TRANSPORTATION SCIENCES
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VERIDIAN REMOTE SIDE IMPACT INFLATABLE OCCUPANT PROTECTION SYSTEM INVESTIGATION
VERIDIAN CASE NO. CA01-021
VEHICLE: 2000 BMW 328Ci
LOCATION: NEW JERSEY
CRASH DATE: DECEMBER 2000

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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 are 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.

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BACKGROUND

This remote investigation focused on the performance of the side impact inflatable occupant protection system of a 2000 BMW 328Ci **(Figure 1)**, 2-door coupe that was involved in a single vehicle run-off-road crash with breakaway luminaire pole. The impact was located on the driver's door and deployed the door mounted side impact air bag and the Head Protection System (HPS), tubular head air bag. The driver sustained multiple abdominal injuries and pelvic fractures. He was admitted to a regional trauma center for six days for treatment of his injuries.

Figure 1. Overall view of the BMW 328Ci.

Notification of this crash was provided to the Veridian SCI team on February 5, 2001 by the investigative contractor for the New Jersey CIREN center. The notification was forwarded to NHTSA and approved for remote investigation on February 7.

SUMMARY

Crash Site

The crash occurred on a four lane road in a commercial area during nighttime hours **(Figure 2)**. In the vicinity of the crash site, the roadway curved to the right with respect to the BMW's path of travel. The asphalt road surface was wet with a posted speed limit of 56 km/h (35 mph). Although the environmental surfaces were wet, the police report noted that the weather was clear and the area was lighted by overhead luminaires. The edges of the road were bordered by shallow barrier curbs and concrete sidewalks. The struck luminaire was located outboard of the sidewalk on a grassy area that was level to the roadway. The luminaire consisted of a frangible base with an aluminum pole and a mast arm with the light fixture that extended over the road edge. The travel lanes were delineated by broken white lane lines and a double yellow center line.

Figure 2. Southbound approach of the BMW.

Vehicle Data

The 2000 BMW 328Ci was a 2-door coupe that was identified by vehicle identification number WBABM534XYJ (production number deleted). The BMW was equipped with a 2.8 liter 6-cylinder conventionally mounted engine linked to a 5-speed manual transmission with rear wheel drive. The braking

system was four-wheel disc with anti-lock. The interior was configured with front bucket seats and a rear bench seat with forward folding backrests. The BMW was equipped with dual stage frontal air bags for the driver and passenger positions, seat belt buckle pre-tensioners, and door mounted side impact air bags and the HPS for both front positions. Due to the lateral impact force, the left side air bag and HPS deployed. The frontal air bag system did not deploy and the front seat belt buckle pre-tensioners did not fire. The manual belt systems consisted of continuous loop webbings, sliding latch plates, and adjustable D-rings for the front outboard seated positions.

Crash Sequence

Pre-Crash

The 25 year old adult male driver of the BMW was traveling in a southerly direction on the outboard lane of the four lane highway at an unknown rate of speed. As he entered the right curve, the driver lost directional control of the BMW and departed the roadway in a clockwise yaw **(Figure 3)**. In the area of the road departure, the barrier curb was approximately 5-8 cm (2-3") in height, therefore the curb did not alter the vehicle's trajectory or damage the alloy wheels or tires.

Figure 3. Point of departure and struck luminaire.

Crash

The left door area of the BMW impacted the luminaire in a near broadside configuration. The lateral impact force was within the 9 o'clock sector with a Collision Deformation Classification (CDC) of 09-LPAW-4. The impact fractured the frangible base **(Figure 4)** of the pole. Although the base fractured, the barrier algorithm of the WinSMASH program was used to compute a total velocity change of 31.4 km/h (19.5 mph) with a lateral component of 31.0 km/h (19.2 mph). As a result of the lateral impact, the left door mounted side impact air bag and the left HPS deployed. There was secondary damage at the left A-pillar area of the vehicle, however, based on the remote nature of this investigation, this damage could not be associated with the crash event.

Figure 4. Replaced frangible base.

Post-Crash

The BMW traveled beyond the position of the pole and came to rest facing in a southerly direction. The front right passenger of the BMW exited the vehicle from the right front door and refused medical treatment. The driver attempted to exit the vehicle from the front right door, however, due to the pain associated with his injuries, he remained in the vehicle in the front right seated position. Emergency medical personnel arrived on-scene and evaluated the driver in the vehicle. He was placed on a long board and removed from the BMW to an ambulance. He was transported by the ambulance to a regional trauma center where he was admitted for six days for treatment of his injuries.

Vehicle Damage

Exterior

The 2000 BMW 328Ci sustained moderately severe left side damage **(Figure 5)** from its impact with the breakaway pole. The direct damage was located on the rear third aspect of the left door and was documented at a length of 22.0 cm (8.7"). Maximum crush was 42 cm (16.5") located at the mid aspect of the door. The damage extended vertically from the sill to the roof side rail which bowed the vehicle. The combined induced and direct damage length extended from the left A-pillar to the leading edge of the left rear wheel opening.

Figure 5. Left side damage from the pole impact.

Components damaged by the impact included the left door, sill, floor, roof and roof side rail. The Collision Deformation Classification was 09-LPAW-4.

Interior

The interior damage to the 328Ci was associated with exterior deformation and the resulting intrusion. The driver contacted numerous components which included the left door and armrest, the left aspect of the knee bolster, and the center console.

Maximum intrusion was approximately 30 cm (12") located at the mid aspect of the left door and sill of the vehicle. Additional intrusions included 28 cm of left side rail displacement, 4 cm of lateral displacement of the left A-pillar, and 23 cm of sill displacement. The intrusion crushed the driver's seat cushion laterally and rotated the seat back in a counterclockwise direction.

Air Bag Systems

The BMW was equipped with dual-stage frontal air bags for the driver and right passenger positions **(Figure 6)**. In addition, the frontal system included seat belt buckle pre-tensioners. Due to the lateral impact, the frontal air bag system did not deploy. The driver air bag was housed in a typical configuration with in the 3-spoke steering wheel rim. The front right passenger air bag was in a top mount position within the right instrument panel area and concealed by a single cover flap.

Figure 6. Non-deployed frontal air bags.

Supplemental side impact protection consisted of door mounted side impact air bags and tubular head air bags (HPS) for the driver and front right passenger. The left side torso bag and the left HPS deployed as a result of the pole impact sequence. The door mounted side impact air bag was concealed by a single cover flap in the door trim panel, above the level of the armrest. The air bag module within the door, was concealed by symmetrical H-configuration flaps. The air bag membrane was approximately 48 cm in length and 21 cm in height **(Figure 7)**. There was no damage or contact evidence on the side impact air bag.

The HPS air bag deployed from the left roof side rail **(Figure 8)**. The head liner separated from the side rail trim panel to allow for the deployment of the HPS. The HPS air bag was approximately 84 cm in length and 5 cm in diameter. The bag was tethered at both the A- and C-pillars. The mid aspect of the HPS was lacerated from probable with the shattered side glass and the struck pole. Although the driver probably contacted the HPS during the crash sequence, there was no evidence of occupant contact.

Figure 7. Deployed door mounted side impact air bag.

Figure 8. Deployed HPS with lacerations to membrane.

Driver Demographics

Age/Sex:	25 year old male
Height:	183 cm
Weight:	84 kg
Manual Restraint System Usage:	None, 3-point lap and shoulder belt system was available.
Usage Source:	Vehicle images
Mode of Transport From Scene:	Ambulance to a regional trauma center
Type of Medical Treatment:	Admitted for six days
Glascow Coma Score on Arrival:	15

Driver Injuries

Driver Injury	Injury Severity AIS90/Update 98	Injury Source
Bilateral iliac fractures**,** bilateral superior high pubic rami fractures, left inferior pubic rami fracture, right sacral ala fracture, non-displaced left acetabulum fracture	Moderate (852600.2,1; 852600.2,2; 852600.2,5; 852600.2,6)	Intruding left door panel and armrest
Left L1 - L3 transverse process fractures, small left retroperitoneal hematoma with hematuria	Moderate (650620.2,8; 650620.2,8; 650620.2,8)	Intruding left door panel and armrest
Anterior subluxation of L5 on S1	Moderate (650604.2,8)	Intruding left door panel and armrest
Right chin abrasion	Minor (290202.1,1)	Flying glass or front right passenger (possible)

* Source of injury data - Trauma center

Driver Kinematics

The driver of the BMW was seated in a presumed upright driving posture with the seat track adjusted to a rear track position and the seat back slightly reclined. He was not wearing the manual belt system.

At impact, the left side impact air bag and left HPS deployed. The driver initiated a lateral trajectory into the path of the intruding left side interior components. His left pelvic region loaded the intruding left door panel and the armrest **(Figure 9)** which resulted in multiple pelvic fractures, fractures of the transverse processes of L1-L3, anterior subluxation of L5 on S1, and a small left retroperitoneal hematoma with hematuria. The intrusion of the left side components displaced the driver against the center armrest **(Figure 10)**. Contact with the interior components was evidenced by scuff marks. His left knee contacted the left aspect of the knee bolster, however, no injury resulted.

Figure 9. Left door panel and side air bag cover flap.

Figure 10. Compressed driver's seat cushion.

The driver's left thoracic region loaded the deployed left door mounted side impact air bag. Although no contact evidence was noted to the bag, the air bag prevented left rib and internal injures. His head contacted the inflated HPS which prevented direct head contact to the struck luminaire. Without the presence of the HPS, the driver probably would have sustained serious or fatal head injuries. The driver did sustain an abrasion of the right chin that possibly resulted from contact with flying glass or the front right passenger.

The driver rebounded into the deformed left front seat back where he came to rest. He attempted to exit the BMW from the right front door, however, due to severe pain, the driver remained in the vehicle in the front right seated position. He was subsequently removed from the vehicle by medical personnel and transported to a regional trauma center where he was admitted for treatment for a period of six days.

Front Right Passenger Data

The front right passenger of the BMW 328Ci was a 26 year old male. He was seated in a presumed upright posture. Although the Police Accident Report (PAR) listed the passenger as restrained, the vehicle did not yield evidence of restraint usage. The PAR coding was limited to interview data since the passenger exited the vehicle prior to police arrival. At impact, the passenger initiated a lateral trajectory to his left. He probably contacted the center console and the driver. Immediately following the crash, the passenger opened the right front door and exited the vehicle. He refused treatment at the scene of the crash.