C. Crash Test Instrumentation and Evaluation

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This presentation examines current crash test instrumentation and evaluation standards described in NCHRP Report 230. In the interest of brevity, I will concentrate only on those areas where modification of the current standards should be considered. As a result, this presentation may sound very negative toward current standards and imply that NCHRP Report 230 was in some way deficient. Nothing is further from the truth. NCHRP Report 230 represented a major improvement in crash test evaluation criteria at the time it was published and has served the safety community well for the last seven years.

Occupant Kinematics

NCHRP Report 230 evaluates the potential for injury during a crash test in terms of the velocity at which an unbelted occupant impacts the interior of the vehicle. The unbelted occupant is modeled as a free missile in the vehicle. Impact with the car's interior is assumed to occur after the free missile travels 2 ft. forward and 1 ft. laterally relative to the vehicle. Longitudinal and lateral impact velocities are estimated by independently integrating longitudinal and lateral accelerometer readings.

This greatly simplified approach can lead to a significant underestimation of actual occupant impact velocities. The biggest source of potential error in occupant impact velocity estimates is associated with the assumption that an occupant impacts the vehicle interior after traveling only 1 ft. laterally. Crash tests of roadside barriers indicate that drivers often are projected across the vehicle and first impact the vehicle's interior at the A pillar on the passenger side of the vehicle. Since, for these cases the occupant travels more than 3 ft. before impacting the vehicle, actual impact velocities are much more than predicted by the NCHRP Report 230 evaluation criteria.

Another potential source of error in occupant impact velocities is related to differences between the vehicle's velocities at the center of gravity and at the point of occupant impact. High speed rotations during an impact give each point in the interior of the vehicle a different velocity relative to the occupant. Analysis of crash test results indicate that the vehicle velocities at the edge of the interior are commonly as much as 4 ft./sec. different in the longitudinal direction and 2 ft./sec. different in the lateral direction. These differences alone represent more than ten percent of the recommended occupant impact velocities.

Occupant ridedown acceleration after impact with the vehicle interior is another primary measure of occupant risk used in NCHRP Report 230. Although accelerometers are placed as near the center of gravity of the vehicle as possible, no effort is made to record the exact location of accelerometer mounts. Crash test and simulation results have shown that accelerations at various points in the interior of the vehicle can vary significantly. Thus, crash test results not only do not give actual vehicle accelerations at the point where an occupant would be pressed against the vehicle interior, the data do not indicate the actual accelerations at the center of gravity of the vehicle.

Elimination of all of these inaccuracies in the estimate of actual occupant impact velocities requires a complete knowledge of the full 3-D motion of the vehicle. Although NCHRP Report 230 recommends vehicles be instrumented with triaxial accelerometers and rate gyros to measure vehicle accelerations and rotation rates in each direction, problems with the differentiation of rate gyro data prevent the accurate determination of vehicle motions from existing crash test data. This problem could be overcome by placing rate gyros with two additional triaxial accelerometers mounted at different points within the vehicle. If the additional cost of the triaxial accelerometers is determined to be excessive, approximate methods for estimating occupant impact velocities could be developed that would account for some of the inaccuracies described above with little or no increase in the cost of accident data collection and analysis.

Wheel Snag

Wheel snagging on roadside barrier elements is generally described by NCHRP Report 230 as unacceptable. This philosophy is based on the premise that wheel snagging generates high deceleration forces and/or post-impact spinout or possible overturn and can thereby increase the probability of occupant injury. However, numerous crash tests have indicated that vehicle accelerations can remain within acceptable limits, even during relatively severe wheel snag events. Further, these tests have shown that wheel snag usually prevents impacting vehicles from exiting the barrier at a high angle and reentering the traffic stream. A new standard for evaluating the severity of wheel snagging during barrier impacts should be developed to properly consider the occupant risk associated with this behavior.

Vehicle Velocity Change

NCHRP Report 230 recommends that the post-impact trajectory of test vehicles be evaluated to determine the risk associated with a disabled vehicle reentering the traffic stream. This criterion requires that impacting vehicles exit a barrier at an angle no more than 40% of the impact angle and that, if the vehicle trajectory would cause the vehicle to penetrate into adjacent traffic lanes, the total velocity change during impact should be less than 25% of the impact speed. Exit angle is used as a measure of the propensity for the vehicle to penetrate into opposing traffic lanes and is measured when the vehicle first loses contact with the barrier. The vehicle's angle relative to the barrier often continues to increase long after loss of contact with the barrier; and although a test vehicle's exit angle may be less than the required limit, the vehicle can still penetrate adjacent traffic lanes at angles much above this value. Further, determination of when a vehicle would penetrate into adjacent traffic lanes is very subjective, and additional clarification is definitely necessary.

The limit on total velocity change of 25% of impact velocity has been found to be more restrictive than any other criterion for 25 degree impacts. The concept behind this limitation is that, if a vehicle reenters the traffic stream at a low speed, there is a high potential for other traffic impacting it in the rear. There is little or no evidence that rear end collisions after barrier impacts represent a significant fraction of injury producing barrier accidents. Further, very few of the barriers in wide use today can meet this strict velocity change requirement. As shown in Table 1, most standard guardrail designs and a vertical concrete wall would fail the velocity change requirements. A careful review of post impact trajectory requirements should be undertaken to determine if rear end impacts are a potential source of injury accidents and if exit angle limitations are the best method for evaluating the potential for vehicles crossing into opposing traffic lanes.

Occupant Compartment Intrusion

NCHRP Report 230 generally describes penetration or intrusion into the occupant compartment as an unacceptable behavior. Although occupant compartment penetration can lead to catastrophic accidents under some circumstances, there are many situations where minor penetration or intrusion poses little or no threat to vehicle occupants. For example, many small highway signs are designed to break away during impacts. Under low speed impact conditions, the remaining post stub can scrape along the bottom of the vehicle and actually cut small holes in the floor pan. Although these test results are often interpreted as failing NCHRP Report 230 safety standards due to this minor occupant compartment penetration, the incidence of occupant injury arising from such impacts is extraordinarily low. The update of NCHRP Report 230 should incorporate a more discerning measure of occupant compartment intrusion in recognition of the potential for inconsequential vehicle intrusion or penetration.

TABLE 1 Velocity Changes During Longitudinal Barrier Impacts

Vehicle Weight (lbs)	Impact Velocity (mph)	Impact Angle (deg)	Service	Velocity Change (mph)
4450	61.8	25.3	G4 (1S) on Box Culvert	24.6
4500	58.2	25	G4 (1S) at Turned Down End	29.4
4490	58.7	25	TSDHPT Guard Fence at Turned Down End	22.6
4490	58.5	23	TSDHPT Guard Fence at Turned Down End	19.2
4740	59.9	24	Rigid Vertical Wall	17.5
4490	61.8	25.6	Rigid Vertical Wall	15.9

Flail Space Model

The flail space model for occupant risk evaluation contained in NCHRP Report 230 may be the best available procedure for estimating the probability of injury during an accident. However, if the flail space model is to be used to compare the performance of various roadside appurtenances, it is important to accurately determine occupant impact velocities and ridedown accelerations. Current data acquisition and reduction procedures are inadequate for this task. If the cost associated with additional vehicle instrumentation proves to be excessive, improved data reduction procedures must be developed for gleaning as much information as possible from available crash test data.

Summary

Although current crash test evaluation criteria contained in NCHRP Report 230 have generally improved the overall level of safety along the nation's roadways, current applications of the document are far beyond the purposes originally intended by the authors. The document was intended as a general guide for research agencies to follow in the evaluation of new safety hardware. NCHRP Report 230 has become a certification standard against which all safety hardware must be compared. Any update of this report will likely be used in a similar fashion. As a result, evaluation criteria must be as objective as possible with a minimum of the subjective language now found in the report.