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ON-SITE CERTIFIED ADVANCED 208-COMPLIANT VEHICLE INVESTIGATION

CASE NUMBER - IN09041
LOCATION - MICHIGAN
VEHICLE - 2009 SMART FORTWO
PASSION CABRIOLET CONVERTIBLE
CRASH DATE - October 2009

Submitted:
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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

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16. <i>Abstract</i> This on-site investigation focused on a 2009 Smart Fortwo Passion Cabriolet Convertible and the sources of the driver's injuries. The Smart was occupied by a restrained 59-year-old female driver. She was traveling southwest on a 3-lane urban roadway. A 2009 Toyota Camry was traveling northeast and the driver initiated a left turn into a shopping center driveway. The front plane of the Smart impacted the front plane of the Toyota. The direction of force on the Smart was within the 11 o'clock sector and the impact force was sufficient to trigger a deployment of the driver's frontal air bag. Both vehicles came to final rest in the driveway. The driver of the Smart sustained minor injuries and was transported by ambulance to a hospital where she was treated in the emergency room and released. The driver of the Toyota was not injured. Both vehicles were towed from the crash scene due to damage.					
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CRASH DIAGRAM 10

This on-site investigation focused on a 2009 Smart Fortwo Passion Cabriolet Convertible (**Figure 1**) and the sources of the driver's injuries. The vehicle was equipped with frontal air bags that were certified by the manufacturer to be compliant to the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208. This crash was brought to our attention on December 4, 2009 by the National Highway Traffic Safety Administration through the sampling activities of the National Automotive Sampling System-General Estimates System (NASS-GES). This investigation was assigned on December 10, 2009. The crash involved the Smart and a 2009 Toyota Camry LE. The crash occurred in October, 2009, at 1440 hours, in Michigan and was investigated by the county sheriff's department. The Smart was inspected on December 15, 2009. The Toyota and crash scene were inspected on December 16, 2009. The driver of the Smart was interviewed on December 17, 2009. Exemplar vehicle inspections were completed on December 21, 2009. This report is based on the police crash report, crash scene inspection, vehicle inspections, exemplar vehicle inspections, driver interview, occupant kinematic principles, and evaluation of the evidence.

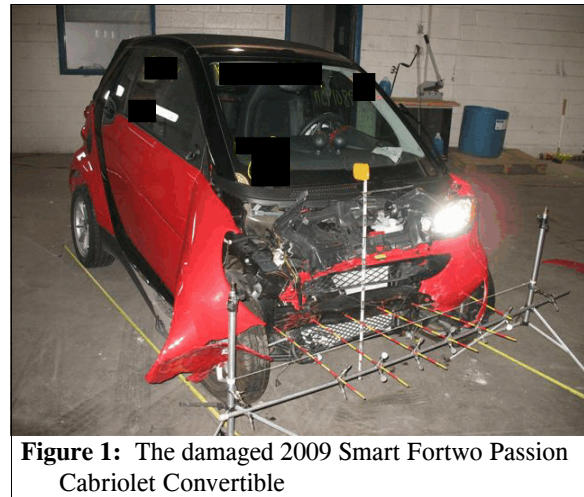


Figure 1: The damaged 2009 Smart Fortwo Passion Cabriolet Convertible

CRASH CIRCUMSTANCES

Crash Environment: The trafficway that both vehicles were traveling on was a 3-lane, undivided, suburban street that traversed in a northeast-southwest direction. The vehicles were approaching an intersection of a driveway access to a retail shopping center. The roadway had one through lane in each direction and a left turn lane for a 4-leg intersection that was immediately northeast of the crash site. The southwestbound lane was 4.8 m (15.7 ft) in width. The northeastbound lane was 3.4 m (11.2 ft) in width and the left turn lane was 3.6 m (11.9 ft) in width. The roadway pavement markings consisted of solid double yellow through lane lines, solid white left turn lane line, and solid white left turn arrows and lettering. At the time of the crash, the light condition was daylight and the atmospheric condition was clear. The roadway pavement was dry, level bituminous and the speed limit was 64 km/h (40 mph). The traffic density at the time of the crash was moderate and the site of the crash was suburban commercial/residential. The Crash Diagram is on page 10 of this report.

Pre-Crash: The Smart was occupied by a restrained 59-year-old female driver. The vehicle was traveling southwest (**Figure 2**) at a driver estimated speed of 64 km/h (40 mph). The driver intended to continue straight ahead. The Toyota was being driven by a restrained 26-year-old male. He was traveling northeast with several other vehicles in the left turn lane. He intended to turn left into a shopping center driveway (**Figure 3**). The driver of the Smart stated during the SCI interview that the Toyota's driver suddenly executed a left turn and she had no time to take

any avoidance maneuvers. The crash occurred within the southwestbound lane in the intersection of the driveway.

Crash: The front plane of the Smart (**Figure 4**) impacted the front plane of the Toyota (**Figure 5**). The direction of force on the Smart was within the 11 o'clock sector and the impact force was sufficient to trigger a deployment of the driver's frontal air bag. The Smart rotated clockwise approximately 90 degrees and came to final rest in the mouth of the driveway heading northwest. The Toyota came to final rest in the mouth of the driveway heading north.



Figure 2: Approach of the Smart, arrow shows approach of the Toyota



Figure 3: Approach of the Toyota; arrow shows approach of the Smart

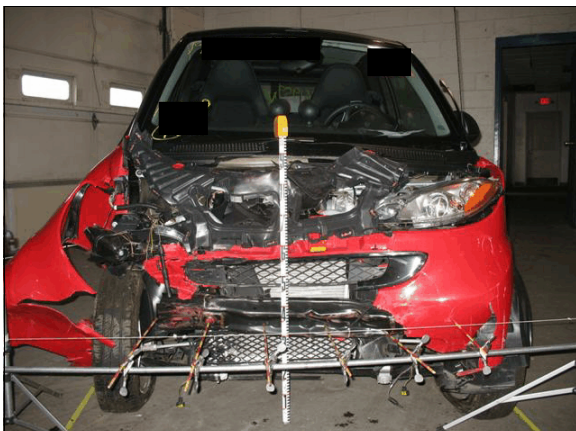


Figure 4: Damage on the front plane of the Smart from the impact with the front plane of the Toyota



Figure 5: Damage to the front plane of the Toyota from the impact with the front plane of the Smart

Post-Crash: The police were notified of the crash at 1435 hours. The driver of the Smart was removed from the vehicle through the left front door by emergency medical personnel and transported by ambulance to a hospital. She was treated in the emergency room for minor injuries and released. The driver of the Toyota was not injured. Both vehicles were towed from the crash scene due to damage.

The 2009 Smart Fortwo Passion Cabriolet was a rear wheel drive, 2-door convertible (VIN: WMEEK3169K-----) that was manufactured in January, 2009. It was equipped with a 1.0-L, 3-cylinder engine, 5-speed automatic transmission, 4-wheel anti-lock brakes with electronic brake force distribution and emergency braking assist, traction control, electronic stability control, and a tire pressure monitoring system. The front row was equipped with bucket seats, integral head restraints, lap-and-shoulder safety belts, driver and front right passenger frontal air bags, and seat-mounted side impact air bags. There was no second row. The vehicle was also equipped with a roll-bar behind the front row. The specified wheelbase was 187 cm (73.6 in).

CASE VEHICLE DAMAGE

Exterior Damage: The impact with the Toyota involved the front plane of the Smart. The front bumper fascia, bumper bar, grille, right headlamp/turn signal assembly, hood, right fender, and the right front wheel were directly damaged. The direct damage began at the front right bumper corner and extended 110 cm (43 in) across the bumper. The crush measurements were taken on the bumper bar and the maximum residual crush was 30 cm (11.8 in) occurring at C₆ (**Figure 6**). The vehicle’s right side wheelbase (**Figure 7**) was reduced 11 cm (4.3 in) while the left side wheelbase was unchanged. Induced damage involved both fenders and the right sill trim cover. The table below shows the front crush profile.

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	110	30	110	17	24	28	27	27	30	10	0
in		43.3	11.8	43.3	6.7	9.4	11.0	10.6	10.6	11.8	3.9	0.0

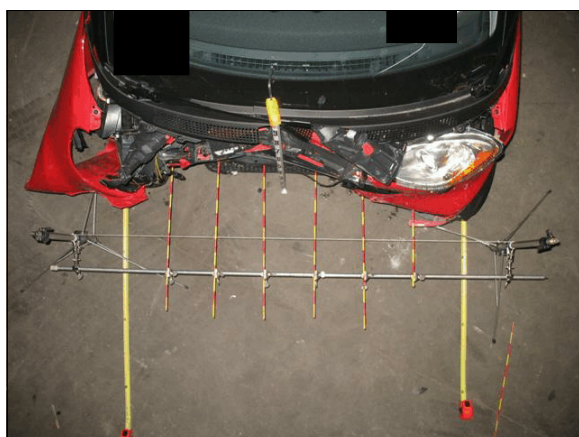


Figure 6: Top view of the crush on the front plane of the Smart



Figure 7: Shortened right side wheelbase and induced damage on the fender and sill trim cover of the Smart

Damage Classification: The Collision Deformation Classification (CDC) for the front impact was 11FDEW4 (340 degrees). The Damage algorithm of the WinSMASH program calculated the total Delta V for the Smart as 29 km/h (18 mph). The longitudinal and lateral velocity changes were -27.3 km/h (-17.0 mph) and 9.9 km/h (6.2 mph), respectively. Based in the damage to both vehicles, the results appeared reasonable.

The manufacturer’s recommended tire size was P155/60R15 for the front wheels and P175/55R15 for the rear wheels. The Smart was equipped with the recommended size tires. The vehicle’s tire data are shown in the table below.

Tire	Measured Pressure		Vehicle Manufacturer’s Recommended Cold Tire Pressure		Tread Depth		Damage	Restricted	Deflated
	kPa	psi	kPa	psi	milli-meters	32 nd of an inch			
LF	Flat	Flat	200	29	6	8	None	No	Yes
LR	179	26	248	36	7	9	None	No	No
RR	193	28	248	36	6	8	None	No	No
RF	Flat	Flat	200	29	7	9	None	Yes	Yes

Vehicle Interior: The inspection of the Smart’s interior (**Figures 8**) revealed a broken windshield wiper lever (**Figure 9**) probably from contact by the driver’s right hand. The lower left instrument panel was lightly scuffed from contact by the driver’s knees. There was no deformation of the steering wheel or compression of the energy absorbing steering column.



Figure 8: Front row of the Smart viewed from left front door; arrows show scuffs on lower instrument panel



Figure 9: The windshield wiper lever was broken from occupant contact

Both doors remained closed and operational. The pre-crash status of the window glazing was either closed or fixed. None of window glazings were damaged. The passenger compartment sustained longitudinal intrusions of the right and left toe pans. The right toe pan intruded 9 cm

(3.5 in), while the left toe pan (Figure 10) intruded 6 cm (2.4 in).

AUTOMATIC RESTRAINT SYSTEM

The Smart was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system. The driver's frontal air bag deployed in this crash. The front passenger seat was equipped with a weight sensor. The deployment of the passenger frontal air bag was suppressed since no passenger was seated in the vehicle at the time of the crash.

The Smart was also equipped with a side impact air bag system that consisted of front seat-mounted side impact air bags. These air bags did not deploy in this crash.

The driver's frontal air bag was located within the steering wheel hub. The module cover was a two flap configuration constructed of pliable vinyl (Figure 11). Each flap was 6.5 cm (2.6 in) wide at the top, 5 cm (2 in) wide at the bottom, and 13 cm (5.1 in) in height. An inspection of the cover flaps revealed that they opened at the designated tear points and were undamaged. The deployed air bag (Figure 12) was 60 cm (23.6 in) in diameter and had one 4 cm (1.6 in) diameter vent port and four 6 cm (2.4 in) tethers. The vent port (Figure 13) was located on the back of the air bag at the 12 o'clock position, near the hub. Inspection of the air bag revealed no discernable evidence of occupant contact and no damage.

MANUAL RESTRAINT SYSTEM

The Smart was equipped with lap-and-shoulder safety belts for both seating positions. The driver's safety belt consisted of continuous loop belt webbing, an Emergency Locking Retractor (ELR), sliding latch plate, and a fixed upper anchor. The front passenger safety belt was similar but was equipped with a switchable ELR/Automatic Locking Retractor (ALR). Both seats were equipped with retractor mounted pretensioners with force limiters. The driver's pretensioner actuated during the crash. The front passenger pretensioner did not actuate.



Figure 10: The left toe pan of the Smart intruded 6 cm (2.4 in)



Figure 11: Air bag module cover flaps



Figure 12: The driver's air bag

The inspection of the driver's safety belt assembly revealed load abrasions on the belt webbing and D-ring (**Figure 14**). The abrasions on the safety belt webbing were located 118 cm (46.5 in) above the stop button. Load abrasions were also present on the latch plate belt guide (**Figure 15**). This evidence indicated that the driver was restrained in this crash.

CASE VEHICLE DRIVER KINEMATICS

Based on the SCI interview, the driver of the Smart [59-year-old, female; 170 cm (67 in) and 73 kg (160 lbs)] was seated in an upright posture with her back against the seat back. The seat track was located between the forward and center positions and the seat back was upright. The driver's hands were positioned on the steering wheel at the 2 and 10 o'clock positions. The steering column was not equipped with a tilt or telescoping adjustment. The driver reported that the lap-and-shoulder safety belt was worn snugly, but the shoulder belt would routinely rub her neck and was uncomfortable. The driver was wearing glasses at the time of the crash.

The impact on the front plane of the Smart displaced the driver forward and left, opposite the 11 o'clock direction of force and she loaded the safety belt. She sustained a contusion on the chest from the safety belt. While there was no discernable evidence of occupant contact on the driver's frontal air bag, occupant kinematic principles and the severity of this crash suggest that her face and chest probably loaded the air bag. Both of the driver's shins contacted the lower left instrument panel causing contusions on the shins. Her right wrist contacted and broke the windshield wiper lever, which caused a laceration on the wrist. Her right elbow and left hand contacted the instrument panel causing a laceration on the elbow and a contusion and laceration on the left hand. The driver also sustained a sprain of the right first toe from contacting the foot controls. The driver remained restrained in her seat position and was removed from the vehicle through the left front door by emergency medical personnel.



Figure 13: Air bag vent port on the driver's frontal air bag of the Smart



Figure 14: Load abrasion on driver's D-ring and belt webbing



Figure 15: Load abrasions on driver's latch plate belt guide

The driver was transported by ambulance to a hospital where she was treated in the emergency room for minor injuries and released. She had one follow-up visit to her family physician and no other injuries were diagnosed. The driver missed seven work days as a result of the crash. The table below presents the driver's injuries and injury sources.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source	Source Confidence	Source of Injury Data
1	Contusion right anterolateral chest wall over right 3 rd -4 th ribs	minor 490402.1,1	Torso portion of safety belt system	Probable	Emergency room records
2	Lacerations, superficial, right lateral wrist, not further specified	minor 790602.1,1	Steering column-mounted windshield wiper lever	Probable	Emergency room records
3	Laceration on right elbow, not further specified	minor 790602.1,1	Center instrument panel	Probable	Interviewee (same person)
4	Contusions dorsum (top) left hand, not further specified	minor 790402.1,2	Left instrument panel	Probable	Interviewee (same person)
5	Lacerations, superficial on dorsum left hand, not further specified	minor 790602.1,2	Left instrument panel	Probable	Emergency room records
6	Abrasions bilateral proximal shins, just below knee caps	minor 890202.1,3	Left lower instrument panel (includes knee bolster)	Certain	Interviewee (same person)
7	Sprain right 1 st (great) toe	minor 851002.1,1	Floor, foot controls	Probable	Emergency room records

OTHER VEHICLE

The 2009 Toyota Camry LE was a front wheel drive, 4-door sedan (VIN: 4T1BE46K99U-----) equipped with a 2.4-liter, 4-cylinder engine, 5-speed automatic transmission, and 4-wheel, anti-lock brakes with electronic brake force distribution and emergency brake assist. The front row was equipped with bucket seats with adjustable head restraints, lap-and-shoulder safety belts, dual stage driver and front passenger frontal air bags, driver knee bolster air bag, front seat-mounted side impact air bags, and side impact inflatable curtain air bags protecting all outboard seating positions. The frontal air bags on this vehicle were certified by the manufacturer to be compliant to the Advanced Air Bag portion of Federal Motor Vehicle Safety Standard (FMVSS) No. 208.

Exterior Damage: The impact with the Smart involved the front plane of the Toyota. The front bumper, bumper fascia, grille, hood, right fender, right headlamp/turn signal assembly, and right front wheel were directly damaged (**Figure 16**). The direct damage began at the front right bumper corner and extended 75 cm (29.5 in) along the front bumper. The crush measurements

were taken at the bumper level and the maximum residual crush was 6 cm (2.4 in) occurring at C₆ (Figure 17). The right side wheelbase was reduced 6 cm (2.4 in), while the left side wheelbase was unchanged. The induced damage involved the hood and right front door. The table below shows the front crush profile.

Units	Event	Direct Damage		Field L	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	75	6	118	0	0	4	6	5	6	49	0
in		29.5	2.4	46.5	0.0	0.0	1.6	2.4	2.0	2.4	19.3	0.0



Figure 16: Damage on the Toyota from the impact with the Smart

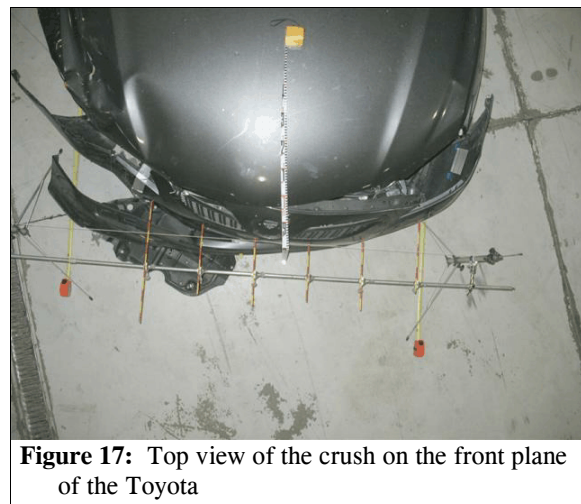


Figure 17: Top view of the crush on the front plane of the Toyota

Damage Classification: The Toyota’s CDC for the front plane impact was 01FZEW1 (20 degrees). The Damage algorithm of the WinSMASH program calculated the Toyota’s total Delta-V as 17 km/h (10.6 mph). The longitudinal and lateral velocity changes were -16 km/h (-9.9 mph) and -5.8 km/h (3.6 mph), respectively. Based on the damage to both vehicles, the results appeared reasonable.

The vehicle manufacturer’s recommended tire size was P215/55R17. The Toyota was equipped with the recommended size tires. The vehicle’s tire data are shown in the table below.

Tire	Measured Pressure		Vehicle Manufacturer’s Recommended Cold Tire Pressure		Tread Depth		Damage	Restricted	Deflated
	kPa	psi	kPa	psi	milli-meters	32 nd of an inch			
LF	214	31	221	32	2	3	None	No	No
LR	221	32	221	32	2	2	None	No	No

Other Vehicle (Continued)

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<i>Tire</i>	<i>Measured Pressure</i>		<i>Vehicle Manufacturer's Recommended Cold Tire Pressure</i>		<i>Tread Depth</i>		<i>Damage</i>	<i>Restricted</i>	<i>Deflated</i>
	kPa	psi	kPa	psi	milli-meters	32 nd of an inch			
RR	41	6	221	32	2	2	None	No	No
RF	221	32	221	32	2	3	None	No	No

Other Vehicle's Occupants: The police crash report indicated that the driver of the Toyota (26-year-old, male) was restrained by the lap-and-shoulder safety belt. His frontal and knee bolster air bags deployed as a result of the crash. The driver did not sustain any injuries and was not transported for medical treatment.

