American Association of State Highway and Transportatio| 243

# Glossary G

**AASHTO**—American Association of State Highway and Transportation Offi cials.

**arrow board/arrow panel**—A lighted board with moving or fl ashing arrows to direct traffi c out of a lane or away from a hazard or work zone.

**ACI**—American Concrete Institute. **AISC**—American Institute of Steel Construction. **AISI**—American Iron and Steel Institute. **ASI**—Acceleration Severity Index. **ASTM**—American Society for Testing and Materials.

**ballast**—Mass added to vehicle, other than simulated occupant(s) and instrumentation, to simulate cargo and/or to achieve desired test inertial mass.

**barrier height**—The height of a longitudinal barrier measured from the surface of the ground at its face to the top of the highest longitudinal element.

**bogie**—A device used as a surrogate for a production model test vehicle. Existing bogies are four- wheeled devices that are towed into the test article. They are typically designed to replicate the dynamic response of a vehicle for specifi c tests, e.g., tests of breakaway features. Bogies typically can be used for both low- and high-speed tests.

**center of gravity (c. g.)**—Point within test vehicle at which its total mass can be assumed to be concentrated.

**clear zone**—The roadside border area, starting at the edge-of-the-traveled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a nonrecoverable slope, and/or a clear run-out area. Although it is desirable to maximize the available clear zone, minimum width requirements are dependent on the traffi c volumes and speeds and on the roadside geometry.

**crash cushion**—A device designed primarily to safely stop a vehicle within a relatively short dis- tance. A redirective crash cushion is designed to contain and redirect a vehicle impacting downstream

244 | Manual for Assessing Safety Hardware

from the nose of the cushion. A non-redirective crash cushion is designed to contain and capture a vehicle impacting downstream from the nose of the cushion.

**crash test**—A test in which a production model test vehicle or a surrogate test vehicle impacts or traverses a highway feature.

**critical impact angle (CIA)**—For a given test and the attendant range of vehicular impact angles, the CIA is the angle within this range judged to have the greatest potential for causing a failure when the test is assessed by the recommended evaluation criteria.

**critical impact point (CIP)**—For a given test, the CIP is the initial point(s) of vehicular contact with a feature judged to have the greatest potential for causing a failure when the test is assessed by the recommended evaluation criteria.

**curb mass**—Mass of test vehicle with standard equipment; maximum capacity of engine fuel, oil and coolant; and, if so equipped, air conditioning and additional optional mass engine. It does not include occupants or cargo.

**device**—Refers to a design or a specifi c part thereof, such as a breakaway device. Note that the terms “device” and “feature” are often synonymous.

**evaluation criteria**—Criteria used to assess the results of a crash test or to assess the in-service performance of a feature.

**exit box**—As defi ned in Chapter 5, the exit box is a rectangular region placed at the point where a vehicle exits from a longitudinal barrier impact. The exit box is utilized to evaluate the vehicle’s trajectory upon exiting a longitudinal barrier installation. It is desirable that an impacting vehicle exits the end of the box rather than the side of the box.

**feature**—Refers to a specifi c element of a highway. It may be a hardware item and its associated foundation, such as a sign or barrier installation, or it may be a geometric element, such as a sides- lope or a ditch cross section.

**FHWA**—Federal Highway Administration.

**fi ll material—**Soil placed around roadside safety device during the embedment process.

**fl ail space**—Hypothetical space in which a hypothetical occupant is permitted to move during impact.

**gating device**—A device designed to allow controlled penetration of a vehicle when impacted up- stream of the beginning of the length of need (LON). Note there is some distance between the end of a gating device and the beginning of the LON of the device.

**geometric feature**—A roadside cross-section element such as a ditch section, an embankment, a driveway, a median crossover, or a curb. It also includes drainage structures, such as inlets and cul- vert ends, and devices such as grates used to improve the safety of these features.

**gross static mass**—Sum of test inertial mass and mass of surrogate occupant(s).

**HVOSM**—Highway-Vehicle-Object-Simulation-Model computer program.

Glossary | 245

**Hybrid III dummy**—An anthropomorphic dummy, representing the 50th percentile male, the speci- fi cations of which are contained in part 572, Subpart E, Title 49 of the Code of Federal Regulations, Chapter V-(10-1-88 Edition).

**impact angle (θ)**—Angle between normal direction of traffi c and approach path of test vehicle into the test article. The impact angle is the actual vector angle of the vehicle’s c. g. with respect to the normal direction of travel at the time of contact with the test article. Note that the reported impact angle is not necessarily the same as the vehicle heading angle at the time of impact. The test article should be oriented as it would typically be in service with respect to the normal direction of traffi c.

**impact point**—The initial point on a test article contacted by the impacting test vehicle.

**impact severity (IS)**—A measure of the impact severity of a vehicle of mass *M*, impacting at a speed

*V*, at an impact angle θ. It is defi ned as follows: IS = 1/2*M*(*V*sinθ)2.

**installation length—**The entire length of a safety feature installation. The installation length is mea- sured parallel to the roadway and includes end treatments.

**length of need (LON)**—That part of a longitudinal barrier or terminal designed to contain and redi- rect an errant vehicle.

**longitudinal barrier**—A device whose primary function is to safely redirect an errant vehicle away from a roadside or median hazard. The three types of longitudinal barriers are roadside barriers, me- dian barriers, and bridge rails.

**longitudinal channelizers**—A line of longitudinal elements that are connected together to provide delineation of the edge of the travelway. These systems are normally used to provide a clear indica- tion of the appropriate route through a work zone or an area with temporary lane deviations. Most longitudinal channelizers utilize plastic water-fi lled barrier elements with only a small amount of water to assure that they remain in placed under environmental loadings. Longitudinal channelizers are not positive barriers and should never be utilized where a positive barrier is warranted.

**non-gating device**—A device with redirectional capabilities along its entire length. Note that the end of a non-gating device is the beginning of the length of need for the device.

**occupant impact velocity (OIV)**—Velocity at which a hypothetical “point mass” occupant impacts a surface of a hypothetical occupant compartment.

**pendulum**—A device used as a surrogate for a production model test vehicle. A mass is attached to cables, which are in turn suspended from a fi xed point. The mass is raised to a selected height and released, allowing gravity to accelerate the mass as it swings into the test article. The structure of the mass can be designed to replicate the dynamic crush properties of a production model test vehicle. It is basically a low-speed test device.

**permanent feature**—A feature with an anticipated long duration of service, as opposed to those used in a work or construction zone having a relatively short duration of service.

**pocketing**—An undesirable behavior of a redirective device involving relatively large lateral dis- placements within a relatively short longitudinal distance. The behavior tends to generate large

246 | Manual for Assessing Safety Hardware

longitudinal decelerations as the front of the vehicle contacts a portion of a barrier deformed at a sharp angle relative to the vehicle’s path.

**post-impact head deceleration (PHD)**—The resultant acceleration experienced by a hypotheti- cal “point mass” occupant subsequent to impact with a hypothetical occupant compartment. Differs

from ridedown acceleration due to the occupant contact being calculated based on the combination of vehicle deceleration and yaw motion, and the acceleration is a resultant of both the lateral and longi- tudinal acceleration values after occupant impact.

**production model test vehicle**—A commercially available vehicle with properties matching those required in a given test.

**ridedown acceleration**—Acceleration experienced by a hypothetical “point mass” occupant subse- quent to impact with a hypothetical occupant compartment.

**SAE**—Society of Automotive Engineers.

**SI**—International System of Units.

**sprung mass**—All mass that is supported by a vehicle’s suspension system, including portions of the mass of the suspension members.

**snagging**—Contact between a portion of a vehicle, such as a wheel or frame element and a barrier system component that is approximately perpendicular to the normal direction of vehicle travel. The most common type of snagging is when a wheel engages the side of a post. The degree of snag- ging depends on the degree of engagement. Snagging can cause large and unacceptable vehicular decelerations.

**soil strength**—A measure of the support of the surrounding soil provided to ground mounted safety devices. As described in Appendix B, soil strength is measured in terms of the lateral resistance pro- vided by soil for a standardized guardrail post subjected to static and dynamic loading.

**support structure**—A system used to support a sign panel, chevron panel, luminaire, utility line, mailbox, or emergency call box. The system includes the post(s), pole(s), structural elements, founda- tion, breakaway mechanism if used, and accompanying hardware used to support the given feature.

**surrogate occupant**—A dummy, set of sand bags, or other artifact used to simulate the mass effects, to study the dynamic response of an occupant in a vehicle, or both.

**surrogate test vehicle**—A bogie, pendulum, or other substitute device designed to replicate the dy- namic response of a production model vehicle when in collision with a roadside feature.

**temporary feature**—A feature used in a work, construction, or maintenance zone. Its duration of use is normally relatively short, usually one year or less.

**terminal**—A device designed to treat the end of a rigid hazard or longitudinal barrier. A terminal may function by (1) decelerating a vehicle to a safe stop within a relatively short distance, (2) permitting controlled penetration of the vehicle behind the device, (3) containing and redirecting the vehicle, or

(4) a combination of 1, 2, and 3.

Glossary | 247

**test article (test feature)**—All components of a system, including the foundation, being evaluated in a crash test. Note that the system may be a geometric feature such as a ditch or driveway slope.

**test inertial mass**—Mass of test vehicle and all items rigidly attached to vehicle’s structure, includ- ing ballast and instrumentation. Mass of surrogate occupant(s), if used, is not included in test inertial mass.

**Test Level (TL)**—A set of conditions, defi ned in terms of vehicular type and mass, vehicular impact speed, and vehicular impact angle, that quantifi es the impact severity of a matrix of tests.

**test vehicle**—A commercially available production model vehicle or an approved surrogate vehicle used in a crash test to evaluate the impact performance of a test article.

**Theoretical Head Impact Velocity (THIV)**—The resultant velocity at which a hypothetical “point mass” occupant impacts the surface of a hypothetical occupant compartment. Differs from occupant impact velocity due to the occupant contact being calculated based on the combination of vehicle deceleration and yaw motion and the impact velocity is a result of both the lateral and longitudinal occupant velocity values at the time of occupant impact.

**track width**—Center-of-tire-to-center-of-tire distance for a given axle of a vehicle.

**transition**—That part of a longitudinal barrier system between and connecting sections of differing lateral stiffness and/or sections of differing design or geometry.

**trailer-mounted attenuator**—A cushioning device, attached to the rear of the changeable message sign trailer, which reduces the severity of impacts on the trailer for both the impacting vehicle and for others in the work zone.

**truck-mounted attenuator (TMA)**—An energy-absorbing device attached to the rear of a truck or utility vehicle. A TMA is designed to bring a vehicle impacting the rear of the truck to a controlled stop.

**TMA support vehicle**—The vehicle to which a truck-mounted attenuator is attached. Because the support vehicle often rolls forward during an impact with the TMA, the mass of the support truck can affect the performance of the safety device.

**unsprung mass**—All mass which is not carried by the suspension system, but is supported directly by the tire or wheel and considered to move with it.

**utility pole**—A support structure used to support power transmission or communication lines.

**variable message sign (VMS)**—A mobile sign system that utilizes a lighted display board to present virtually any message. VMS devices are often used in work zones to provide important information to motorists.

**vehicle rebound**—The distance that a vehicle rebounds from an impact with a crash cushion or end treatment. Vehicle rebound is intended to provide a measure of the risk that a vehicle will bounce off of an attenuator and roll backwards into the travelway.

248 | Manual for Assessing Safety Hardware

**working width**—The distance between the traffi c face of the test article before the impact and the maximum lateral position of any major part of the system or vehicle after the impact.

**work-zone traffi c control device**—A device used in a work zone to regulate, warn, and guide road users and advise them how to traverse a section of highway or street in the proper manner. Work- zone traffi c control devices of interest herein include signs, plastic drums, and lights that may be used thereon; cones, barricades, chevron panels, and their support system; and any other such device(s) commonly exposed to traffi c that may pose a hazard to occupants of a vehicle, to work-zone personnel, or to both.

| 249

# References and Bibliography

R

1. AA. *Aluminum Design Manual*. ADM-1. Aluminum Association, Inc., Washington, DC, 2005.
2. AASHTO. *Construction Manual for Highway Construction*. American Association of State Highway and Transportation Offi cials, Washington, DC, 1990.
3. AASHTO. *Roadside Design Guide*. American Association of State Highway and Transportation Offi cials, Washington, DC, 2006.
4. AASHTO. *Standard Specifi cations for Highway Bridges*. American Association of State Highway and Transportation Offi cials, Washington, DC, 2002.
5. AASHTO. *Standard Specifi cations for Structural Supports for Highway Signs, Luminaires, and Traffi c Signals*. American Association of State Highway and Transportation Offi cials, Washington, DC, 2009.
6. AASHTO. *AASHTO/AWS D1.5M/D1.5: 2008 Bridge Welding Code, 2009 AASHTO Interim*.

American Association of State Highway and Transportation Offi cials, Washington, DC, 2009.

1. AASHTO–AGC–ARTBA. *A Guide to Standardized Highway Lighting Pole Hardware*. Joint Report from Task Force 13, American Association of State Highway and Transportation

Offi cials, Associated General Contractors of America, American Road and Transportation Builders Association. AASHTO, Washington, DC, April 1980.

1. AASHTO–AGC–ARTBA. *A Guide to Standardized Highway Barrier Hardware*. Joint Report from Task Force 13, American Association of State Highway and Transportation Offi cials, Associated General Contractors of America, American Road and Transportation Builders Association. AASHTO, Washington, DC, 1995.
2. AASHTO–AGC–ARTBA. *A Guide to Small Sign Support Hardware*. Joint Report from Task Force 13, American Association of State Highway and Transportation Offi cials, Associated General Contractors of America, American Road and Transportation Builders Association. AASHTO, Washington, DC, 1998.
3. AISC. *Steel Construction Manual*, 13th Edition. American Institute of Steel Construction, Inc., Chicago, IL, 2005.
4. Alberson, D. C. and D. L. Ivey. Improved Breakaway Utility Pole, AD-IV. In *Transportation Research Record 1468*. Transportation Research Board, Washington, DC, December 1994.

250 | Manual for Assessing Safety Hardware

1. Beason, W. L. and T. J. Hirsch. *Measurement of Heavy Vehicle Impact Forces and Inertial Properties*, FHWA-RD-89-120. Texas Transportation Institute, Texas A&M University, College Station, Texas, May 1989.
2. Beedle, L. S. *Plastic Design of Steel Frames*. John Wiley &Sons, Inc., New York, NY, 1958.
3. Bligh, R. P., D. C. Albertson, W. L. Menges, and R. R. Haug. Evaluation of Dual Support, Triangular Slip-Base Sign Installations. In *Accident Investigation Quarterly and Journal*, No. 41. Accident Reconstruction Network (ARC Network), Waldorf, MD, 2006.
4. Bligh, R. P., H. E. Ross, and D. L. Bullard. *Test and Evaluation of Arizona Slip-Away Base Luminaire Supports: Final Report*. Report No. 7236-1F. Final Report to the Arizona Department of Transportation. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, September 1994.
5. Bligh, R. P. and D. L. Sicking. Applications of Barrier VII in the Design of Flexible Barriers. In

*Transportation Research Record 1233*. Transportation Research Board, Washington, DC, 1990.

1. Brauer, S. K., J. B. Mayer, and R. E. Kirksey. 1*800-lb Pendulum Mass with 10-Stage Crushable Nose Element Calibration Tests PCAL-1 & PCAL-2, Southwest Research Institute Test Report*. Southwest Research Institute, San Antonio, TX, October 1987.
2. Bronstad, M. E. Guardrail Ends. *Proceedings for the American Association for Automotive Medicine*, San Antonio, TX, 1983, pp. 389–407.
3. Bronstad, M. E., L. R. Calcote, and C. E. Kimball. *Concrete Median Barrier Research*. Final Report, Contract DOTFH-11-8130, Volumes I and II. Southwest Research Institute, San Antonio, TX, June 1976.
4. Bronstad, M. E. and J. D. Michie. *National Cooperative Highway Research Program Report 239: Multiple-Service-Level Highway Bridge Railing Selection Procedures*. NCHRP, Transportation Research Board, Washington, DC, November 1981.
5. Bronstad, M. E., J. D. Michie, and J. D. Mayer, Jr. *National Cooperative Highway Research Program Report 289: Performance of Longitudinal Traffi c Barriers*. NCHRP, Transportation Research Board, Washington, DC, June 1987.
6. Bronstad, M. E., et al. *Guardrail-Bridge Rail Transition Designs*. Research Report FHWA/RD- 86/178, Volume I. Southwest Research Institute, San Antonio, TX, April 1988.
7. Brown, C. M. *Validation of the ENSCO Surrogate Bogie Vehicle*. Research Report, U.S. Department of Transportation Contract No. DTFH61-91-Z-00002, Federal Highway Administration Report No. FHWA-Rd-93-074. Advanced Technology & Research Corp., Laurel, MD, for Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1994.
8. Buth, C. E., W. L. Menges, K. K. Mak, and R. P. Bligh. Transitions from Guardrail to Bridge Rail That Meet Safety Performance Requirements. In *Transportation Research Record 1720*. Transportation Research Board, Washington, DC, 2000.
9. Buth, E., et al. *Development of Safer Bridge Railing Designs*. Final Report Draft, FHWA Contract FH-1-9181. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, February 1981.

References and Bibliography | 251

1. Buth, E., et al. *Performance Limits of Longitudinal Barrier Systems*. Final Report on Contract DTFH61-82-C-00051. Texas Transportation Institute, Texas A&M Research Foundation, College Station, TX, May 1985.
2. Calcote, L. R. *Development of a Cost-Effectiveness Model for Guardrail Selection*. Final Report on Contract DOT-FH11-8827. Southwest Research Institute, San Antonio, TX, November 1977.
3. Campise, W. L. *Comparative Crash Tests Conducted on Seven Different Makes and Models of Truck Mounted Attenuators (TMAs): Final Report*. Final Report to the Texas Department of Transportation, Texas Transportation Institute, Texas A&M University, College Station, TX, August 1991.
4. Carney, J. F., III. *Development of a Metal Tube Crash Cushion for Narrow Hazard Highway Sites*. Report FHWA-CTRD-HPR-1080. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1986.
5. Carney, J. F., III, S. Chatterjee, and R. B. Albin. Development of a 100-km/h Reusable High- Molecular Weight/High-Density Polyethylene Truck-Mounted Attenuator. In *Transportation Research Record 1647*. Transportation Research Board, Washington, DC, November 1998.
6. Carney, J. F., III, C. E. Dougan, and E. C. Lohrey. NCHRP Report 350 Crash Test Results for Connecticut Truck-Mounted Attenuator. In *Transportation Research Record 1528*. Transportation Research Board, Washington, DC, 1996.
7. Chisholm, D. B. and J. G. Viner. *Dynamic Testing of Luminaire Supports*. Report No. FHWA- RD-73-55. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1972.
8. Chou, C. C., K. Hancock, and S. Basu. NARD: Numerical Analysis of Roadside Design, Version

2.0. Final Report on Contract DTFH61-87-Z-00116. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, July 1989.

1. Chou, C. C., et al. *Guard Version 3.1 Users and Programmers Manual*. Final Report on Contract DTFH61-87-Z-00116. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, July 1989.
2. Consolazio, G., K. Gurley, R. Ellis, and J. Wilkes. *Temporary Low Profi le Barrier for Roadside Safety: Phase II*. Phase II Report to the Florida Department of Transportation, University of Florida, Gainesville, FL, January 2003.
3. Council, F. M., et al. *Safe Geometric Design for Minicars*. Report No. FHWA/RD-87/047.

Federal Highway Administration, U.S. Department of Transportation, Washington, DC, March 1987.

1. Crain Communications, Inc. *Market Data Book*. Published by Automotive News magazine.

Crain Communications, Inc., Detroit, MI, 2008.

1. Deleys, N. J. *Safety Aspects of Roadside Cross Section Design*. Final Report, FHWA Contract No. DOT-FH-11-8189, Report No. FHWA-RD-75-41. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, February 1975.
2. Deleys, N. J. and L. O. Parada. *Rollover Potential of Vehicles on Embankments, Side Slopes, and Other Roadside Features*. Final Report, Contract No. DTFH61-83-C-00060. Calspan Corp., Buffalo, NY, August 1986.

252 | Manual for Assessing Safety Hardware

1. Dewey, J. F., et al. *A Study of the Soil-Structure Interaction Behavior of Highway Guardrail Posts*. Research Report 3431. Texas Transportation Institute, Texas A&M University System, College Station, TX, July 1983.
2. Edwards, T. C., et al. *National Cooperative Highway Research Program Report 77: Development of Design Criteria for Safer Luminaire Supports*. NCHRP, Transportation Research Board, Washington, DC, 1969.
3. Eggers, D. W., and T. J. Hirsch. *The Effects of Embedment Depth, Soil Properties, and Post Type on the Performance of Highway Guardrail Post*. Research Report 405-1. Texas Transportation Institute, Texas A&M University System, College Station, TX, August 1986.
4. European Committee for Standardization. *Road Restraint Systems*. BS EN 1317.
5. Faller, R. K., K. A. Polivka, Beau D. Kuipers, R. W. Bielenberg, J. D. Reid, J. R. Rohde, and D. L. Sicking. Midwest Guardrail System for Standard and Special Applications. In

*Transportation Research Record 1890*. Transportation Research Board, Washington, DC, 2004.

1. Faller, R. K., J. D. Reid, and J. R. Rohde. Approach Guardrail Transition for Concrete Safety Shape Barriers. In *Transportation Research Record 1647*. Transportation Research Board, Washington, DC, November 1998.
2. Faller, R. K., M. A. Ritter, S. R. Duwadi, and Barry T. Rosson. Railing Systems for Use on Timber Deck Bridges. In *Transportation Research Record 1656*. Transportation Research Board, Washington, DC, 1999.
3. Faller, R. K., B. T. Rosson, M. A. Ritter, E. A. Keller, and S. R. Duwadi. Development of Two Test Level 2 Bridge Railings and Transitions for Use on Transverse Glue-Laminated Deck Bridges. In *Transportation Research Record 1743*. Transportation Research Board, Washington, DC, 2001.
4. Faller, R. K., D. L. Sicking, K. A. Polivka, J. R. Rohde, and B. W. Bielenberg. Long-Span Guardrail System for Culvert Applications. In *Transportation Research Record 1720*. Transportation Research Board, Washington, DC, 2000.
5. FHWA. *Cost-Effectiveness of Small Highway Sign Supports*. FHWA Contract FH-11- 8821, Report No. HWA/RD/80/502. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1980.
6. FHWA. *Specifi cations for the Collection and Storage of Crash Test Data*, Volume II. Report No. FHWA-RD-91-039. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1991.
7. FHWA. *Manual on Uniform Traffi c Control Devices* (MUTCD). Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 2009.
8. Fleck, J. T. *Validation of the Crash Victim Simulator*. Report No. DOT-HS-806 279, Volumes I through IV. U.S. Department of Transportation, Washington, DC, December 1981.
9. Foedinger, R., J. F. Boozer, M. E. Bronstad, and J. W. Davidson. Development of Energy- Absorbing Composite Utility Pole. In *Transportation Research Record 1851*. Transportation Research Board, Washington, DC, 2003.

References and Bibliography | 253

1. Ford Motor Company. *2005 Body Builder Layout Book, Truck Body Builder Advisory Service, Appendix—Design Recommendations, Second Unit Body Mounting*. Ford Motor Company, 2005, pp. 186–194. [https://www.fl eet.ford.com/truckbbas/topics/2005/subm.html]
2. Ghanoudi, M. K., C. M. Brown. *Testing of a Modifi ed Oregon Multidirectional Slip-Base Sign Support, Foil Test Numbers*. Report to MiTech Incorporated for Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1997.
3. Griffi n, L. I., III, et al. *An Evaluation of Selected Truck Mounted Attenuators (TMAs) with Recommended Performance Specifi cations*. Texas Transportation Institute, Texas A&M University, College Station, TX, December 1990.
4. Gurfi nkel, G. *Wood Engineering*. Southern Forest Products Association, New Orleans, LA, 1973.
5. Hansen, A. G., M. W. Hargrave, and C. R. Horr. Validation of a Surrogate Vehicle for Luminaire Support Certifi cation Testing. In *Transportation Research Record 1233*. Transportation Research Board, Washington, DC, 1989.
6. Hargrave, M. W., A. G. Hansen, and J. A. Hinch. *A Summary of Recent Side Impact Research Conducted by the Federal Highway Administration*. American Society of Civil Engineers, Reston, VA, 1989.
7. Hascall, J. A. Investigating the Use of Small-Diameter Softwood for Guardrail Posts. Master’s Thesis, Submitted to the Graduate College of the University of Nebraska-Lincoln, Lincoln, NE, December 2005.
8. Henson, A., et al. *Development of Additional Federal Outdoor Impact Laboratory (FOIL) Facilities, Volume II: Validation of the FOIL Pendulum Upgrade*. Research Report, U.S. Department of Transportation Contract No. DTFH61-87-X-00044, Federal Highway Administration Report No. FHWA-RD-90-085. Scientex Corporation for Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1990.
9. Heydinger, G. J. and R. A. Bixel. *Rollover Stability Measurements for 2002 New Car Assessment Program (NCAP)*. Final Report on Contract DTNH22-01-C-02004. National Highway Traffi c Safety Administration, S.E.A. Inc., Columbus, OH, December 2002.
10. Hinch, J., et al. *Foil Construction, Laboratory Procedures to Determine the Breakaway Behavior of Luminaire Supports in Mini-Sized Vehicle Collisions*, Volume I, II, III, Report Numbers FHWA-RD-86-105-107. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1987.
11. Hinch, J., et al. Impact Attenuators: A Current Engineering Evaluation. *In Transportation Research Record 1198*. Transportation Research Board, Washington, DC, 1988.
12. Hirsch, T. J. Longitudinal Barriers for Busses and Trucks. In *Transportation Research Record 1052*. Transportation Research Board, Washington, DC, 1986.
13. Holloway, J. C., D. L. Sicking, and B. T. Rosson. *Performance Evaluation of NDOR Mountable Curbs*. Report No. TRP-03-37-93. Final Report to the Nebraska Department of Roads, Midwest Roadside Safety Facility, Civil Engineering Department, University of Nebraska-Lincoln, Lincoln, NE, June 1994.

254 | Manual for Assessing Safety Hardware

1. Humphries, J. and T. D. Sullivan. Guidelines for the Use of Truck-Mounted Attenuators in Work Zones. In *Transportation Research Record 1304*. Transportation Research Board, National Research Council, Washington, DC, 1991.
2. ISO. *Road Vehicles with Two Axles-Determination of Centre of Gravity*. Reference Number ISO 10392:1992(E), First Edition. International Organization for Standardization, Geneva, Switzerland, June 6, 1992.
3. Ivey, D. L. and Morgan, J. R. Timber Pole Safety by Design. In *Transportation Research Record 1065*. Transportation Research Board, Washington, DC, 1986.
4. Ivey, D. L. and D. L. Sicking. “The Infl uence of Pavement Edge and Shoulder Characteristics on Vehicle Handling and Stability.” In *Transportation Research Record 1084*. Transportation Research Board, Washington, DC, 1986.
5. James, M. E. and H. E. Ross, Jr. *HVOSM User’s Manual*. Research Report 140-9. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1974.
6. Klien, R. M., W. A. Johnson, and H. T. Szostak. *Infl uence of Roadway Disturbances on Vehicle Handling*. Final Report, Contract DOT-HS-5-01223. Systems Technology, Inc., Joliet, IL, October 1976.
7. Labra, J. J. *Development of Safer Utility Poles*. Contract DOT-FH-11-8909, Final Report.

Southwest Research Institute, San Antonio, TX, February 1980.

1. Laker, I. B. and A. R. Payne. *Transportation Research Circular Number 396: Theoretical Head Impact Velocity Concept*. Transportation Research Board, National Research Council, Washington, DC, May 1992.
2. Lampela, A. A. and A. H. Yang. *Analysis of Guardrail Accidents in Michigan*. Report TSD-243-

74. Michigan Department of State Highways and Transportation, July 1974.

1. Lawrence, L. R. and J. H. Hatton, Jr. C*rash Cushions Selection Criteria and Design*. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, September 1975.
2. Leonin, C. and R. Powers. *In-Service Evaluation of Experimental Traffi c Barriers: An Interim Report*. Report No.FHWA-DP64/EP7-1. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, April 1986.
3. Livermore Software Technology Corporation. LS-DYNA software. Livermore Software Technology Corporation, 7374 Las Positas Rd., Livermore, CA.
4. Mak, K. K., R. P. Bligh, and W. B. Wilson. Wyoming Road Closure Gate. In *Transportation Research Record 1528*. Transportation Research Board, Washington, DC, September 1996.
5. Mak, K. K. and D. L. Sicking. Rollover Caused by Concrete Safety Shaped Barrier. In

*Transportation Research Record 1258*. Transportation Research Board, Washington, DC, 1992.

1. Mak, K. K., D. L. Sicking, and H. E. Ross, Jr. Real World Impact Conditions for Ran-Off-the- Road Accidents. In *Transportation Research Record l065*. Transportation Research Board, Washington, DC, 1986.
2. Mauer, F., D. L. Bullard, D. C. Alberson, and W. L. Menges. Development and Testing of Steel U-Channel Slip Safe Sign Support. In *Transportation Research Record 1599*. Transportation Research Board, Washington, DC, 1997.

References and Bibliography | 255

1. Michie, J. D. *National Cooperative Highway Research Program Report 230: Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*. NCHRP, Transportation Research Board, Washington, DC, March 1981.
2. Michie, J. D. *Performance and Operational Experience of Truck-Mounted Attenuators*, NCHRP Project 20-5, Topic 22-01. National Academy Press, Transportation Research Board, Washington, DC, 1992.
3. Michie, J. D., L. R. Calcote, and M. E. Bronstad. *National Cooperative Highway Research Program Report 115: Guardrail Performance and Design*. NCHRP, Transportation Research Board, Washington, DC, 1971.
4. NCHRP. *Determination of Safe/Cost Effective Roadside Slopes and Associated Clear Distances*.

National Cooperative Highway Research Program Project 17-11, Texas Transportation Institute, Texas A&M University, College Station, Texas. (in progress).

1. NCHRP. *Identifi cation of Vehicular Impact Conditions Associated with Serious Ran-Off-Road Crashes*. NCHRP Project 17-22. Midwest Roadside Safety Facility, University of Nebraska- Lincoln, Lincoln, NE for National Cooperative Highway Research Program, Transportation Research Board, Washington, DC, (in progress).
2. NHTSA. *National Accident Sampling System, Vehicle Measurement Techniques*. National Highway Traffi c Safety Administration, U.S. Department of Transportation, Oklahoma City, Oklahoma, 1998.
3. NSC. *Vehicle Damage Scale for Traffi c Accident Investigators*. National Safety Council, 444 Michigan Avenue, Chicago, Illinois, 60611, 1984.
4. Olson, R. M., et al. *National Cooperative Highway Research Program Report 149: Bridge Rail Design: Factors, Trends, and Guidelines*. NCHRP, Transportation Research Board, Washington, DC, 1974, 49 pp.
5. Olson, R. M., et al. *National Cooperative Highway Research Program Report 150: Effect of Curb Geometry and Location on Vehicle Behavior*. NCHRP, Transportation Research Board, Washington, DC, 1974.
6. Paulsen, G. W. and J. D. Reid. Nonlinear Finite-Element Analysis of Dual Support Breakaway Sign. In *Transportation Research Record 1528*. Transportation Research Board, Washington, DC, September 1996.
7. Perchonok, K. et al. *Hazardous Effect of Highway Features and Roadside Objects*, Vol. 2, FHWA Report No. FHWA-RD-78-202. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, September 1978.
8. Perera, H. S. Development of an Improved Highway-Vehicle-Object- Simulation Model for Multi-Faced Rigid Barriers. In T*ransportation Research Record 1233*. Transportation Research Board, Washington, DC, 1989.
9. Pfi efer, B. G., J. C. Holloway, R. K. Faller, E. R. Post, and D. L. Christiansen. Full-Scale Crash Tests on a Luminaire Support 4-Bolt Slipbase Design. In *Transportation Research Record 1367*. Transportation Research Board, Washington, DC, 1992.

256 | Manual for Assessing Safety Hardware

1. Pinelli, J. P., C. S. Subramanian, and J. Tabora. Experimental Study of Breakaway Highway Sign Connections. In *Journal of Transportation Engineering*, Vol 128, No. 1. American Society of Civil Engineers, Reston, VA, January 2002.
2. Polivka, K. A., R. K. Faller, J. C. Holloway, J. R. Rohde, and D. L. Sicking. *Safety Performance Evaluation of Missouri’s Self-Driving Temporary Sign Stands*. Transportation Research Report No. TRP-03-97-00. Final Report to the Midwest States’ Regional Pooled Fund Program, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, NE, December 13, 2000.
3. Polivka, K. A., R. K. Faller, and J. R. Rohde. Guardrail Connection for Low-Fill Culverts. In

*Transportation Research Record 1851*. Transportation Research Board, Washington, DC, 2003.

1. Polivka, K. A., R. K. Faller, D. L. Sicking, J. D. Reid, J. R. Rohde, and J. C. Holloway. *Crash Testing of Missouri’s W-Beam to Thrie Beam Transition Element*. Final Report to the Midwest State’s Regional Pooled Fund Program, Transportation Research Report No. TRP-03-94-00, Project No. SPR-3(017)-Year 9. Midwest Roadside Safety Facility, University of Nebraska, Lincoln, NE, September 12, 2000.
2. Polivka, K.A., et al. Development of the Midwest Guardrail System (MGS) W-Beam to Thrie- Beam Transition. In *Transportation Research Record 2025*. Transportation Research Board, National Research Council, Washington, DC, 2007.
3. Powell, G. H. A Computer Program for Evaluation of Automobile Barrier Systems. Report DOT- RD-73-51. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, 1973.
4. Ray, M. H. Preliminary Recommendations for Performing Side Impact Crash Tests of Roadside Safety Features. In *Issues for Improving Roadside Safety, Transportation Research Circular*. Transportation Research Board, Washington, DC, 1999.
5. Ray, M. H. and J. F. Carney, III. *Side Impact Test and Evaluation Procedures for Roadside Structure Crash Tests*. Final Report, Contract DTFH61-88-R-00092, Department of Civil and Environmental Engineering, Vanderbilt University, Nashville, TN, March 1992.
6. Ray, M. H. and J. F. Carney, III. Test and Evaluation Criteria for Side Impact Crash Tests. In *ASCE Journal of Transportation*, Vol. 120 No. 4. American Society of Civil Engineers, Reston, VA, July/August 1993.
7. Ray, M. H., M. W. Hargrave, J. F. Carney, III, and K. Hiranmayee. Side Impact Test and Evaluation Criteria for Roadside Safety Hardware. In *General Design and Roadside Safety Features, Transportation Research Record 1647*. Transportation Research Board, Washington, DC, 1999.
8. Ray, M. H. and K. Hiranmayee. Evaluating Human Risk in Side Impact Collisions with Roadside Objects. In *Roadside Safety Features and Hydraulic, Hydrology and Water Quality Issues, Transportation Research Record 1720*. Transportation Research Board, Washington, DC, 2000.
9. Ray, M. H. and J. D. Michie. *Evaluation of Design Analysis Procedures and Acceptance Criteria for Roadside Hardware Vol. IV: The Importance of the Occupant Risk Criteria*. Report No. FHWA/RD-87/099. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, July 1987.

References and Bibliography | 257

1. Ray, M. H., J. A. Weir, and J. A. Hopp. *National Cooperative Highway Research Program Report No. 490: In-Service Performance of Traffi c Barriers*. NCHRP, Transportation Research Board, Washington, DC, 2003.
2. Ray, M. H., et al. *Evaluation of Design Analysis Procedures and Acceptance Criteria for Roadside Hardware Vol. V: Hazards of the Redirected Car*. Report No. FHWA/RD-87/100, Federal Highway Administration, U.S. Department of Transportation, Washington, DC, July 1987.
3. Reid, J. D. Designing for the Critical Impact Point on a New Bullnose System. In *International Journal of Crashworthiness*, Vol. 5, No. 2. Taylor and Francis Group, Oxfordshire, UK, 2000, pp. 141–152.
4. Reid, J. D. Dual-Support Breakaway Sign with Modifi ed Fuse Plate and Multidirectional Slip Base. In *Transportation Research Record 1528*. Transportation Research Board, Washington, DC, September 1996.
5. Reid, J. D. New Breakaway Mailbox Designed Using Nonlinear Finite Element Analysis. In *Finite Elements in Analysis and Design*, Vol. 32, No. 1. Elsevier Ltd., Kiplington Oxford, UK, March 1999, pp. 37–49.
6. Reid, J. D. and G. W. Paulsen. Design and Simulation of Large Breakaway Signs. In *Journal of Transportation Engineering*, Vol. 124, No. 1. American Society of Civil Engineers, Reston, VA, 1998.
7. Reid, J. D., J. R. Rohde, and D. L. Sicking. Box-Beam Burster Energy-Absorbing Single-Sided Crash Cushion. In *Transportation Research Record 1797*. Transportation Research Board, Washington, DC, 2002.
8. Reid, J. D., D. L. Sicking, and R. P. Bligh. Critical Impact Point for Longitudinal Barriers. In *Journal of Transportation Engineering*, Vol 124, No. 1. American Society of Civil Engineers, Reston, VA, January–February 1998, pp. 65–72.
9. Rohde, J. R., D. L. Sicking, and J. D. Reid. Box-Beam Burster Energy-Absorbing Terminal Bridge Pier Protection System. In *Transportation Research Record 1851*. Transportation Research Board, Washington, DC, 2003.
10. Ross, H. E. Jr., H. S. Perera, D. L. Sicking, and R. P. Bligh. *National Cooperative Highway Research Program, Report 318: Roadside Safety Design for Small Vehicles*. Transportation Research Board, Washington, DC, 1989, 70 pp.
11. Ross, H. E., Jr., and E. R. Post. *Criteria for Guardrail Need and Location on Embankments*.

Research Report 140-4. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1971.

1. Ross, H. E. Jr., D. L. Sicking, R. A. Zimmer, and J. Michie. *National Cooperative Highway Research Program Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features*. NCHRP, Transportation Research Board, Washington, DC, 1993, 132 pp.
2. Ross, H. E., Jr., et al. Safety Treatment of Roadside Drainage Structures. In *Transportation Research Record 868*. Transportation Research Board, Washington, DC, 1982.

258 | Manual for Assessing Safety Hardware

1. Rowhani, P., D. Glauz, and R. L. S. Stoughton. Vehicle Crash Tests of Concrete Median Barrier Retrofi tted With Slipformed Concrete Glare Screen. In *Transportation Research Record 1419*. Transportation Research Board, Washington, DC, 1993.
2. SAE. Collision Deformation Classifi cation, Recommended Practice J224a. Society of Automotive Engineers, New York, NY, 1972.
3. SAE. On-Highway Vehicles and Off-Highway Machinery, Volume 4 of *1986 SAE Handbook*.

Society of Automotive Engineers, Warrendale, PA, 1986.

1. Salmon, C. G. and J. E. John. *Steel Structures*. Harper & Row Publishers, New York, NY, 1990.
2. Schiefferly, C. and J. Marlow. *Development of a Lightweight Truck Mounted Attenuator*. Report 32036-609934. California Department of Transportation, Sacramento, CA, July 1983.
3. Segal, D. J. *Highway-Vehicle-Object-Simulation-Model 1976*, Report No. FHWA-RD-75- 162 through 165, Four volumes. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, February 1976.
4. Sicking, D. L., S. Hemsorach, and R. P. Bligh. Critical Impact Locations for Longitudinal Barriers. In *Journal of Transportation Engineering*, Vol 124, No. 1. American Society of Civil Engineers, Reston, VA, January–February 1998, pp. 65–72.
5. Sicking, D. L., J. R. Rohde, and J. D. Reid. Design and Development of Steel Breakaway Posts.

In *Transportation Research Record 1720*. Transportation Research Board, Washington, DC, 2000.

1. Sicking, D. L. and H. E. Ross, Jr. Structural Optimization of Strong Post W-beam Guardrail. In

*Transportation Research Record 1133*. Transportation Research Board, Washington, DC, 1987.

1. SIS. European Standard EN 1317-1, Road restraint systems—Part 1: Terminology and general criteria for test methods. European Committee for Standardization, Ref. No. EN 1317-1:1998 E. Swedish Standards Institution, Stockholm, Sweden, March 1998.
2. SIS. European Standard EN 1317-2, Road restraint systems—Part 2: Performance classes, impact test acceptance criteria, and test methods for safety barriers. European Committee for Standardization, Ref. No. EN 1317-2:1998 E. Swedish Standards Institution, Stockholm, Sweden, March 1998.
3. SIS. European Standard EN 1317-3, Road restraint systems—Part 3: Performance classes, impact test acceptance criteria, and test methods for crash cushions. European Committee for Standardization, Ref. No. EN 1317-3:1998 E. Swedish Standards Institution, Stockholm, Sweden, March 1998.
4. Snyder, R. G. State-of-the-Art-Human Impact Tolerances. SAE 700398 (rev. August 1970); reprinted from *1970 International Automobile Safety Conference Compendium*, May 1970.
5. Solomon, D. and H. Boyd. *Model Procedure for In-Service Evaluation of Roadside Safety Hardware Devices*. Report No. FHWA-IP-86-8. Federal Highway Administration, U.S. Department of Transportation, Washington, DC, April 1986.
6. Solomon, P. L. *The Simulation Model of Automobile Collisions (SMAC) Operator’s Manual*.

National Highway Traffi c Safety Administration, Washington, DC, October 1974.

References and Bibliography | 259

1. Stoughton, R. L., J. R. Stoker, and E. F. Nordlin. *Vehicular Impact Tests of a Truck Mounted Attenuator Containing Vermiculite Concrete Cells*. Report 33001-609936. California Department of Transportation, Sacramento, CA, June 1980.
2. Stout, D., J. Hinch, and D. Sawyer. *Guardrail Testing Program*. Final Report on Contract DTFH71-87-C-00002, Ensco Inc., Springfi eld, VA, June 1990.
3. Stout, D., J. Hinch, and T. L. Yang. *Force-Defl ection Characteristics of Guardrail Posts*. Final Report on Contract DTFH61-85-C-00099. Ensco Inc., Springfi eld, VA, September 1988.
4. TASS. MADYMO. Computer simulation program developed by TASS, 38701 Seven Mile Road, Suite 260, Livonia, MI 48152.
5. Thomson, R. and J. Valtonen. Vehicle Impacts in V-Shaped Ditches. In *Transportation Research Record 1797*. Transportation Research Board, Washington, DC, 2002.
6. TRB. Proposed Full-Scale Testing Procedures for Guardrails. In *Highway Research Board Circular 482*. Transportation Research Board, Washington, DC, September 1962.
7. TRB. Recommended Procedures for Vehicle Crash Testing of Highway Appurtances. In

*Transportation Research Circular 191*. Transportation Research Board, Washington, DC, 1978.

1. TTI. *Test Risk Assessment Program (TRAP) Version 2.2, User’s Manual*. Developed by CAPSHER Technology, Inc. for Texas Transportation Institute, Texas A&M University, College Station, Texas, July 2002.
2. U.S. DOT. V*ehicle Measurement Techniques*. National Automotive Sampling System (NASS), Transportation Safety Institute, U.S. Department of Transportation, Oklahoma City, OK, September 29, 1998.
3. UMTRI. *Delphi V-Forecast and Analysis of the U.S. Automotive Industry through the Year 2000*.

University of Michigan Transportation Research Institute, Ann Arbor, MI, July 1989.

1. Viano, D. C., and I. V. Lau. *Biomechanics of Impact Injury*. Research Publication GMR-6894.

General Motors Research Laboratories, Warren, Michigan, December 1989.

1. Wards. *Wards Automotive Yearbook 2002*. Wards Communications, Southfi eld, MI, 2002.
2. Weaver, G. D., E. L. Marquis, and R. M. Olson. *National Cooperative Highway Research Program Report 158: The Relation of Side Slope Design to Highway Safety*. NCHRP, Transportation Research Board, Washington, DC, 1975.
3. Zimmer R. R. and D. L. Ivey. *Infl uence of Roadway Surface Holes on the Potential for Vehicle Loss of Control*. Research Report 328-2F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1983.
4. MwRSF Report TRP-03-265-12
	* Research Report (Report # TRP-03-265-12)
	* Title - Test Matrices for Evaluating Cable Median Barriers Placed in V-Ditches
	* Authors - Mongiardini, M., Faller, R.K., Rosenbaugh, S.K., and Reid, J.D.
	* Performing Organization – Midwest Road Safety Facility, University of Nebraska, Lincoln, NE
	* Sponsoring Organization – Midwest States Regional Pooled Fund Program
5. **DRAFT** Report Title - *Vehicle Dynamics Analysis of MASH Pickup and Small Car Traversal through Symmetric V-Ditch*
	* Authors – Fahad Ha Que and Nauman M. Sheikh, P. E.
	* Institute – Texas A&M Transportation Institute, Texas A&M University, College Station, TX
	* Date – September 2013
6. Marzougui, D., Mahadevaiah, U., Tahan, F., Kan, C.D., McGinnis, R., and Powers, R., *Development of Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems*, National Cooperative Highway Research Program (NCHRP) Report No. 711, Transportation Research Board of the National Academies, Washington D.C., 2012.
<http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1640>
7. Marzougui, D., Kan C.D., and Opiela K., *Further Considerations for Effective Median Barrier Lateral Placement for Varying Highway Cross Sections*, Journal of the Transportation Research Board, pp 63-77, Issue 2437, Washington DC, 2014.
<http://trrjournalonline.trb.org/doi/pdf/10.3141/2437-07>
8. Marzougui, D., Kan C.D., and Opiela, K.S., *Vehicle Dynamics Investigations to Develop Guidelines for Crash Testing Cable Barriers on Sloped Surfaces*, Working Paper NCAC 2010-W-009, National Crash Analysis Center, George Washington University, Ashburn, Virginia, August 201**0.**
9. Karcher, J., *Vehicle Dynamics Modeling and Simulation for the Safety Evaluation, Selection, and Placement of Cable Barrier Systems*, Master’s Thesis, THE GEORGE WASHINGTON UNIVERSITY, 2009, 171 pages.

[http://catalog.wrlc.org/cgi-bin/Pwebrecon.cgi?Search\_Arg=Vehicle%20Dynamics%20Modeling%20and%20Simulation%20for%20the%20Safety%20Evaluation,%20Selection,%20and%20Placement%20of%20Cable%20Barrier%20Systems&Search\_Code=GKEY^&SL=None&CNT=25&DB=local](http://catalog.wrlc.org/cgi-bin/Pwebrecon.cgi?Search_Arg=Vehicle%20Dynamics%20Modeling%20and%20Simulation%20for%20the%20Safety%20Evaluation,%20Selection,%20and%20Placement%20of%20Cable%20Barrier%20Systems&Search_Code=GKEY%5e&SL=None&CNT=25&DB=local)

1. Marzougui, D., Kan C.D., and Opiela K.S., *Evaluation of the Influences of Cable Barrier Design and Placement on Vehicle to Barrier Interface*, NCAC Document 2008-W-001, National Crash Analysis Center, George Washington University, Washington, D.C., 2008.
2. **DRAFT** TTI Test Report for MwRSF Cable Barrier
	* Report – Test Report 478730-1
	* Title – MASH TL-3 Testing and Evaluation of the Midwest Cable Median Barrier
	* Authors – Roger P. Bligh, P. E. and Wanda L. Menges
	* Performing Organization – Texas Transportation Institute Proving Ground, Texas A&M University, College Station, TX
	* Sponsoring Organization – National Cooperative Highway Research Program
	* Date – December 2011
3. Stolle, C.S., Cable Median Barrier Failure Analysis and Remediation. PhD Dissertation. University of Nebraska-Lincoln, Lincoln, Nebraska, December 2012.
4. Research article – *Cable Median Barrier Failure Analysis and Prevention*
	* Report No. TRP-03-275-12
	* Authors – Stolle, C.S. and Sicking, D.L.
	* Performing Organization – Midwest Roadside Safety Facility, University of Nebraska, Lincoln, NE
	* Sponsoring Organization – Midwest States Regional Pooled Fund Program & Mid-America Transportation Center
5. Marzougui, D., Opiela, K.S., Story, C.C., Kan, C.D., and Arispe, E., *Testing and Analyses of Sloped Terrain Effects on Vehicle Trajectories and Kinematics*, Internal Report, Center for Collision Safety and Analysis, George Mason University, Virginia, 2014.