Each travel direction had three through lanes and bituminous shoulders. Each travel lane was approximately 3.7 meters (12 feet) in width. The median shoulders were approximately 1.5 meters (4.9 feet) in width, the outside shoulders were approximately 4.2 meters (13.8 feet) in width, and the grass median was approximately 9 meters (29.5 feet) in width. The case vehicle's approach to the crash location was uncontrolled and the posted speed limit was 105 km.p.h. (65 m.p.h.). The regulatory speed limit sign was posted just prior to the crash location. Pavement markings consisted of solid white outside edge lines, broken white lane lines and solid yellow median edge lines. At the time of the crash the light condition was dark, the atmospheric condition was clear, and the roadway pavement was dry, level, traffic polished bituminous with an estimated coefficient of friction of 0.65. Traffic density was light and the site of the crash was rural. See the Crash Diagram at the end of this report.

**Pre-Crash:** The case vehicle was traveling south in the outside lane (**Figure 1**) at a driver estimated speed of 97 km.p.h. (60 m.p.h.). The driver was intending to continue southbound in the outside lane. The driver stated that a car swerved into her lane from the middle lane. The case vehicle's driver steered right in an attempt to avoid a crash and the case vehicle traveled toward the outside shoulder and begin rotating clockwise. Based on the police reported measurements, the case vehicle produced 33.7 meters (110.6 feet) of tire marks on the roadway extending to the point where it entered the grass (**Figure 2** below). The police reported tire marks were not present at this contractor's scene inspection. The crash occurred on the west side of the roadway.



**Figure 1:** Approach of case vehicle southbound in outside lane to area of roadway departure



**Figure 2:** Area of case vehicle's roadway departure. Arrows show left front wheel furrow on right, left rear wheel furrow on left

**Crash:** The case vehicle was rotated approximately 65 degrees from its original travel heading as it departed the roadway and entered the grass (**Figure 2** above). The case vehicle continued to rotate clockwise and traveled an additional approximate 27 meters (89 feet) tripped and rolled over driver side leading (**Figures 3, 4 and 5**). The case vehicle rolled over at least two full rolls (i.e., 8 quarter rolls) across a distance of approximately 25 meters (82 feet). During the last portion of the rollover, the case vehicle impacted a wire fence (**Figure 6**).



**Figure 3:** Area of rollover, arrow shows area of final rest on other side of fence



**Figure 4:** Overview of rollover damage to hood, roof and right side of case vehicle



**Figure 5:** Overview of rollover damage to hood, roof and left side of case vehicle



**Figure 6:** Area of fence impact (fence repaired), arrow shows area of final rest of case vehicle

**Post-Crash:** The case vehicle came to rest on its wheels heading northeast (**Figure 6**). The driver remained in the case vehicle and was removed by rescue personnel.

### CASE VEHICLE

The 2004 Mazda 6s was a front wheel drive, four-door hatchback (VIN: 1YVHP84D245-----) equipped with a 3.0L, V6 engine; automatic transmission; four wheel, anti-lock brakes and traction control. The front seating row was equipped with bucket seats with adjustable head restraints; manual, three-point, lap-and-shoulder safety belt systems with adjustable upper anchors; dual stage driver and front right passenger air bags, driver and front right passenger seat back-mounted side impact air bags and side curtain air bags. The back seating row

was equipped with a bench seat with folding backs and adjustable head restraints in the outboard seating positions; three-point, lap-and-shoulder safety belts in all three seating positions and a LATCH system for securing child safety seats. The case vehicle's odometer reading at the time of the vehicle inspection could not be determined because the vehicle was equipped with an electronic odometer. However, the driver estimated that the case vehicle's odometer reading was approximately 12,874 kilometers (8,000 miles) at the time of the crash. Finally, the case vehicle's wheelbase was 267 centimeters (105.1 inches).

### CASE VEHICLE DAMAGE

**Exterior Damage:** The direct damage from the rollover involved the case vehicle's front bumper, hood, roof, and the totality of both sides of the vehicle (Figures 7 and 8). In addition, the left and right edges of the hatch were directly damaged in a few areas. Impact with the fence during the rollover scratched the top of the left portion of the front bumper, the roof near the left "A"-pillar (Figure 7) and the left fender and left front door (Figure 9). The damage in the area of the left side view mirror appeared to be due to impact with one of the wooden fence posts.

The case vehicle's left side wheelbase was reduced approximately 2 centimeters (0.8 inch). The right side wheelbase was unchanged. The induced damaged involved the same components as the direct damage, as well as the windshield and back bumper.

The case vehicle's recommended tire size was: P205/60R16 or P215/50R17, the vehicle was equipped with tires size P215/50R17. The left rear tire was observed to be extensively shredded, and the circumference of the rim flange had grinding marks on it. There was no evidence this damage was associated with this crash. At the crash site, no gouges or rim scratches were observed in the pavement leading to the case vehicle's point of roadway departure. Therefore, this



Figure 7: Overview of rollover damage to front and left side of case vehicle, arrows show scratches from fence impact



Figure 8: Overview of rollover damage to roof and right side

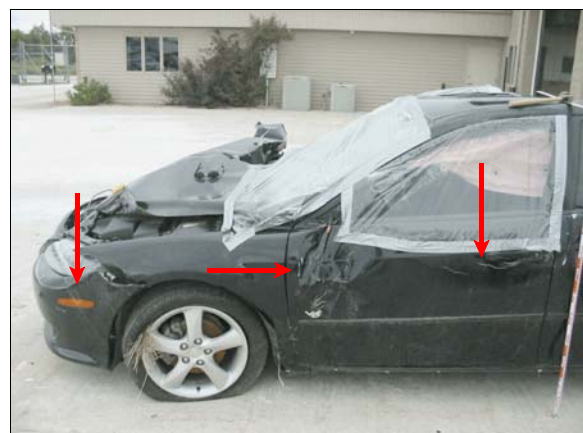


Figure 9: Arrows show damage to left fender and door from fence impact



damage did not appear associated with the pre-crash movement of the case vehicle. It is possible the damage to the tire and rim may have occurred due to post-impact towing of the vehicle with a flat left rear tire. The case vehicle’s tire data are shown in the table below.

Tire	Measured Pressure		Recommend Pressure		Tread Depth		Damage	Restricted	Deflated
	kpa	psi	kpa	psi	milli-meters	32 <sup>nd</sup> of an inch			
LF	Flat	Flat	221	32	7	9	Bead separated and grass in bead	No	Yes
RF	172	25	221	32	6	8	None, but grass in bead	No	No
LR	Flat	Flat	221	32	7	9	Unknown	No	Yes
RR	179	26	221	32	7	9	None	No	No

**Vehicle Interior:** Inspection of the case vehicle’s interior (**Figure 10**) revealed a few black scuff marks on the left roof side rail; however, they did not appear due to occupant contact. There were also a few scuff marks and blood spots on the driver’s seat back-mounted side impact air bag. The blood spots were most likely the result of blood drops striking the air bag, not the result of direct transfer due to occupant contact to the air bag. No other evidence of occupant contact was observed to any other interior surfaces or components. The case vehicle sustained several intrusions of the passenger compartment including 19 centimeters (7.5 inches) of vertical roof intrusion into the front right seat position, and 16 centimeters (6.3 inches) of vertical roof intrusion into the back right seating position. There was no intrusion into the driver’s seating position. Lastly, there was no evidence of compression of the energy absorbing steering column, and no deformation of the steering wheel rim was observed (**Figure 10**).



**Figure 10:** Overview of steering wheel, instrument panel and windshield

**Damage Classification:** Based on the vehicle inspection, the CDCs for the case vehicle were determined to be: **00-TDDO-3** for the rollover and: **00-TYLS-1** and **00-LYEW-1** for damage from the fence that occurred during the rollover. The WinSMASH reconstruction program could not be used on this crash because rollovers are out-of-scope for the program. Based on the extent of roof crush, the rollover severity was determined to be moderate. The case vehicle was towed due to damage.

The case vehicle was equipped with driver and front right passenger dual stage front air bags, front seat back-mounted side impact air bags and side curtain air bags. The left side curtain air bag and driver's seat back-mounted side impact air bag deployed in this crash when the left side of the case vehicle impacted the ground during the rollover. The driver and front right passenger air bags did not deploy because there was no front impact to the case vehicle. In addition, the right side curtain air bag and front right passenger's seat back-mounted side impact air bag did not deploy.



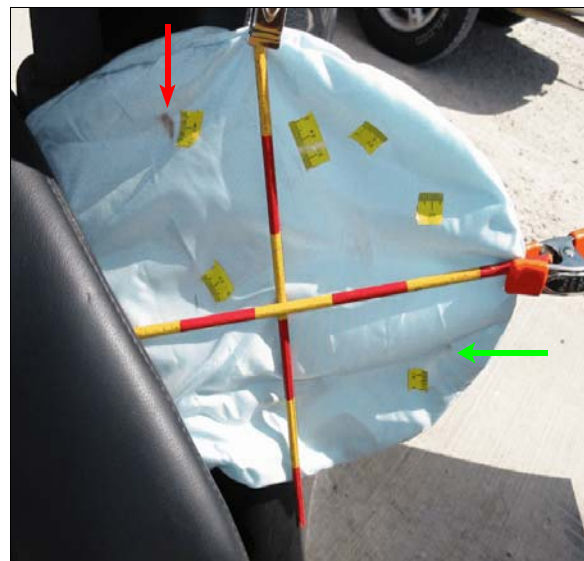
**Figure 11:** Case vehicle's driver's side curtain air bag

The left side curtain air bag (**Figures 11** and **12** below) was located along the left roof side rail under the headliner. The air bag was 142 centimeters (55.9 inches) in length and 36 centimeters (14.2 inches) in height. It was attached to the left "A"-pillar by an anchor strap approximately 24 centimeters (9.4 inches) in length. The air bag was irregular in shape and constructed without vent ports or tethers. The air bag stitching formed several inflatable chambers adjacent to the driver and back left passenger's seat positions and was designed to provide head protection in the event of a side impact. Inspection of the air bag revealed no evidence of damage due to deployment. In addition, there was no evidence of occupant contact to the side curtain air bag, although the driver's head most likely impacted the side curtain air bag during the crash.



**Figure 12:** Back left passenger's side curtain air bag

The case vehicle driver's seat back-mounted side impact air bag (**Figure 13** and **Figure 14** below) was located in the outboard side of the driver's seat back. An inspection of the air bag and the single air bag module cover flap (**Figure 15** below) revealed that the cover flap opened as designed, and there was no evidence of damage during the deployment to the cover flap or the air bag fabric. The deployed side impact air bag was approximately oval in shape and was constructed without tethers and had a single vent port (**Figure**



**Figure 13:** Driver's seat back-mounted side impact air bag, arrow shows blood spot, yellow pieces of tape show small scuffs, green arrow shows brown discoloration

14) 2 centimeters (0.8 inch) in diameter located on the outboard side near the front bottom edge of the air bag. The air bag was 29 centimeters (11.4 inches) in length and 28 centimeters (11 inches) in height. A blood spot, several thin scuffs and a brown discoloration were observed on the inside surface of the air bag (Figure 13 above). Several blood spots and an area of brown discoloration were also noted on the outboard side of the air bag (Figure 14). The blood spots were most likely the result of blood drops striking the air bag, not the result of direct transfer due to occupant contact to the air bag.

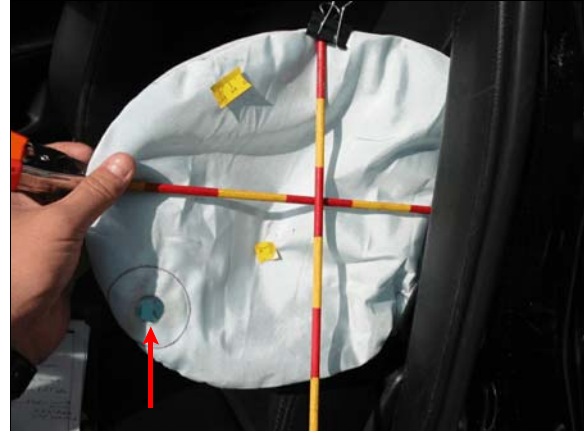


Figure 14: Outboard side of case vehicle's seat back-mounted side impact air bag, arrow shows vent port, blood spots at yellow tape near center

### CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash sequence, the case vehicle's driver [34-year-old, White (non-Hispanic) female, 165 centimeters and 55 kilograms (65 inches, 122 pounds)] was seated in an upright position with her back against the seat back, her left hand on the steering wheel, right arm on the center armrest, left foot on the floor and right foot on the accelerator pedal. The driver's seat track was located between its forward and middle position, the seat back was slightly reclined and the tilt steering column was adjusted to between its center and full up position. The driver was wearing contact lenses at the time of the crash.

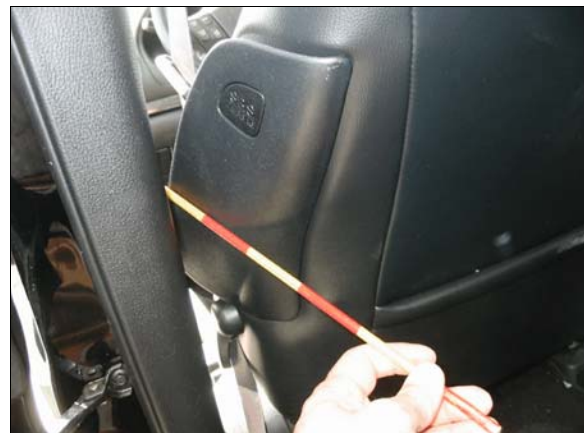


Figure 15: Driver's side impact air bag module cover flap

The case vehicle's driver was restrained by her manual, three-point, lap-and-shoulder safety belt system. Inspection of the safety belt assembly revealed load abrasions on the shoulder belt (Figure 16). The driver stated she was wearing the lap belt low on her lap and the shoulder belt over her left shoulder.

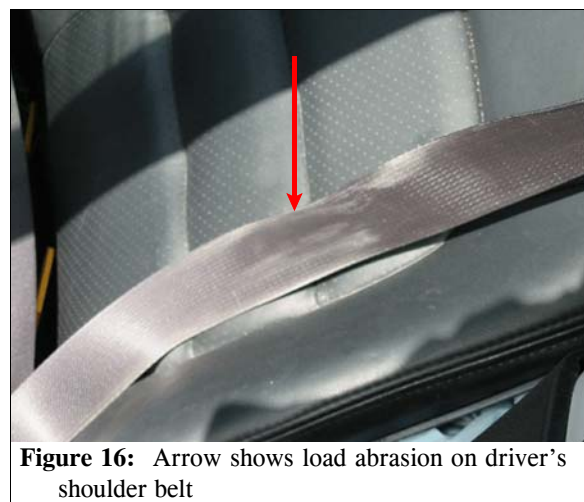


Figure 16: Arrow shows load abrasion on driver's shoulder belt

The driver's right steer maneuver to avoid the non-contact car caused the case vehicle to rotate clockwise. The driver's safety belt retractor most likely locked as the vehicle rotated and the driver moved to the left. She was most likely up against her door as the case vehicle departed the right side of the roadway and became broadside. As the case vehicle rolled over, driver side

leading, the driver moved to the left and toward the roof. The driver loaded her safety belt as the top impacted the ground during the second quarter roll. The driver most likely loaded down into her seat as the case vehicle landed on its wheels at the completion of the first full roll. The driver moved back to the left as the case vehicle impacted its left side during the fifth quarter roll. It is this contractor's opinion that the left side curtain air bag and driver's seat back-mounted side impact air bag most likely deployed during this impact. The driver's head most likely impacted the side curtain air bag and her left arm most likely impacted the seat back-mounted side impact air bag causing an abrasion to her left upper arm. As case vehicle completed its eighth and final quarter roll and landed on its wheels, the driver loaded down into her seat and moved to the left impacting her left side on her door and fracturing several left ribs. The driver remained restrained in her seat following the crash and was removed from the case vehicle by rescue personnel. The driver's use of her safety belt system and the deployment of her left side curtain air bag and seat back-mounted side impact air bag during the rollover most likely prevented the driver from sustaining more serious injury.

### CASE VEHICLE DRIVER INJURIES

The police crash report indicated the driver sustained an "A" (incapacitating) injury. The driver was transported from the scene by ambulance to a local hospital and was treated in the emergency room and released. The driver stated she received one follow-up medical visit for physical therapy to her right shoulder and lost five work days as a result of the crash. The case vehicle driver's injuries and injury mechanisms are shown in the table below.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Fracture, non-displaced {minor} left lateral rib(s), not further specified	moderate 450220.2,2	Left side interior surface, excluding hardware and/or armrest	Probable	Interviewee (same person)
2	Sprain {damage} to muscle right shoulder and collar bone area, not further specified	minor 751020.1,1	Unknown contact mechanism	Unknown	Interviewee (same person)
3	Abrasion, small, on left lateral arm, not further specified	minor 790202.1,2	Air bag, driver's side impact	Probable	Interviewee (same person)
4	Laceration {glass embedded in} middle of right calf, not further specified	minor 890600.1,1	Noncontact injury: flying glass, left front glazing	Probable	Interviewee (same person)

