TABLE OF CONTENTS

This page intentionally left blank.

@Seismicisolation

SECTION 15

DESIGN OF SOUND BARRIERS

15.1—SCOPE

This Section applies to the structural design of sound barriers which are either ground-mounted or structure-mounted and the design of the foundations of ground-mounted sound barriers.

C15.1

This Section specifies the design forces and the design requirements unique to sound barriers constructed along highways. This Section does not cover sound barriers constructed adjacent to railroad tracks or the acoustical requirements for sound barriers.

These provisions are largely based on the requirements of the *Guide Specifications for Structural Design of Sound Barriers* (1989).

15.2—DEFINITIONS

Clear Zone—The total roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles.

Crashworthy—A traffic railing system that has been successfully crash-tested to a currently acceptable crash test matrix and test level or one that can be geometrically and structurally evaluated as equal to a crash-tested system.

Ground-Mounted Sound Barriers—Sound barriers supported on shallow or deep foundations.

Post-and-Panel Construction—Type of sound barrier construction consisting of vertical posts supported on a structure or on the foundations and panels spanning horizontally between adjacent posts.

Right-of-Way—The land on which a roadway and its associated facilities and appurtenances are located. The highway right-of-way is owned and maintained by the agency having jurisdiction over that specific roadway.

Right-of-Way Line—The boundary of the right-of-way.

Sound Barrier—A wall constructed along a highway to lower the highway noise level in the area behind the wall.

Sound Barrier Setback—The distance between the point on the traffic face of the sound barrier wall that is closest to traffic and the closest point on the traffic face of the traffic railing the sound barrier is mounted on or located behind as defined in Article 15.8.4.

Structure-Mounted Sound Barriers—Sound barriers supported on bridges, crashworthy traffic railings, or retaining walls.

Traffic Railing—Synonymous with vehicular railing; used as a bridge- or structure-mounted railing rather than as a guardrail or median barrier, as in other publications.

Vehicular Railing—Synonymous with traffic railing; used as a bridge- or structure-mounted railing rather than as a guardrail or median barrier, as in other publications.

15.3—NOTATION

S = setback distance of sound barrier (15.8.4)
φ = soil angle of internal friction (degrees) (C15.4.2)
γ_p = load factor for permanent loads (15.9.9)

15.4—GENERAL FEATURES

15.4.1—Functional Requirements

15.4.1.1—General

Consult a roadway professional for sight-distance and sound barrier height and length requirements.

15.4.1.2—Lateral Clearance

Unless dictated by site conditions and approved by the Owner, sound barriers shall be located outside the clear zone or, when the clear zone is wider than the distance between the edge of the traffic lanes and the edge of the available right-of-way, just inside the right-of-way.

C15.4.1.2

Locating the sound barrier farther from the edge of the traffic lanes reduces the possibility of vehicular collision with the barrier. The most desirable location for a sound barrier is outside the clear zone, which minimizes the possibility of vehicular collision. In many cases, because sound barriers are typically used in urban areas, the width of available right-of-way is less than the width of the clear zone.

When conditions make it impractical to locate the sound barrier at adequate distance from the edge of traffic lanes and the sound barrier is mounted on a traffic barrier, the recommended minimum clearance from the edge of traffic lanes to the face of the traffic barrier is 10.0 ft. Lateral clearances greater than 10.0 ft should be used when feasible. Guardrail or other traffic barriers should be considered for use when the sound barrier is located inside the clear zone.

In addition to safety considerations, maintenance requirements should be considered in deciding sound barrier locations. Sound barriers placed within the area between the shoulder and right-of-way line complicate the ongoing maintenance and landscaping operations and lead to increased costs, especially if landscaping is placed on both sides of the sound barrier. Special consideration should be given to maintaining the adjoining land behind the sound barrier and adjacent to the right-of-way line.

15.4.2—Drainage

Adequate drainage shall be provided along sound barriers.

C15.4.2

It is important to have drainage facilities along sound barriers to ensure soil stability. Soils with an angle of internal friction, φ, of 25 degrees or less may develop flowing characteristics when saturated. Limits on fines, especially clay and peat, should be specified.

15.4.3—Emergency Responder and Maintenance Access

Provisions for emergency and maintenance access shall be provided. Local fire department requirements for fire hose and emergency access shall be satisfied.

C15.4.3

Provisions may be necessary to allow firefighters and hazardous material clean-up crews access to fire hydrants on the opposite side of the sound barrier. The designer should consult with local fire and emergency officials regarding their specific needs.

Shorter barriers may be traversed by throwing the fire hose over the wall. Taller barriers may require an opening through which the hose is passed. Such an opening can consist of a formed or cored hole, a hollow masonry block turned on its side, a maintenance access

@Seismicisolation

gate, etc. A small sign may be placed adjacent to the emergency access location on the traffic side of the sound barrier. This sign would bear the street name on which the hydrant is located, thus aiding emergency crews in identifying the hydrant nearest the opening.

Access to the back side of the sound barrier must be provided if the area is to be maintained. In subdivision areas, access can be via local streets, when available. If access is not available via local streets, access gates or openings are essential at intervals along the sound barrier. Offset barriers concealing the access opening must be overlapped a minimum of 2.5 times the offset distance in order to maintain the integrity of the main barrier's sound attenuation. Location of the access openings should be coordinated with the appropriate agency or land owner.

15.4.4—Differential Settlement of Foundations

For long masonry sound barriers supported on spread footings, provisions should be made to accommodate differential settlement.

C15.4.4

Provisions should be made to accommodate differential settlement when sound barriers are supported on continuous spread or trench footings or cap beams.

15.5—LIMIT STATES AND RESISTANCE FACTORS

15.5.1—General

Structural components shall be proportioned to satisfy the requirements at all appropriate service, strength, and extreme event limit states.

Limit states applicable to sound barrier foundation design shall be in accordance with Article 15.9. Limit states applicable to the structural design of sound barrier components shall be as presented herein.

The limit states shall apply using the applicable load combinations in Table 3.4.1-1 and the loads specified herein.

Where masonry or other proprietary walls are utilized, the Owner shall approve the design specifications to be used.

C15.5.1

These Specifications do not include design provisions for masonry structures. Design provisions for masonry structures should be taken from other specifications.

15.5.2—Service Limit State

The resistance factors for the service limit states for post, wall panel, and foundation components shall be as specified in Article 1.3.2.1. Design for service limit states shall be in accordance with the applicable requirements of Articles 5.5.2, 6.5.2, 7.5.1, and 8.5.1.

15.5.3—Strength Limit State

The resistance factors for the strength limit states for post, wall panel, and foundation components shall be as specified in Articles 5.5.4, 6.5.4, 7.5.4, and 8.5.2.

15.5.4—Extreme Event Limit State

The resistance factors for the extreme event limit states for post, wall panel, and foundation components shall be as specified in Article 1.3.2.1.

15.6—EXPANSION DEVICES

15.6.1—General

Adequate noise sealant material shall be placed at expansion joints of sound barriers.

15.6.2—Structure-Mounted Sound Barriers

Except for post-and-panel construction, as a minimum, expansion joints shall be provided in the sound barriers at the location of expansion joints in the supporting structure, at bridge intermediate supports, and at the centerline of bridge spans.

When post-and-panel construction is utilized, wall panels may be allowed to bridge the expansion joints in, or at the ends of, the deck of the supporting structure where the panels' seat width on the posts is sufficient to accommodate the expansion joint movements and the dimensional and installation tolerances; otherwise, posts shall be placed on either side of any expansion joint in the supporting structure.

C15.6.2

When the type of construction utilized for sound barriers does not inherently allow movements between the sound barrier components, allowance should be made to accommodate the movement and deformations of the supporting structure. Therefore, expansion devices are required in the sound barriers at expansion joint locations in order not to restrict the movement of the expansion joints of the supporting structures.

Sound barriers mounted on bridges stiffen the supporting bridge superstructures, resulting in longitudinal stresses developing in the sound barriers. The higher curvature of bridge girders at high moment locations near midspans and, for continuous bridges, at intermediate supports increases the magnitude of these stresses. Providing expansion joints in the sound barriers at these locations reduces the effect of the stiffness of the sound barrier on the deformations of the girders and the stresses in the barrier due to live load deflection of the bridge.

When mounted on bridges, additional expansion devices in the sound barrier may be utilized as required to further minimize the stresses on the barrier due to the live load deflection of the bridge.

Post-and-panel sound barriers inherently provide an expansion joint at either end of each wall panel. Typical posts are made of steel rolled I-shapes or concrete I-sections. Characteristically, the seat width of the wall panels on the posts is relatively small as it corresponds to the width of the post flange overhang on either side of the post web. These typical seat widths provide for dimensional and installation tolerances and dimensional changes caused by panel deformations due to applied loads and temperature changes. For smaller post flange widths, unless a post is provided on either side of an expansion joint in the supporting structure, the change in the opening of the structure expansion joint may be larger than the panel seat width on the post and may cause the failure of the panel straddling the structure expansion joint due to the loss of panel seat width.

15.6.3—Ground-Mounted Sound Barriers

Except for post-and-panel construction, expansion devices shall be provided at adequate spacing to allow for thermal expansion of the sound barriers. For sound

C15.6.3

For sound barriers not utilizing post-and-panel construction, minimizing the relative deflection between the wall sections on either side of an expansion joint barriers prone to vehicular collision, relative deflection between the sound barriers on either side of an expansion joint shall be restricted.

improves the performance of the barrier during vehicular collision near the expansion joint. This can be accomplished by installing a sliding dowel-and-sleeve connection, similar to the one shown in Figure C15.6.3-1, near the top of the wall.

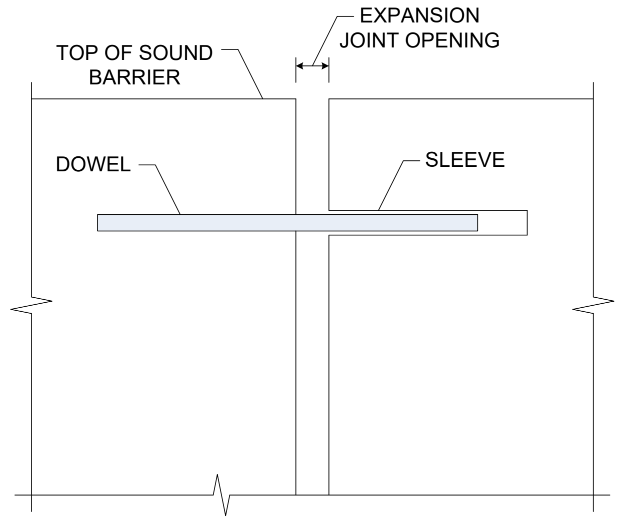

Figure C15.6.3-1—Sliding Dowel-and-Sleeve Connection

15.7—SOUND BARRIERS INSTALLED ON EXISTING BRIDGES

When sound barriers are installed on existing bridges, the effects of the sound barrier forces on existing bridge components shall be investigated, including the effect of unbalanced mass.

C15.7

Sound barrier forces transmitted to the bridge include the weight of the barrier, wind loads, seismic loads, vehicular collision forces, and any other forces that may act on the sound barriers. These forces affect railings, bridge deck overhangs, floorbeams, and girders.

When sound barriers are added on an existing bridge, the bridge should be reanalyzed to determine its load rating taking into account the forces applied to the sound barriers. The stiffening effect of the sound barriers may be considered when determining the load rating of the bridge.

15.8—LOADS

15.8.1—General

Unless explicitly modified below, all applicable loads shall be applied in accordance with the provisions of Section 3.

15.8.2—Wind Load

The provisions of Article 3.8.1 shall apply.

C15.8.2

The wind load provisions included in Article 3.8.1 are applicable to all structures, including sound barriers. This deviates from earlier specifications where special wind provisions for sound barriers were included.

15.8.3—Earth Load

The provisions of Article 3.11 shall apply.

C15.8.3

Article 3.11.5.10 contains specific requirements for the determination of earth pressure on sound barrier foundation components.

@SeismicIsolation

The possibility of difference between the actual finished grade and that shown on the contract documents should be considered in the design.

Soil build-up against sound barriers has been observed in some locations. Owners may determine the earth loads for the worst load case assuming an allowance in the finished grade elevation.

15.8.4—Vehicular Collision Forces

Sound barrier systems consisting of a traffic railing and a sound barrier that have been successfully crash-tested may be used with no further analysis.

The depth of aesthetic treatments into the traffic face of sound barrier that may be subjected to vehicular collision shall be kept to a minimum.

Sound barrier materials shall be selected to limit shattering of the sound barrier during vehicular collision.

In lieu of crash-testing, the resistance of components and connections to Extreme Event II force effects may be determined based on a controlled failure scenario with a load path and sacrificial elements selected to ensure desirable performance of a structural system containing the soundwall. Vehicular collision forces shall be applied to sound barriers located within the clear zone as follows:

Case 1: For sound barriers on a crashworthy traffic railing and for sound barriers mounted behind a crashworthy traffic railing with a sound barrier setback no more than 1.0 ft: vehicular collision forces specified in Section 13 shall be applied to the sound barrier at a point 4.0 ft above the surface of the pavement in front of the traffic railing for Test Levels 3 and lower and 6.0 ft above the surface of the pavement in front of the traffic railing for Test Levels 4 and higher.

Case 2: For sound barriers behind a crashworthy traffic railing with a sound barrier setback of 4.0 ft: vehicular collision force of 4.0 kips shall be applied. The collision force shall be assumed to act at a point 4.0 ft above the surface of the pavement in front of the traffic railing for Test Levels 3 and lower and 14.0 ft above the surface of the pavement in front of the traffic railing for Test Levels 4 and higher.

C15.8.4

Minimizing the depth of aesthetic treatment into the traffic face of sound barriers that may be in contact with a vehicle during a collision reduces the possibility of vehicle snagging.

Sound barrier systems may contain sacrificial components or components that could need repair after vehicular collision. Limiting shattering of sound barriers is particularly important for sound barriers mounted on bridges crossing over other traffic. When reinforced concrete panels are utilized for structure-mounted sound barriers, it is recommended that two mats of reinforcement are used to reduce the possibility of the concrete shattering during vehicular collision. Restraint cables placed in the middle of concrete panels may be used to reduce shattering while avoiding the increased panel thickness required to accommodate two layers of reinforcement.

The bridge overhang or moment slabs need not be designed for more force effects than the resistance of the base connection of the sound barrier.

The design strategy involving a controlled failure scenario is similar in concept to the use of capacity protected design to resist seismic forces. Some damage to the soundwall, traffic barrier, or connections is often preferable to designing an overhang or moment slab for force effects due to vehicular collision. The bridge overhang or moment slabs need not be designed for more force effects than the resistance of the base connection of the sound barriers.

Some guidance on desirable structural performance of sound barriers can be found in European Standard EN1794-2 (2003).

Very limited information is available on crash-testing of sound barrier systems. The requirements of this Article, including the magnitude of collision forces, are mostly based on engineering judgment and observations made during crash-testing of traffic railings without sound barriers.

In the absence of crash test results for sound barrier systems, sound barriers that have not been crash-tested are often used in conjunction with vehicular railings that have been crash-tested as stand-alone railings, i.e. without sound barriers. The collision forces specified herein are meant to be applied to the sound barrier portion of such systems.

Crash Test Levels 3 and lower are performed using small automobiles and pick-up trucks. Crash Test Levels 4 and higher include single-unit, tractor-trailer trucks, or

@Seismicisolation

Case 3: For sound barriers behind a crashworthy traffic railing with a sound barrier setback between 1.0 ft and 4.0 ft: vehicular collision forces and the point of application of the force shall vary linearly between their values and locations specified in Case 1 and Case 2 above.

Case 4: For sound barriers behind a crashworthy traffic railing with a sound barrier setback more than 4.0 ft: vehicular collision forces need not be considered.

The setback of the sound barrier, *S*, shall be taken as shown in Figure 15.8.4-1.

both. The difference in height of the two groups of vehicles is the reason the location of the collision force is different at different Test Levels.

For crash Test Levels 3 and lower, the point of application of the collision force on the sound barriers is assumed to be always 4.0 ft above the pavement.

During crash-testing of traffic railings for crash Test Level 4 and higher, trucks tend to tilt above the top of the railing and the top of the truck cargo box may reach approximately 4.0 ft behind the traffic face of the traffic railing. For such systems, the point of application of the collision force is expected to be as high as the height of the cargo box of a truck, assumed to be 14.0 ft above the pavement surface.

For sound barriers mounted on crashworthy traffic barriers or with a small setback assumed to be less than 1.0 ft, the full crash force is expected to act on the sound barrier. The point of application of this force is assumed to be at the level of the cargo bed, taken as 6.0 ft above the surface of the pavement.

For a sound barrier mounted with a setback more than 1.0 ft behind the traffic face of the traffic railing, it is expected that the truck cargo box, not the cargo bed, will impact the sound barrier. It is expected that the top of the cargo box will touch the sound barrier first. Due to the soft construction of cargo boxes, it is assumed that they will be crushed and will soften the collision with the sound barrier. The depth of the crushed area will increase with the increase of the collision force, thus lowering the location of the resultant of the collision force. The magnitude of the collision force and the degree to which the cargo box is crushed are expected to decrease as the setback of the sound barrier increases.

In the absence of test results, it is assumed that a collision force of 4.0 kips will develop at the top of the cargo box when it impacts sound barriers mounted with a setback of 4.0 ft.

The collision force and the point of application are assumed to vary linearly as the sound barrier setback varies between 1.0 ft and 4.0 ft.

@Seismicisolation

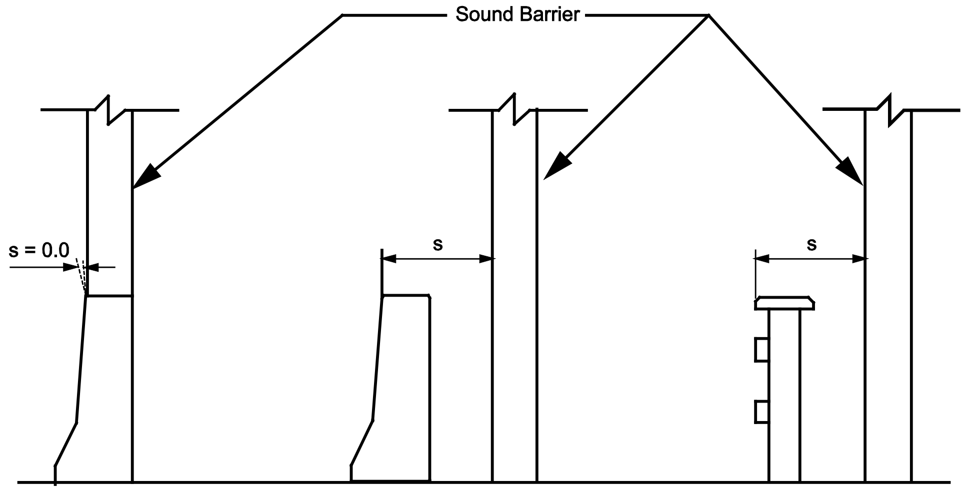

Figure 15.8.4-1—Sound Barrier Setback Distance

Collision forces on sound barriers shall be applied as a line load with a length equal to the longitudinal length of distribution of collision forces, L_t, specified in Appendix A13.

For sound barriers prone to vehicular collision forces, the wall panels and posts and the post connections to the supporting traffic barriers or footings shall be designed to resist the vehicular collision forces at the Extreme Event II limit state.

For post-and-panel construction, the design collision force for the wall panels shall be the full specified collision force placed on one panel between two posts at the location that maximizes the load effect being checked. For posts and post connections to the supporting components, the design collision force shall be the full specified collision force applied at the point of application specified earlier in Cases 1 through 3.

In some cases, the wall panel is divided into a series of horizontal elements. In these situations, each horizontal strip should be designed for the full design force.

The vehicular railing part of the sound barrier/railing system does not need to satisfy any additional requirements beyond the requirements specified in Section 13 of these Specifications for the stand-alone railings, including the height and resistance requirements.

Unless otherwise specified by the Owner, vehicular collision forces shall be considered in the design of sound barriers.

Owners may elect to ignore vehicular collision forces in the design of sound barriers at locations where the collapse of the sound barrier or portions of thereof has minimal safety consequences.

15.9—FOUNDATION DESIGN

15.9.1—General

Unless otherwise specified by the Owner, the geotechnical resistance of materials supporting sound barrier foundations shall be estimated using the procedures presented in Article 10.6 for spread footings, Article 10.7 for driven piles, and Article 10.8 for drilled shafts.

C15.9.1

Although sound barriers may be supported on spread footing or driven pile foundations, drilled shafts are more commonly used because drilled shafts facilitate controlling the vertical alignment of sound barrier structural wall supports and the lateral spacing between them.

@Seismicisolation

15.9.2—Determination of Soil and Rock Properties

The provisions of Articles 2.4 and 10.4 shall apply.

15.9.3—Limit States

Sound barriers shall be designed to withstand lateral wind and earth pressures, self-weight of the wall, vehicular collision loads, and earthquake loads in accordance with the general principles specified in this Section and in Sections 10 and 11.

Sound barriers shall be investigated for vertical and lateral displacement at the Service I Limit State. Tolerable deformation criteria shall be developed based on maintaining the required barrier functionality, achieving the anticipated service life, and the consequences of unacceptable movements.

Sound barrier foundations shall be investigated at the strength limit states using Eq. 1.3.2.1-1 for:

- Bearing-resistance failure,
- Overall stability, and
- Structural failure.

Sound barrier foundations shall be investigated at the extreme event limit states using the applicable load combinations and load factors specified in Table 3.4.1-1.

15.9.4—Resistance Requirements

The factored resistance, R_R, calculated for each applicable limit state shall be the nominal resistance, R_n, multiplied by an appropriate resistance factor, ϕ, specified in Articles 10.5.5.1, 10.5.5.2, 10.5.5.3, 11.5.6, or 11.5.7.

C15.9.4

Procedures for calculating nominal geotechnical resistance of footings, driven piles, and drilled shafts are provided in Articles 10.6, 10.7, and 10.8. These methods are generally accepted for barriers supported on spread footings or footings on two or more rows of driven piles or drilled shafts. The nominal geotechnical resistance of a single row of driven piles or drilled shafts or by a continuous embedded foundation wall (commonly referred to as a “trench footing”) is more appropriately calculated using the provisions in Article 11.8 for nongravity cantilever walls.

Procedures for calculating nominal structural resistance for concrete and steel components are provided in Sections 5 and 6.

15.9.5—Resistance Factors

The resistance factors for geotechnical design of foundations shall be as specified in Table 10.5.5.2.2-1 for spread footing foundations, Table 10.5.5.2.3-1 for driven pile foundations, Table 10.5.5.2.4-1 for drilled shaft foundations, and Table 11.5.7-1 for permanent retaining walls.

If methods other than those prescribed in these Specifications are used to estimate geotechnical resistance, the resistance factors chosen shall provide reliability equal or greater than those given in Tables 10.5.5.2.2-1, 10.5.5.2.3-1, 10.5.5.2.4-1, and 11.5.7-1.

@Seismicisolation

15.9.6—Loading

The provisions of Section 3, as modified by Article 15.8, shall apply.

15.9.7—Movement at the Service Limit State

The provisions of Articles 10.6.2, 10.7.2, 10.8.2, or 11.8.3, as appropriate, shall apply.

15.9.8—Safety against Geotechnical Failure at the Strength Limit State

Spread footings or footings supported on two or more rows of driven piles or drilled shafts shall be designed in accordance with the provisions of Articles 10.6.3, 10.7.3, or 10.8.3, respectively.

Footings supported on a single row of driven piles or drilled shafts or on a continuous embedded foundation wall ("trench footing") shall be designed in accordance with the provisions of Article 11.8.4 using the earth pressure diagrams provided in Article 3.11.5.10.

For overall stability, the provisions of Article 11.6.3.7 shall apply.

15.9.9—Seismic Design

The effect of earthquake loading shall be investigated using the Extreme Event I limit state of Table 3.4.1-1 with load factor $\gamma_p = 1.0$, and an accepted methodology.

15.9.10—Corrosion Protection

The provisions of Article 11.8.7 shall apply.

15.9.11—Drainage

Where sound barriers support earth loads or can impede water flow, the provisions of Article 11.8.8 shall apply.

15.10—REFERENCES

AASHTO. *Guide Specifications for Structural Design of Sound Barriers*, with 1992 and 2002 interims, GSSB-1M. American Association of State Highway and Transportation Officials, Washington, DC, 1989.

Bullard, Jr. D. L., N. M. Sheikh, R. P. Bligh, R. R. Haug, J. R. Schutt, and B. J. Storey. *Aesthetic Concrete Barrier Design,* NCHRP Report 554. Transportation Research Board, National Research Council, Washington, DC, 2006.

Washington State Department of Transportation. *Wind Loading Comparison*. Washington State Department of Transportation, Olympia, WA, 2006.

White, M., J. Jewell, and R. Peter. 2002. *Crash Testing of Various Textured Barriers*, FHWA/CA/TL-2002/03. California Department of Transportation, Sacramento, CA, 2002.

@Seismicisolation