Center for Auto Safety

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Dynamic Roof Crush Tests of Ten 2005-07Passenger Vehicles

Dynamic rollover roof crush tests have been conducted for the Center for Auto Safety (CAS) by the Center for Injury Research (C*f*IR) using the Jordan Rollover System (JRS). This work was funded by the Santo Family Foundation on the following ten 2005-07 vehicles that were donated by State Farm Insurance. The results were.

Year, Make and Model	FMVSS 216 SWR	JRS Results
2007 Pontiac G6	2.3	Extensive windshield header and roof panel buckling, intrusion of roof panel over driver position, poor seat belt performance, and side window failure. Generally poor performance.
2006 Chrysler 300	2.5	Extensive windshield header buckling and intrusion of roof panel over driver position. No side window failures. Generally fair to poor performance.
2006 Hyundai Sonata	3.4	Moderate intrusion of passenger side roof, side window failure, and sunroof intrusion. Generally fair to poor performance
2007 Toyota Camry	4.3	Poor windshield header performance but otherwise good roof performance. No side window failures.
2007 VW Jetta	5.1	Moderate windshield header buckling and roof intrusion above dummy's head. No side window failures. Generally good performance.
2006 Honda Ridgeline	2.4	Roof structure failed catastrophically. The top of the A-pillar was forced below the belt line of vehicle. Side window failures. Performance considered unacceptable.
2005 Volvo XC90	4.6+	Best performing vehicle with little roof damage. Side windows remaining intact.
2007 Honda CR-V	2.6	Modest damage to trailing roof edge at top of A pillar. Driver window broke on second roll. Generally good performance.
2007 Chevrolet Tahoe	2.1	Roof had substantial crush, windshield header buckled, and side windows failed. Generally poor performance.
2007 Jeep Grand Cherokee	2.2	Major damage and intrusion of roof panel with substantial inward buckling of roof header over driver position. Side window failures. Generally very poor performance.

The purpose of this program was to alert the public to the dramatic difference in structural roof performance and rollover safety of the vehicles they buy; and to show the inadequacies in the recently amended roof crush resistance standard, FMVSS 216, issued by the National Highway Traffic Safety Administration (NHTSA).

Since 1970, the auto industry has fought efforts by NHTSA to issue a dynamic roof crush standard to protect occupants in rollover crashes. During that time, the number of deaths to occupants in rollover crashes climbed from 1,400 to over 10,000 each year while total occupant fatalities declined from 43,200 to 28,900 in 2007. Although the federal courts have upheld the dolly rollover test as a legitimate dynamic test, NHTSA has stuck with the outdated, static roof crush standard issued in 1971 even though it was to have been phased out by 1977. In the other major crash modes, front and side impacts, NHTSA has issued effective dynamic crash test standards that have significantly reduced death and serious injury.

Out of the ten tested vehicles only the Volvo XC90 showed a high degree of rollover occupant protection. The Honda CR-V was nearly as good as the Volvo XC90 despite having a strength-to-weight ratio of only 2.6, and thus would not meet the amended Federal roof crush resistance standard.

The VW Jetta and the Camry showed substantially better dynamic roof crush performance than typical vehicles now on the road. Nevertheless, in the JRS tests these two vehicles both showed structural failures in their windshield headers that were not revealed by NHTSA's static roof crush test.

Two of the tested vehicles from the same manufacturer, the Honda CR-V and the Ridgeline, had similar SWRs in the FMVSS 216 test; but showed radically different performance on the JRS. While the CR-V was one of the best performers on the JRS (except for the failure of the driver's side window on the second roll test), the Ridgeline suffered severe windshield header buckling, forming a pointed wedge that intruded rapidly and dramatically into the driver's survival space.

The differences in the injury potential performance of these two vehicles demonstrate why a dynamic test is critical to accurately and efficiently measuring the rollover occupant protection capability of vehicles. The Sonata has a sunroof with internal structure that collapses inward in a dynamic rollover but not in a static test. Except for the CR-V, all of the vehicles that had FMVSS 216 SWR below 3 performed poorly in the JRS tests.

These tests demonstrate the importance of a dynamic test:

- Only a dynamic test such as the JRS can show the contribution of vehicle geometry. Vehicles with the very square roofs such as the Honda Ridgeline are more vulnerable to roof crush. A vehicle with a more rounded roof, such as the XC90, can roll more like a barrel with less force on the corners of the roof.
- The failure mode of a roof is critical to its ability to protect occupants. If any of the critical roof structural elements buckles, it loses strength and permits major roof intrusion that can injure belted occupants who are seated underneath.

- Even tempered side glazing can survive a rollover if the roof above it and the frame around it does not suffer significant distortion. In three of the five cars tested, the window frames did not distort or bend to a major extent. The side windows survived and would have provided a barrier to ejection.
- Only a dynamic test can demonstrate whether seat belts, pre-tensioners and side curtains function to protect occupants from ejection and injury in rollovers.

After over 35 years during which time rollover fatalities increased dramatically because of inadequate roof strength and ineffective rollover standards along with the major increase in the use of SUVs and pickups and personal vehicles, it is time for a dynamic roof crush standard using the JRS to match the lifesavings from other dynamic standards. NHTSA has boasted that occupant fatalities decreasing to fewer than 30,000 in 2007. That's not a victory but a tragedy because the toll could have gone under 25,000 if most vehicles had been designed with strong roofs.

The following figures show the detailed results of JRS testing of the five passenger cars and five light trucks.

	2007 VW Jetta		2007 Toyota Camry		2006 Hyundai Sonata		2006 Chrysler 300		2006 Pontiac G6	
	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2
Roof FMVSS 216 SWR	5.1	5.1	4.3	4.3	3.2	3.2	2.5	2.5	2.3	2.3
Road Speed (kph)	24	24	24	24	24	24	24	24	24	24
Pitch Angle at Impact (deg)	5	10	5	10	5	10	5	10	5	10
A-Pillar										
Peak Dynamic Crush (cm)	6.9	16.0	8.6	18.3	11.9	17.5	21.3	26.4	18.0	25.4
Cumulative Residual Crush (cm)	2.5	8.6	4.1	10.9	6.6		14.2	18.8	12.4	17.8
Maximum Crush Speed (kph)	9.2	11.4	8.0	13.2	8.0	--	12.07	17.06	12.07	21.08
B-Pillar										
Peak Dynamic Crush (cm)	3.8	6.1	4.6	10.7	--	6.6	11.2	13.5	9.1	15.0
Cumulative Residual Crush (cm)	1.5	3.3	1.8	5.3	--	2.0	6.9	8.6	6.4	8.6
Maximum Crush Speed (kph)	6.1	5.6	5.1	8.0	--	6.6	8.7	12.23	10.14	14.32
Compressive Neck Load, Fz	5158	5394	4211	2669	4835	3457	5598	1979	2399	1916
Peak Upper, Flexion Moment (N m)	279	318	--	--	--	--	414	155	198	155
Upper Neck, Nij*	0.96	1.08	0.78	0.76	1.63	1.15	1.80	0.40	0.66	0.54
Lower Neck, Nij**	1.17	1.28	--	--	--	--	1.44	0.57	0.68	0.54

*Based on by NHTSA: Compression 6160 N, Flexion 310 Nm, Extension 135 Nm

**Based on values presented in Mertz, et. al, 2003: Compression 6200 N, Flexion 610 Nm, Extension 266 Nm

Volvo XC90 SWR-4.6 IBM-11.3 | Honda CRV SWR=2.6 IBM=18.7 | Honda Ridgeline SWR=2.4 IBM=28.9 | Jeep Grand Cherokee SWR=2.2 IBM=29.4 | Chevrolet Tahoe SWR=2.1 IBM=21.8

	2005 Volvo XC90		2007 Honda CRV		2006 Honda Ridgeline		2007 Jeep Grand Cherokee		2007 Chevrolet Tahoe	
	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2	Roll 1	Roll 2
Roof FMVSS 216 SWR	4.6	4.6	2.6	2.6	2.4	2.4	2.2	2.2	2.1	2.1
Road Speed (kph)	24	24	24	24	24	24	24	24	24	24
Pitch Angle at Impact (deg)	5	10	5	10	5	10	5	10	5	10
A-Pillar		***								
Peak Dynamic Crush (cm)	4.3	8.1	8.6	16.5	19.8	36.6	21.3	30.0	20.1	35.6
Cumulative Residual Crush (cm)	1.3	2.5	4.6	9.1	12.7	27.7	16.5	23.1	14.7	27.7
Maximum Crush Speed (kph)	3.1	5.1	6.4	8.5	13.2	24.1	11.75	13.84	9.8	18.67
B-Pillar										
Peak Dynamic Crush (cm)	3.0	5.3	5.1	8.6	15.2	28.2	18.5	25.7	13.2	24.9
Cumulative Residual Crush (cm)	0.5	1.8	2.0	3.6	8.6	18.8	14.2	19.8	8.9	17.5
Maximum Crush Speed (kph)	2.7	3.5	4.2	5.5	9.0	11.1	12.71	10.46	6.8	11.27
Compressive Neck Load, Fz	2889	3628	5583	3687	10006	4685	9757	6781	6101	3318
Peak Upper, Flexion Moment (N m)	128	259	255	328	492	324	470	396	304	247
Upper Neck, Nij*	0.52	1.05	1.02	1.30	1.64	1.19	1.75	2.07	1.09	0.81
Lower Neck, Nij**	0.62	0.87	1.20	1.10	2.10	1.06	2.00	1.59	1.02	0.87

*Based on by NHTSA: Compression 6160 N, Flexion 310 Nm, Extension 135 Nm

**Based on values presented in Mertz, et. al, 2003: Compression 6200 N, Flexion 610 Nm, Extension 266 Nm

*** Determined through photoanalysis of High Speed Video