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ON-SITE ROLLOVER INVESTIGATION

CASE NUMBER - IN10029
LOCATION - MISSOURI
VEHICLE - 2010 HYUNDAI ACCENT SE
CRASH DATE - July 2010

Submitted:

January 10, 2011

Contract Number: DTNH22-07-C-00044

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. *Report No.* IN10029	2. *Government Accession No.*	3. *Recipient's Catalog No.*	
4. *Title and Subtitle* On-Site Rollover Investigation Vehicle - 2010 Hyundai Accent SE Location - Missouri		5. *Report Date:* January 10, 2011 6. *Performing Organization Code*	
7. *Author(s)* Special Crash Investigations Team #2		8. *Performing Organization Report No.*	
9. *Performing Organization Name and Address* Transportation Research Center Indiana University 501 South Madison Street, Suite 105 Bloomington, Indiana 47403-2452		10. *Work Unit No. (TRAIS)* 11. *Contract or Grant No.* DTNH22-07-C-00044	
12. *Sponsoring Agency Name and Address* U.S. Department of Transportation (NVS-411) National Highway Traffic Safety Administration National Center for Statistics and Analysis Washington, D.C. 20590-0003		13. *Type of Report and Period Covered* Technical Report Crash Date: July 2010 14. *Sponsoring Agency Code*	
15. *Supplementary Notes* On-site rollover investigation involving a 2010 Hyundai Accent SE.			
16. *Abstract* This on-site investigation focused on the rollover of a 2010 Hyundai Accent SE and the sources of the driver's injuries. The restrained 35-year-old male driver and sole occupant of the Hyundai was traveling west in the outside lane of a 4-lane divided U.S. Highway during day time hours and clear, dry weather conditions. The vehicle departed the left side of the roadway onto the bituminous median shoulder. The driver initiated a right steering maneuver and the vehicle began to yaw clockwise and reentered the roadway in a northwest direction. The driver initiated a left steering maneuver and the vehicle departed the right side of the road in a counterclockwise yaw and rolled over right side leading 12 quarter turns. The driver remained restrained within the vehicle throughout the crash. He was transported by air ambulance to a trauma center and admitted. He sustained a serious injury and was hospitalized for three days.			
17. *Key Words* Rollover Motor Vehicle Traffic Crash Injury Severity		18. *Distribution Statement* General Public	
19 *Security Classif. (of this report)* Unclassified	20. *Security Classif. (of this page)* Unclassified	21. *No. of Pages* 8	22. *Price*

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IN10029

This on-site investigation focused on the rollover of a 2010 Hyundai Accent SE (**Figure 1**) and the sources of the driver's injuries. This crash was brought to the National Highway Traffic Safety Administration's (NHTSA) attention on August 10, 2010 by Special Crash Investigation Team 2. The investigation was assigned on August 20, 2010. The crash involved only the Hyundai, which departed the roadway and rolled over. The crash occurred in July, 2010, at 1050 hours, in Missouri and was investigated by the Missouri State Highway Patrol. The crash scene was inspected on August 25, 2010. The Hyundai was inspected on August 27, 2010. The driver was interviewed on September 14, 2010. This report is based on the police crash report, vehicle inspection, crash scene inspection, exemplar vehicle inspection, driver interview, medical records, occupant kinematic principles, and evaluation of the evidence.

Figure 1: The damaged 2010 Hyundai Accent SE

CRASH CIRCUMSTANCES

Crash Environment: This crash occurred on a 4-lane divided U.S. highway during daylight hours and clear and dry weather conditions. The trafficway had two straight bituminous lanes in each direction and was divided by a grass median. Each roadway was bordered by bituminous shoulders. Each travel lane was approximately 3.7 m (12 ft) wide. The outside shoulder was 3.4 m (11.2 ft) wide, while the median shoulder was 3.2 m (10.5 ft) wide. A gravel driveway 3.4 m (11.2 ft) in width was located on the north side of the highway. The gravel driveway ran parallel to the highway and intersected a second gravel driveway, which formed a T-intersection with the highway. The speed limit was 105 km/h (65 mph). There was no other traffic on the roadway at the time of the crash. The Crash Diagram is on page 8 of this report.

Pre-Crash: The restrained 35-year-old male driver was traveling west in the first lane from the right. The vehicle entered the second lane and for unknown reasons departed the left side of the roadway onto the bituminous median shoulder. The driver initiated a right steering maneuver and the vehicle began to yaw clockwise and reentered the roadway in a northwest direction (**Figure 2**). The driver initiated a left steering maneuver and the vehicle departed the right side of the road (**Figure 3**) in a counterclockwise yaw and traversed down a negative 13% grass covered

Figure 2: View to northwest where the Hyundai reentered the roadway from the median shoulder; arrow shows area of rollover initiation

grade. The vehicle entered the gravel driveway that ran parallel to the highway. The initiation of the rollover occurred on this driveway (**Figure 4**).

Crash: The right side tires of the Hyundai created furrows in the gravel and the vehicle tripped and rolled over right side leading. The vehicle rolled over on the driveway and across the second gravel driveway, which intersected the highway. The vehicle continued to rollover along a positive 8.3% grade back toward the highway. The vehicle came to final rest on its wheels with the front end partially on the north shoulder of the roadway facing southeast. During the crash, the driver's seat-mounted side impact air bag and side impact inflatable curtain (IC) air bag deployed.

Post-Crash: The police and emergency medical personnel responded to the crash scene. The driver was transported by air ambulance to a trauma center and hospitalized. The vehicle was towed due to damage.

Figure 3: The Hyundai departed the road in a counterclockwise yaw and approached the area of rollover initiation

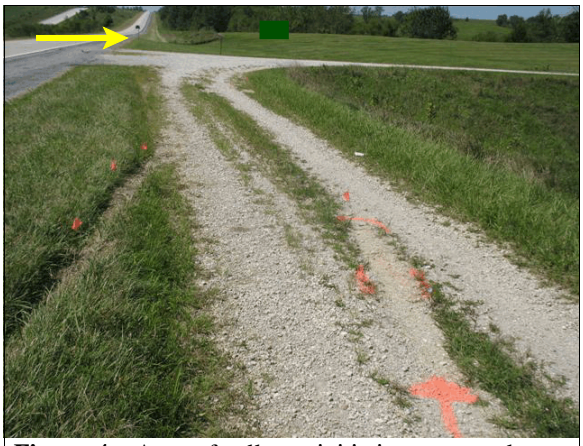

Figure 4: Area of rollover initiation; arrow shows area of final rest

CASE VEHICLE

The 2010 Hyundai Accent was a front wheel drive, 5-passenger, 2-door coupe (VIN: KMHCN3ACXAU------) equipped with a 1.6-liter, I-4 engine and a 4-speed automatic transmission. The front row was equipped with bucket seats, adjustable head restraints, lap-and-shoulder safety belts, driver and front right passenger dual stage frontal air bags, front seat-mounted side impact air bags, and side impact inflatable curtain (IC) air bags that provided protection for the front and second row outboard seating positions. The second row was equipped with a bench seat with folding back, lap-and-shoulder safety belts, adjustable head restraints, and Lower Anchors and Tethers for Children (LATCH) in the outboard seating positions. The driver estimated the vehicle's mileage was approximately 644 kilometers (400 miles). The vehicle's specified wheelbase was 250 cm (98.4 in).

CASE VEHICLE DAMAGE

Exterior Damage: The Hyundai sustained damage on the top and both side planes (**Figures 5** and **6**) during the rollover. The direct damage on the left side plane began 48 cm (18.9 in) forward of the left front axle and extended 338 cm (133 in) rearward along the left side plane of the vehicle. Rocks and grass were embedded in the bead of the left front tire, which was still inflated. Grass was embedded in the bead of the left rear tire, which was deflated and positively cambered 20 degrees. The direct damage on the right side plane began on the top of the right fender located

222 cm (87.4 in) forward of the right rear axle and extended rearward 220 cm (86.6 in) on the A-pillar and roof side rail. There was no direct damage on the right front door or quarter panel. Grass was embedded in the bead of the right front and right rear tires. The right rear tire was deflated and the wheel was positively cambered 40 degrees. The right front wheel was positively cambered approximately 20 degrees. The left side wheelbase was extended 5 cm (2 in), while the right side wheelbase was reduced 2 cm (0.8 in). The direct damage on the top plane resided primarily on both roof side rails with minor scratches located behind the sunroof. There was no direct damage on the hood. The maximum vertical crush was 8 cm (3.1 in), which occurred on the roof adjacent to the left rear window and 9 cm (3.5 in) inboard of the roof side rail. The maximum lateral crush was 9 cm (3.5 in), which occurred on the left roof side rail located 133 cm (52.4 in) rear of the left front axle.

Figure 5: Damage from the rollover on the left side and top planes of the Hyundai

Figure 6: Damage from the rollover on the right side and top planes of the Hyundai

Damage Classification: The Collision Deformation Classification (CDC) for the rollover was 00TZDO2. The WinSMASH program could not be used to calculate a Delta V since rollovers are out of scope for the program. Based on the extent of the roof crush, the severity of the damage was minor.

The vehicle manufacturer's recommended tire size was P205/45R16. The vehicle was equipped with the recommended size tires. The Hyundai'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	32nd of an inch			
LF	214	31	221	32	7	9	None	No	No
LR	Flat	Flat	221	32	8	10	Debeaded	No	Yes
RR	Flat	Flat	221	32	7	9	Debeaded	No	Yes
RF	207	30	221	32	7	9	None	No	No

Vehicle Interior: The inspection of the interior of the Hyundai revealed no discernable evidence of occupant contact. There was no damage to the steering wheel or compression of the energy absorbing steering column. The right front and right rear doors remained closed and operational. The rear hatch was jammed shut. The right front and left front glazing was partially open prior to the crash. The sunroof glazing was closed, while the remaining glazing was fixed. The left front, left rear, right rear, and sunroof glazing was disintegrated from impact forces. The windshield was cracked and had collapsed from weathering. The remaining glazing was undamaged.

The vehicle sustained eight intrusions of the passenger compartment. The most severe intrusions into the driver's space involved the left roof side rail, left B-pillar, and roof. The left roof side rail and B-pillar intruded laterally 7 cm (2.8 in) and 5 cm (2 in), respectively. The roof intruded vertically approximately 5 cm (2 in).

ROLLOVER DISCUSSION

The Hyundai was not equipped with any rollover mitigation features. The NHTSA has given the vehicle a four star rollover rating on a five star scale and a Static Stability Factor of 1.35[1]. A four star rating indicates that the vehicle has a 10%-20% chance of a rollover when involved in a single vehicle crash. The chance of rollover for this vehicle was rated at 10%. The Static Stability Factor (SSF) is a calculation based on the vehicle's track width and height of its center of gravity. The result of the calculation is a measure of a vehicle's resistence to rollover. A higher SSF indicates a more stable vehicle. The majority of passenger vehicles have an SSF of 1.30 to 1.50[2]. This vehicle model also did not tip-up in the dynamic steering maneuver test in which the test vehicle is put through a fish-hook shaped steering maneuver (i.e., hard left and hard right steer) at a speed of between 56 km/h-80km/h (35-50 mph).

The rollover of the Hyundai was initiated as the vehicle was in a counterclockwise yaw following the right roadside departure. As the right side tires produced furrows on the gravel driveway, the lateral force on the tires was sufficient to trip the vehicle and it rolled over right side leading 12 quarter turns across a distance of 53 m (173.8 ft). The calculated speed of the vehicle at the trip point was as 81 km/h (50.3 mph).

AUTOMATIC RESTRAINT SYSTEM

The Hyundai was equipped with a Certified Advanced 208-Compliant (CAC) frontal air bag system that consisted of dual stage driver and front right passenger air bags, driver seat position sensor, buckle-mounted pretensioners, and a front right passenger pattern recognition sensor. Based on the Holmatro Rescuer's Guide to Vehicle Safety Systems, the vehicle's front satellite impact sensors were located within the driver and passenger side inner frame rails. The

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[1] www.safercar.gov, 9/9/10

[2] "Trends in the Static Stability Factor of Passenger Cars, Light Trucks, and Vans", NHTSA Technical Report, DOT HS 809 868, June 2005

manufacturer has certified that the vehicle is compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. Neither of the frontal air bags deployed during the crash.

The vehicle was also equipped with front seat-mounted side impact air bags and side impact IC air bags. The side impact sensors were located within the lower B-pillars, on the floorboard. Both IC air bags and front seat-mounted side impact air bags deployed in this crash.

The Hyundai's IC air bags were located along the roof side rails inside the headliner, and extended from the top of the A-pillar to the C-pillar. The deployed left IC air bag was 124 cm (48.8 in) in width. The height of the air bag was 27 cm (10.6 in) adjacent to the front and second row seating positions. The air bag was 11 cm (5.9 in) above the belt line just aft of the B-pillar since the intruded B-pillar was impeding the air bag. The air bag extended 11 cm (5.9) below the beltline near the C-pillar. The portion of the air bag adjacent to the driver's seating position had been cut. The air bag was tethered to the A-pillar with a 15 cm (5.9 in) nylon cord. The space between the front of the air bag and the A-pillar was 28 cm (11 in) at the approximate center of the air bag. The front right passenger's IC air bag had the same dimensions. It did not fully deploy and was entrapped at the B-pillar (**Figures 7** and **8**).

Figure 7: The Hyundai's right IC air bag was entrapped at the top of the right B-pillar and did not fully deploy

Figure 8: The partially deployed right IC air bag

The driver's seat-mounted side impact air bag was located in the outboard side of the seat back and deployed through a tear-seam. The deployed air bag was 42 cm (16.5 in) in height and 23 cm (9.1 in) in width. Inspection of the deployed air bag revealed no discernable evidence of occupant contact and the air bag was undamaged. The deployed front right passenger's air bag was identical.

MANUAL RESTRAINT SYSTEM

The Hyundai was equipped with lap-and-shoulder safety belts in the front and second rows. The driver's safety belt was equipped with continuous loop belt webbing, an adjustable upper anchor that was in the full down position, buckle-mounted pretensioner, sliding latch plate, and an Emergency Locking Retractor (ELR). The front right safety belt was similarly equipped, but had a switchable ELR/Automatic Locking Retractor (ALR). The front pretensioners did not

actuate. The second row safety belts were similar to the front right safety belt, but had fixed upper anchors and were not equipped with pretensioners.

The driver's safety belt webbing had been cut and the belt webbing and latch plate were not present at the SCI inspection. The driver's buckle-mounted pretensioner had not actuated. The driver stated during the SCI interview that he was restrained in this crash.

CASE VEHICLE DRIVER KINEMATICS

The restrained driver of the Hyundai [35-year-old male, 175 cm (69 in) and 64 kg (140 in)] was seated in an upright posture with his back against the seat back and both hands on the steering wheel. The seat track was adjusted to between the middle and rear position and the seat back was slightly reclined. The head restraint was adjusted to the full down position and the distance from the top of the seat back to the top of the head restraint was 18 cm (7.1 in). The tilt steering column was located in the center position. The driver was wearing glasses at the time of the crash.

Immediately prior to the rollover initiation, the vehicle was in a counterclockwise yaw and the driver was displaced to the right within the safety belt as the vehicle decelerated. When the vehicle rolled over right side leading, the driver was redirected toward the roof. While there was no discernable evidence of occupant contact on the roof, occupant kinematic principles suggest that the driver probably contacted his head on the roof during the rollover. He sustained a concussion with loss of consciousness, a fracture of C_6, and a compression fracture of T_6 from this contact. The driver sustained a comminuted fracture of the left humerus from contact with the left front door. He also sustained multiple abrasions and lacerations. He exited the vehicle through the left front door with the assistance of rescue personnel.

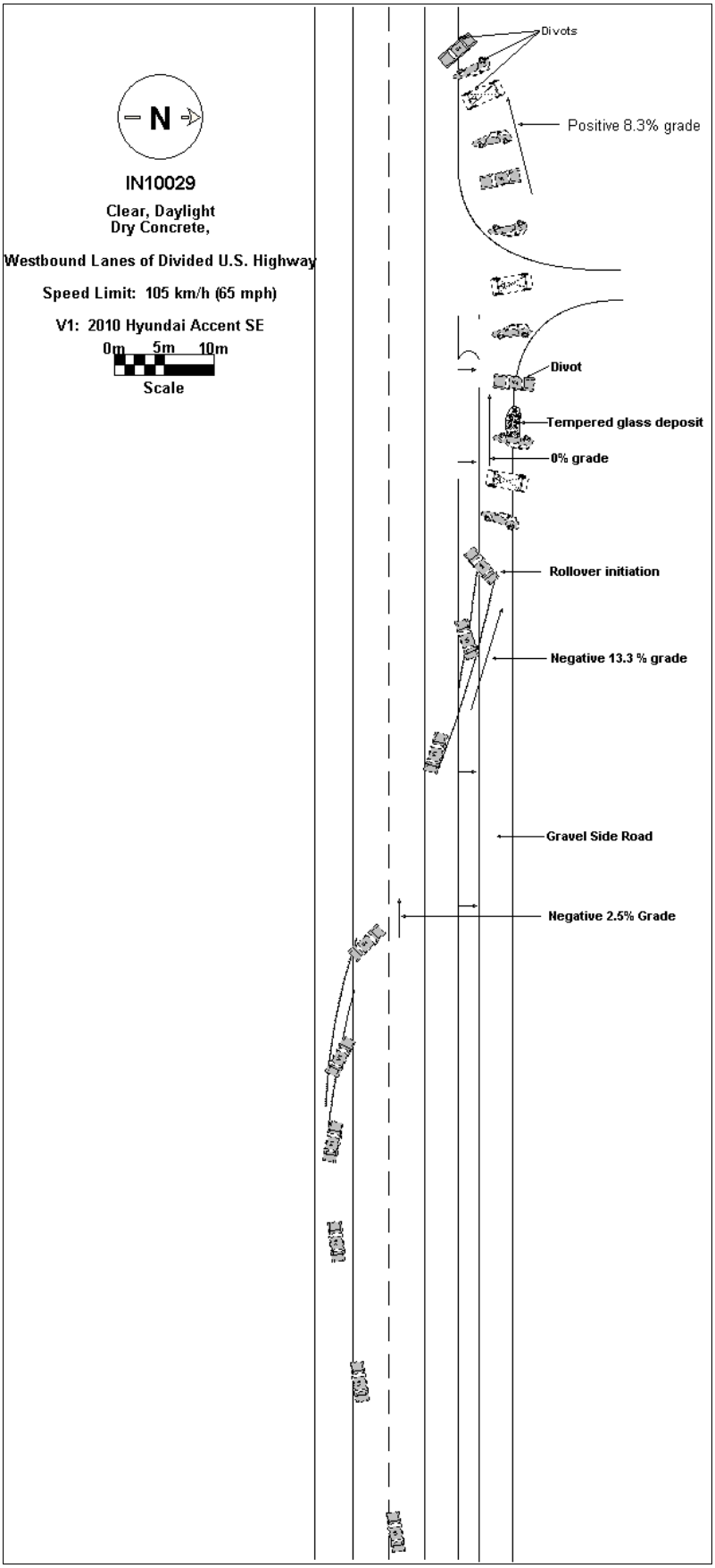
CASE VEHICLE DRIVER INJURIES

The driver was transported by air ambulance to a hospital and hospitalized for three days. The driver had one follow-up visit to a physician. He was not working at the time of the crash. The table below presents the driver's injuries and injury sources.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 2005	Injury Source	Source Confidence	Source of Injury Data
1	Concussion with loss of consciousness and little recollection of crash	moderate 161002.2,0	Roof	Probable	Hospitalization records
2	Fracture left superior articular facet of C_6 extending up to posterior superior margin (wall) of transverse foramen	moderate 650222.2,6	Roof	Probable	Hospitalization records

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 2005	Injury Source	Source Confidence	Source of Injury Data
3	Fracture, compression, T_6 vertebral body with 30% muscle height compared to T_7	serious 650434.3,7	Roof	Probable	Hospitalization records
4	Fracture, severely comminuted, left humerus at junction of middle and distal thirds with 4 fragments[3] with overriding	moderate 751271.2,2	Left front door panel, rear upper quadrant	Probable	Hospitalization records
5	Abrasion left antecubital fossa, not further specified	minor 710202.1,2	Noncontact injury: flying glass, left front glazing	Probable	Hospitalization records
6	Abrasions throughout consistent with recent motor vehicle crash, not further specified	minor 910202.1,9	Unknown injury source	Unknown	Hospitalization records
7	Lacerations throughout consistent with recent motor vehicle crash, not further specified	minor 910600.1,9	Unknown injury source	Unknown	Hospitalization records
8	Laceration (wound, puncture), open, left elbow	minor 740600.1,2	Noncontact injury: flying glass, left front glazing	Probable	Hospitalization records

[3] Open reduction and internal fixation was required to reduce this lesion.


N
IN10029
Clear, Daylight
Dry Concrete,
Westbound Lanes of Divided U.S. Highway
Speed Limit: 105 km/h (65 mph)
V1: 2010 Hyundai Accent SE
0m 5m 10m
Scale
Divots
Positive 8.3% grade
Divot
Tempered glass deposit
0% grade
Rollover initiation
Negative 13.3 % grade
Gravel Side Road
Negative 2.5% Grade