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ON-SITE VEHICLE ROLLOVER INVESTIGATION

CASE NUMBER - IN-06-019

LOCATION - OKLAHOMA

VEHICLE - 2006 HYUNDAI TIBURON GL

CRASH DATE - May 2006

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 report covers an on-site investigation of a rollover crash that involved a 2006 Hyundai Tiburon GL (case vehicle), which was sideswiped by a hit-and-run vehicle, ran-off-road, impacted a concrete median barrier and rolled over. This crash is of special interest because the case vehicle rolled over, and the case vehicle's driver [20-year-old, (unknown race and ethnic origin) female sustained a police reported "B" (non-incapacitating-evident) injury as a result of the crash. The case vehicle was traveling southwest in the outside through lane of a two-lane, Interstate feeder ramp. A hit-and-run vehicle sideswiped the left side of the case vehicle (event 1), the driver lost control, steered left, right and left again in an attempt to regain control. The front of the case vehicle then impacted the concrete median barrier (event 2) causing the case vehicle's driver and front right passenger air bags to deploy. The front left of the case vehicle rode up the median barrier causing the case vehicle to roll over (event 3) two quarter rolls onto its right side and onto its top. The case vehicle came to final rest on the east shoulder on its top heading southwest. The driver was not restrained by her manual, three-point, lap-and-shoulder safety belt. She was transported by ambulance to a hospital.					
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This on-site investigation was brought to NHTSA's attention on or before July 7, 2006 by NASS GES sampling activities. This crash involved a 2006 Hyundai Tiburon (case vehicle), which was sideswiped by a hit-and-run vehicle, ran-off-road, impacted a concrete median barrier and rolled over. The crash occurred in May 2006, at 12:51 a.m., in Oklahoma and was investigated by the Oklahoma Highway Patrol. This crash is of special interest because the case vehicle rolled over and the case vehicle's driver [20-year-old, (unknown race and ethnic origin) female] sustained a police reported "B" (non-incapacitating-evident) injury as a result of the crash. This contractor inspected the scene and case vehicle on July 17, 2006. This contractor was unable to contact the case vehicle's driver for an interview. This report is based on the police crash report, scene and vehicle inspections, occupant kinematic principles, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling southwest in the outside through lane of a two-lane, Interstate feeder ramp and the driver was intending to continue southwestbound. A hit-and-run vehicle sideswiped the left side of the case vehicle (event 1), the driver lost control, steered left, right and left again in an attempt to regain control. The case vehicle traveled across both travel lanes and crossed the median shoulder. The front of the case vehicle then impacted the concrete median barrier (event 2) causing the case vehicle's driver and front right passenger air bags to deploy. The front left of the case vehicle rode up the median barrier causing the case vehicle to roll over (event 3) two quarter rolls onto its right side and onto its top. The case vehicle traveled approximately 33.8 meters (111 feet) from the area of impact with the barrier to its final rest position on the east shoulder of the median. The case vehicle came to final rest on its top heading southwest. At the time of the crash the light condition was dark, but illuminated by overhead luminaires, the atmospheric condition was clear and the roadway pavement was dry.

The case vehicle's CDC for the left sideswipe impact was determined to be: **06-LZMS-1 (190 degrees)**. The maximum residual left side crush occurred at mid-door and was measured as 5 centimeters (20.1 inches) occurring at C₃. The CDC for the front impact with the concrete median barrier was determined to be: **12-FDEW-2 (350-degrees)**. The maximum residual bumper crush was measured as 51 centimeters (20.1 inches) occurring at C₁. The CDC for the rollover was determined to be: **00-TYDO-2**. The maximum vertical crush occurred in the center of the roof between the sunroof and windshield header and was approximately 3 centimeters (1.2 inches). There was no lateral roof displacement.

The WinSMASH reconstruction program, barrier algorithm, calculated the case vehicle's Total, Longitudinal, and Lateral Delta Vs for the median barrier impact (i.e., most severe impact) respectively as: 40.0 km.p.h. (24.9 m.p.h.), -39.4 km.p.h. (-24.5 m.p.h.), and 6.9 km.p.h. (4.3 m.p.h.). The case vehicle's calculated impact speed range with the median barrier was approximately 69 to 76 km.p.h. (43 to 47 m.p.h.). The crash severity for the rollover was determined to be minor based on the extent of roof crush. The crash severity for the sideswipe was also determined to be minor based on the extent of side plane crush. The case vehicle was towed due to damage.

The case vehicle's driver was not restrained by her manual, three-point, lap-and-shoulder safety belt system. She impacted and rode down her deployed air bag and loaded the steering wheel displacing the steering column forward slightly and slightly deforming the upper half of the steering wheel rim. The driver sustained a police reported "B" (non-incapacitating-evident) injury and was transported by ambulance to a medical facility. The nature and extent of her injuries was not determined. The treating hospital did not honor this contractor's request for the driver's medical records.

CRASH CIRCUMSTANCES

Crash Environment: The trafficway on which the case vehicle was traveling was a curved, two-lane, feeder ramp connecting two Interstate highways traversing in a southwest direction. The roadway had two through lanes and wide concrete shoulders. There was a concrete median barrier separating the ramp from the Interstate and a concrete traffic barrier along the outside shoulder. Each lane was approximately 3.8 meters (12.5 feet) in width, the median shoulder was approximately 3.7 meters (12 feet) in width and the outside shoulder was approximately 2.4 meters (8 feet) in width. Pavement markings consisted of a solid yellow median edge line, broken white center centerline, solid white edge line and white diagonal outside shoulder designation lines. At the time of the crash the light condition was dark, but illuminated by overhead luminaires, the atmospheric condition was clear and the roadway pavement was dry, traffic polished concrete with an estimated coefficient of friction of 0.65. The case vehicle's roadway was curved right and had an unknown negative grade. The speed limit was 97 km.p.h. (60 m.p.h.). Traffic density was not determined, and the site of the crash was commercial. See the Crash Diagram at the end of this report.

Pre-Crash: The case vehicle was traveling southwest in the outside through lane (**Figure 1**), and the driver was intending to continue southwestbound. A second vehicle was overtaking the case vehicle in the inside through lane. The initial impact occurred in the outside through lane. The case vehicle's driver most likely took no actions to avoid the initial impact.

Crash: The second vehicle sideswiped the left side of the case vehicle (event 1), the driver lost control, steered left and the case vehicle began traveling toward the median. The second vehicle did not stop. The police crash schematic indicated that the case vehicle's driver steered right and left in an attempt to regain control of her vehicle. It is not known if the police schematic was based on any observed tire marks on the roadway or discussion with the driver. Following the final left steer, the case vehicle traveled across both travel lanes and crossed the median shoulder. The front of the case vehicle (**Figure 2** below) then impacted the concrete median barrier (event 2) causing the case vehicle's driver and front right



Figure 1: Overview of case vehicle's southwestbound approach, police crash report indicates case vehicle was initially southwestbound in outside lane

passenger air bags to deploy. The case vehicle's calculated impact speed range was approximately 72 to 77 km.p.h. (45 to 48 m.p.h.). The front left of the case vehicle then rode up the median barrier causing the case vehicle to roll over (event 3) two quarter rolls onto its right side (Figures 3 and 4) and onto its top (Figure 5).



Figure 2: Damage to front of case vehicle from concrete median barrier impact and to top plane from rollover, increments on vertical scale are in tenths of meter, each increment on rods is 5 cm (2 in)



Figure 3: Overview of rollover damage (arrows) to right side of case vehicle



Figure 4: Rollover damage to right fender, hood, and right front door



Figure 5: Rollover damage to roof and hood

Post-Crash: Based on police reported measurements, the case vehicle traveled approximately 33.8 meters (111 feet) from the area of impact with the barrier to its final rest position on the east shoulder of the median. The case vehicle came to final rest on its top heading southwest.

CASE VEHICLE

The 2006 Hyundai Tiburon GL was a two-door, front wheel drive coupe (VIN: KMHH65DX6U-----) equipped with a 2.0L, four cylinder engine; four-speed automatic transmission and four wheel, anti-lock brakes. The front seating row was equipped with bucket seats with adjustable head restraints, redesigned driver and front right passenger air bags, front seat back-mounted side impact air bags and driver and front right passenger manual, three-point, lap-and-shoulder safety belt systems with adjustable upper anchors, pretensioners and force limiters. The back seating row was equipped with a bench seat with folding backs (designed to

accommodate two passengers); three-point, lap-and-shoulder safety belt systems and a LATCH system for securing child safety seats.

CASE VEHICLE DAMAGE

Exterior Damage: The sideswipe impact (event 1) involved the left side of the vehicle. The left quarter panel and left front door were directly damaged and crushed inward. The direct damage began 45 centimeters (17.7 inches) rear of left rear axle and extended 237 centimeters along the left side of the vehicle. The maximum residual crush was measured as 5 centimeters (20.1 inches) occurring at C₃. The table below shows the left side 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	237	5	241	0	1	5	1	0	0	-74	-79
in		93.3	2.0	94.9	0.0	0.4	2.0	0.4	0.0	0.0	-29.1	-31.1

The case vehicle’s impact with the median barrier (event 2) involved the front of the case vehicle. The front bumper, hood, left headlamp/turn signal assembly and front of the left fender were directly contacted and crushed rearward. The direct damage began at the front left bumper corner and extended 116 centimeters (45.7 inches) across the bumper. Crush measurements were taken at the bumper and the maximum residual crush was measured as 51 centimeters (20.1 inches) occurring at C₁ (**Figure 6**). The table below shows the case vehicle’s front crush profile.

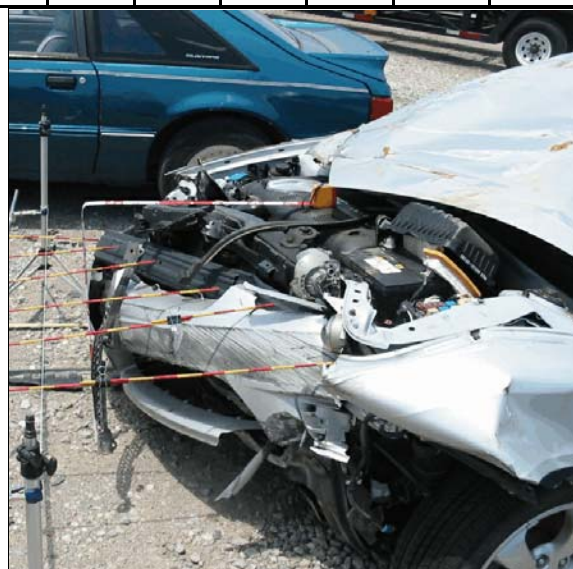


Figure 6: Crush to case vehicle’s front bumper from impact with concrete median barrier

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	2	116	51	119	51	49	45	28	23	0	-13	0
in		45.7	20.1	46.9	20.1	19.3	17.7	11.0	9.1	0.0	-5.1	0.0

The rollover (event 3) involved the top and right side of the case vehicle. The direct damage involved the full width of the roof from the sun roof to the windshield header. The maximum

vertical crush occurred in the center of the roof between the sunroof and windshield header and was approximately 3 centimeters (1.2 inches). There was no lateral roof displacement. The direct damage from the rollover also involved the right fender, right front door, right sill, right quarter panel and right side of the back bumper fascia. In addition, there were grinding marks on the rims of the right front and right rear wheels.

The left side wheelbase was reduced 13 centimeters (5.1 inches) while the right side wheelbase was extended 3 centimeters (1.2 inches). Induced damage also involved the roof, right front door, right quarter panel and left fender.

The case vehicle’s recommended tire size was: P205/55R16, and the vehicle was equipped with tires of this size. 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 nd of an inch			
LF	0	0	207	30	7	9	Sidewall cut	Yes	Yes
RF	276	40	207	30	7	9	None	No	No
LR	276	40	207	30	8	10	No damage to tire, but rim abraded	No	No
RR	276	40	207	30	8	10	No damage to tire, but rim abraded	No	No

Vehicle Interior: Inspection of the case vehicle’s interior (**Figure 7**) revealed occupant contact to the knee bolster on both sides of the steering wheel. The knee bolster was loose and the fuse panel cover was knocked off. In addition, the steering column was displaced forward, which separated the plastic steering column housing at its assembly seam (**Figure 8** below), indicating the driver rode down the air bag during the impact with the median barrier and loaded the steering assembly. There was also 2 centimeters (0.8) of deformation of the upper half of the steering wheel. Lastly, the windshield intruded vertically 8 to 15 centimeters (3.1 inches to 6 inches) into the left, middle and right zones of the front seating row. The windshield header also intruded vertically approximately 3 centimeters (1.2 inches) into the center zone of the front seating area.



Figure 7: Case vehicle’s windshield, steering wheel and instrument panel

Damage Classification: Based on the vehicle inspection, the case vehicle's CDC for the left sideswipe impact (event 1) was determined to be: **06-LZMS-1 (190 degrees)**. The front impact with the concrete median barrier (event 2) was determined to be: **12-FDEW-2 (350-degrees)**. The CDC for the rollover (event 3) was determined to be: **00-TYDO-2**. The WinSMASH reconstruction program, barrier algorithm, was used to reconstruct the case vehicle's Delta Vs due to the median barrier impact (i.e., most severe impact). The Total, Longitudinal, and Lateral Delta Vs are, respectively: 40.0 km.p.h. (24.9 m.p.h.), -39.4 km.p.h. (-24.5 m.p.h.), and 6.9 km.p.h. (4.3 m.p.h.). The crash fits the reconstruction model and the results appear reasonable. Using the principle of conservation of energy, the case vehicle's impact speed range with the median barrier was calculated as 69 to 76 km.p.h. (43 to 47 m.p.h.). The crash severity for the rollover was determined to be minor based on the extent of roof crush. The crash severity for the sideswipe was also determined to be minor based on the extent of side plane crush. The case vehicle was towed due to damage.



Figure 8: Case vehicle's energy absorbing steering column was compressed separating the steering column cover at assembly seam (arrows)

AUTOMATIC RESTRAINT SYSTEM

The case vehicle was equipped with redesigned air bags at the driver and front right passenger positions. Both air bags deployed as a result of the case vehicle's front impact with the median barrier.

The case vehicle's driver air bag was located in the steering wheel hub. The air bag module cover consisted of two approximately triangular-shaped cover flaps (**Figure 9**) separated by a horizontal tear seam. They were constructed of pliable vinyl. The upper flap's overall dimensions were 15.5 centimeters (6.1 inches) in width and 4 centimeters (1.6 inches) in height. There was a semi-oval cut-out at the bottom center of the flap to accommodate the manufacturer's logo located in the top center of the lower flap. The overall dimensions of the bottom flap were 15.5 centimeters (6.1 inches) in width and 10 centimeters (3.9 inches) in height along the center of the flap. An inspection of the air bag module cover flaps and the air bag fabric revealed that the cover flaps opened at the designated tear points. There was no evidence of damage during the deployment to the air bag module cover flaps or the air bag. The deployed driver's air bag



Figure 9: Case vehicle driver's air bag module cover flaps

(**Figure 10**) was round with a diameter of approximately 62 centimeters (24.4 inches). The air bag was designed with two tethers, each approximately 12 centimeters (4.7 inches) in width and had two vent ports (**Figure 11**), each approximately 3.5 centimeters (1.4 inches) in diameter, located at the 10:30 and 1:30 o'clock positions. The distance between the mid-center of the driver's seat back, as positioned as the time of the vehicle inspection (i.e., seat between middle and forward-most track position, seat back slightly reclined), and the front surface of the air bag's fabric at approximate full excursion was 24 centimeters (9.4 inches). Inspection of the air bag fabric revealed no evidence of occupant contact.



Figure 10: Case vehicle's driver air bag

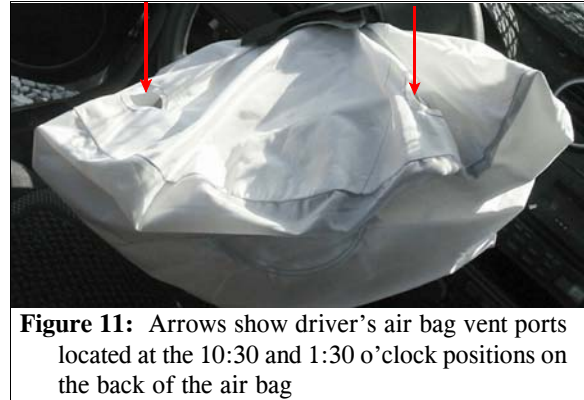


Figure 11: Arrows show driver's air bag vent ports located at the 10:30 and 1:30 o'clock positions on the back of the air bag



Figure 12: Case vehicle's front right passenger air bag module cover



Figure 13: Case vehicle's front right passenger air bag

The front right passenger air bag was located in the top of the instrument panel (**Figure 12**). The air bag module cover consisted of a single rectangular cover flap constructed of plastic and covered with thin, padded vinyl. Its overall dimensions were 30 centimeters (11.8 inches) in width and 15 centimeters (5.9 inches) in height. An inspection of the cover flap (**Figure 12**) and the air bag fabric revealed that the cover flap opened at the designated tear points. There was no evidence of damage during the deployment to the air bag module cover flap or the air bag. The deployed front right passenger's air bag (**Figure 13**) was rectangular in shape and was

approximately 56 centimeters (22 inches) in height and 47 centimeters (18.5 inches) in width. The air bag was designed with two tethers, each approximately 40 centimeters (15.7 inches) in width and had two vent ports, each approximately 4.5 centimeters (1.8 inches) in diameter, located at the 8:00 and 4:00 o'clock positions. The distance between the mid-center of the front right passenger's seat back, as positioned as the time of the vehicle inspection (i.e., seat at forward-most track position, seat back slightly reclined), and the front surface of the air bag's fabric at approximate full excursion was 34 centimeters (13.3 inches). Inspection of the air bag was unremarkable with the exception of a few areas of dirt and grease that may have been related to post-crash handling of the air bag.

CASE VEHICLE DRIVER KINEMATICS

Immediately prior to the crash the case vehicle's driver [20-year-old (unknown race and ethnic origin) female; unknown height and weight] was most likely seated in a nominal upright driving position. The position of her hands is unknown. Her right foot was most likely on the accelerator pedal and her left foot was on the floor. During the vehicle inspection, the driver's seat track was found located between its middle and forward-most positions and her seat back was slightly reclined. This was most likely the seat position at the time of the crash. The tilt steering column was found adjusted to its full up position during the vehicle inspection, which was most likely the steering column's position at the time of the crash. It is not known if the driver was wearing glasses or contact lenses at the time of the crash.

The evidence observed during the vehicle inspection indicates the case vehicle's driver was not restrained by her manual, three-point, lap-and-shoulder safety belt system. Inspection of the safety belt assembly revealed no evidence of loading. In addition, there was no evidence of activation of the pretensioner.

The initial impact to the left side of the case vehicle most likely caused the case vehicle's driver to moved rearward and to the left. She most likely loaded her seat back and her left arm and shoulder most likely contacted the left front door. She remained in an upright seated position during the steering maneuvers just prior to the median barrier impact. The driver was most likely upright with both hands on the steering wheel and bracing for impact when the case vehicle impacted the median barrier. The evidence indicates that the case vehicle's front impact with the median barrier caused the case vehicle's driver to continue forward and slightly left along a path opposite the case vehicle's 350 degree direction of principal force as the case vehicle decelerated. The driver's knees loaded her knee bolster and her face and chest impacted her deployed air bag. She rode down the deployed air bag and loaded the steering wheel compressing the steering column sufficiently to separate the steering column cover at its assembly seam and slightly deforming the upper half of the steering wheel. As the case vehicle rode up the barrier and tilted to the right, the unrestrained driver most likely moved to the right and then toward the roof as the case vehicle rolled over onto its roof. Her head and upper torso most likely impacted the roof and she came out of her seat position and most likely came to rest on the roof. It is not known how the driver exited the case vehicle.

The police crash report indicated that the driver sustained a “B” (non-incapacitating-evident) injury and was transported by ambulance to a hospital. The driver’s treatment status and the nature and extent of her injuries is not known. The treating hospital did not honor this contractor’s request for the driver’s medical records.

