Application of AASHTO LRFD Specifications to Design of Sound Barriers

Prepared for:
The National Cooperative Highway Research Program (NCHRP)

Prepared by:
Wagdy G. Wassef, Ph.D., P.E.
John M. Kulicki, Ph.D., P.E.
Modjeski and Masters, Inc., Harrisburg, Pennsylvania

James L. Withiam, Ph.D., P.E.
Edward P. Voytko, P.E.
D’Appolonia, Monroeville, Pennsylvania

and

Dennis Mertz, Ph.D., P.E.
University of Delaware

June, 2010

The information contained in this report was prepared as part of NCHRP Project 20-07, Task 270, National Cooperative Highway Research Program.

SPECIAL NOTE: This report IS NOT an official publication of the National Cooperative Highway Research Program, Transportation Research Board, National Research Council, or The National Academies.
Acknowledgements

This study was conducted for the American Association of Highway and Transportation Officials (AASHTO), with funding provided through the National Cooperative Highway Research Program (NCHRP) Project 20-07 Task 270, Application of AASHTO LRFD Specifications to Design of Sound Barriers. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. Project 20-07 is intended to fund quick response studies on behalf of the Highway Subcommittee on Bridges and Structures. The report was prepared by Wagdy G. Wassef, Ph.D., P.E., Senior Associate, Modjeski and Masters, Inc., Harrisburg, Pennsylvania and Dr. John M. Kulicki, Ph.D., P.E., Chairman/CEO, Modjeski and Masters, Inc., Harrisburg, Pennsylvania. Provisions related to the geotechnical aspects were developed by Dr. James L. Withiam, Ph.D., P.E. and Mr. Edward P. Voytko, P.E; both of D’Appolonia Engineering Division of Ground Technology, Inc., Monroeville, Pennsylvania. The proposed specifications were reviewed by Dr. Dennis Mertz, Ph.D., P.E. of the University of Delaware to with other provisions of the specifications.

The work was guided by a technical working group that included:

- David Benton, Arizona DOT
- Naveed Burki, Indiana DOT
- Douglas Dunrud, California DOT
- Christopher Gale, Maryland State Highway Administration
- Gary P. Gordon, Pennsylvania DOT
- Jugesh Kapur, Washington State DOT
- Bijan Khaleghi, Washington State DOT
- Steve Wyche, Georgia DOT

The project was managed by Dr. Waseem Dekelbab, NCHRP Senior Program Officer.

Disclaimer

The opinions and conclusions expressed or implied are those of the research agency that performed the research and are not necessarily those of the Transportation Research Board or its sponsoring agencies. This report has not been reviewed or accepted by the Transportation Research Board Executive Committee or the Governing Board of the National Research Council.
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 1</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Section 2</td>
<td>Proposed Specifications</td>
<td>2</td>
</tr>
<tr>
<td>Section 3</td>
<td>Example of Sound Barrier Design Forces</td>
<td>24</td>
</tr>
</tbody>
</table>
SECTION 1

INTRODUCTION

The current design criteria for sound barriers are based on the AASHTO Standard “Guide Specifications for Design of Sound Barriers” dated 1989 and interims through 2002. The content of the AASHTO Guide Specifications for Design of Sound Barriers is not consistent with the requirements of the AASHTO LRFD Bridge Design Specifications. The load and load combinations of the AASHTO Guide Specifications Article 1.2.1 and 1.2.2 do not conform to the ones specified in the AASHTO LRFD Section 3.4.1. In addition, the vehicular impact load and load factors included in the Guide Specifications for design of sound barriers adjacent to roadways are different from the ones required by the AASHTO LRFD Specifications.

NCHRP Project 20-07/Task 270, was initiated to produce updated sound barriers design provisions suitable for inclusion in the AASHTO LRFD Bridge Design Specifications.

This report includes the proposed design provisions and an example of the determination of the design loads on a sound barrier using the proposed specifications. The proposed specifications included in this report has been prepared assuming that the design provisions for sound barriers will be included in a separate new section (Section 15) to be added to the AASHTO LRFD Bridge Design Specifications. In addition, required revisions to relevant existing design provisions are also included.
SECTION 2

PROPOSED SPECIFICATIONS
# SECTION 15: DESIGN OF SOUND BARRIERS

## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.1</td>
<td>SCOPE</td>
<td>4</td>
</tr>
<tr>
<td>15.2</td>
<td>DEFINITIONS</td>
<td>4</td>
</tr>
<tr>
<td>15.3</td>
<td>NOTATION</td>
<td>4</td>
</tr>
<tr>
<td>15.4</td>
<td>General Features</td>
<td>5</td>
</tr>
<tr>
<td>15.4.1</td>
<td>Aesthetics</td>
<td>5</td>
</tr>
<tr>
<td>15.4.1.1</td>
<td>Standard Aesthetic Treatments</td>
<td>5</td>
</tr>
<tr>
<td>15.4.1.2</td>
<td>End Treatment</td>
<td>5</td>
</tr>
<tr>
<td>15.4.1.3</td>
<td>Cost</td>
<td>5</td>
</tr>
<tr>
<td>15.4.2</td>
<td>Sound Barrier Materials</td>
<td>5</td>
</tr>
<tr>
<td>15.4.3</td>
<td>Functional Requirements</td>
<td>6</td>
</tr>
<tr>
<td>15.4.3.1</td>
<td>Lateral Clearance</td>
<td>6</td>
</tr>
<tr>
<td>15.4.3.2</td>
<td>Sight Distance Requirements</td>
<td>6</td>
</tr>
<tr>
<td>15.4.3.3</td>
<td>Sound Barriers Height</td>
<td>6</td>
</tr>
<tr>
<td>15.4.3.4</td>
<td>Sound Barriers Length</td>
<td>6</td>
</tr>
<tr>
<td>15.4.3.5</td>
<td>Sound Barrier Location</td>
<td>7</td>
</tr>
<tr>
<td>15.4.3.6</td>
<td>Type of Foundation</td>
<td>7</td>
</tr>
<tr>
<td>15.4.3.7</td>
<td>Drainage</td>
<td>7</td>
</tr>
<tr>
<td>15.4.3.8</td>
<td>Emergency Responders and Maintenance Access</td>
<td>7</td>
</tr>
<tr>
<td>15.4.3.9</td>
<td>Deferential Settlement of Foundations</td>
<td>7</td>
</tr>
<tr>
<td>15.5</td>
<td>LIMIT STATES AND RESISTANCE FACTORS</td>
<td>8</td>
</tr>
<tr>
<td>15.5.1</td>
<td>General</td>
<td>8</td>
</tr>
<tr>
<td>15.5.2</td>
<td>Service Limit State</td>
<td>8</td>
</tr>
<tr>
<td>15.5.3</td>
<td>Strength Limit State</td>
<td>8</td>
</tr>
<tr>
<td>15.5.4</td>
<td>Extreme Event Limit State</td>
<td>8</td>
</tr>
<tr>
<td>15.6</td>
<td>EXPANSION DEVICES</td>
<td>8</td>
</tr>
<tr>
<td>15.6.1</td>
<td>General</td>
<td>8</td>
</tr>
<tr>
<td>15.6.2</td>
<td>Bridge-Mounted Sound Barriers</td>
<td>8</td>
</tr>
<tr>
<td>15.6.3</td>
<td>Ground-Mounted Sound Barriers</td>
<td>9</td>
</tr>
<tr>
<td>15.7</td>
<td>SOUND BARRIERS INSTALLED ON EXISTING BRIDGES</td>
<td>9</td>
</tr>
<tr>
<td>15.8</td>
<td>LOADS</td>
<td>10</td>
</tr>
<tr>
<td>15.8.1</td>
<td>General</td>
<td>10</td>
</tr>
<tr>
<td>15.8.2</td>
<td>Wind Load</td>
<td>10</td>
</tr>
<tr>
<td>15.8.3</td>
<td>Seismic Load</td>
<td>12</td>
</tr>
<tr>
<td>15.8.4</td>
<td>Earth Load</td>
<td>12</td>
</tr>
<tr>
<td>15.8.5</td>
<td>Vehicular Collision Forces</td>
<td>12</td>
</tr>
<tr>
<td>15.8.6</td>
<td>Ice and Snow Drifts Load</td>
<td>14</td>
</tr>
<tr>
<td>15.9</td>
<td>FOUNDATION DESIGN</td>
<td>14</td>
</tr>
<tr>
<td>15.9.1</td>
<td>General</td>
<td>14</td>
</tr>
<tr>
<td>15.9.2</td>
<td>Determination of Soil and Rock Properties</td>
<td>14</td>
</tr>
<tr>
<td>15.9.3</td>
<td>Limit States</td>
<td>14</td>
</tr>
<tr>
<td>15.9.4</td>
<td>Resistance Requirements</td>
<td>15</td>
</tr>
<tr>
<td>15.9.5</td>
<td>Resistance Factors</td>
<td>15</td>
</tr>
<tr>
<td>15.9.6</td>
<td>Loading</td>
<td>15</td>
</tr>
<tr>
<td>15.9.7</td>
<td>Movement and Stability at the Service Limit State</td>
<td>15</td>
</tr>
<tr>
<td>15.9.7.1</td>
<td>Movement</td>
<td>15</td>
</tr>
<tr>
<td>15.9.7.2</td>
<td>Overall Stability</td>
<td>15</td>
</tr>
<tr>
<td>15.9.8</td>
<td>Safety Against Geotechnical Failure at the Strength Limit State</td>
<td>16</td>
</tr>
<tr>
<td>15.9.9</td>
<td>Seismic Design</td>
<td>16</td>
</tr>
<tr>
<td>15.9.10</td>
<td>Corrosion Protection</td>
<td>16</td>
</tr>
<tr>
<td>15.9.11</td>
<td>Drainage</td>
<td>16</td>
</tr>
</tbody>
</table>
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.

Structure-mounted sound barriers are those mounted directly on bridge decks, retaining walls, or on top of vehicular railings mounted on bridge decks or retaining walls.

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.

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 traffic face of the sound barrier wall and the traffic face of the traffic railing the sound barrier is mounted on or behind it.

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

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

15.3 NOTATION

\[ S = \text{setback distance of sound barrier (15.8.5)} \]
\[ V_B = \text{base wind velocity (mph) (15.8.2)} \]
\[ V_0 = \text{friction velocity, a meteorological wind characteristic for various upwind surface characteristics (mph) (15.8.2)} \]
\[ Z_0 = \text{friction length of upstream fetch, a meteorological wind characteristic (ft.) (15.8.2)} \]
\[ \Phi = \text{soil angle of internal friction (°) (C15.4.3)} \]
\[ \gamma_p = \text{load factor for permanent loads (15.9.9)} \]
15.4 GENERAL FEATURES

15.4.1 Aesthetics

15.4.1.1 Standard Aesthetic Treatments

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.

Standard aesthetic treatments for various alternative materials should be considered.

15.4.1.2 End Treatment

Sound barriers should not be designed with abrupt beginnings or ends, unless approved by the Owner.

Generally, the ends of the sound barrier should be tapered or stepped if the height of the wall exceeds 6.0 ft. to produce a more aesthetically pleasing wall.

15.4.1.3 Cost

Some moderate additional cost to enhance the sound barrier's aesthetic quality is warranted.

15.4.2 Sound Barrier Materials

Sound barriers may be constructed from any material deemed suitable by the owner. The materials selected for the sound barrier shall be appropriate for the environment in which it is placed.

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

Sound barriers material selection shall take into consideration the potential long-term effects of material deterioration, seepage, stray currents, and other potentially deleterious environmental factors on each of the material components comprising the structure.
15.4.3 Functional Requirements

15.4.3.1 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.

15.4.3.2 Sight Distance Requirements

Lateral clearances which reduce the stopping sight distance shall be avoided.

Unless otherwise approved by the Owner, the ends of the sound barrier located near a gore area shall be at least 200 feet from the theoretical curb nose location.

15.4.3.3 Sound Barriers Height

Unless proven adequate by site-specific acoustics study and approved by the owner, sound barriers shall have a minimum height consistent with that of a right-of-way fence.

15.4.3.4 Sound Barriers Length

The length of sound barriers shall be determined to provide adequate attenuation to end dwellings and commercial buildings.

C15.4.3.1

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 the 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 to the traffic barrier should be 10 feet from the face of the traffic barrier. Lateral clearances greater than the minimum of 10 feet 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 the location of sound barriers. 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.

C15.4.3.2

The stopping sight distance is of prime importance for sound barriers located on the edge of shoulder along the inside of a horizontal curve.

C15.4.3.3

When sound barriers higher than 16.0 ft. are required, surrounding features should be evaluated such that an exceptionally high wall does not create an unsightly impact on the locale.

C15.4.3.4

Where there is no residential area beyond the end dwelling, consideration should be given to terminating the sound barrier with a section of the barrier perpendicular to the freeway which could reduce the overall barrier length. However, this could require an easement from the property owner to permit construction of the sound barrier off the right-of-way.
15.4.3.5 Sound Barrier Location

Special consideration shall be given to possible roadway icing and other induced environmental conditions caused by the placement of the sound barrier.

15.4.3.6 Type of Foundation

The type and depth of sound barrier foundations shall be selected based on geotechnical recommendations to minimize the possibility of foundation heaving due to frost and soil swelling.

15.4.3.7 Drainage

Adequate drainage shall be provided along sound barriers.

15.4.3.8 Emergency Responders 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.

15.4.3.9 Deferential Settlement of Foundations

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

When 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 panels and foundations 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, 7.5.1 and 8.5.1.

15.5.3 Strength Limit State

The resistance factors for the strength limit states for post, wall panels and foundations 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 panels and foundations 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.

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 bridge girders. Therefore, expansion devices are required in the sound barriers at bridge expansion joint locations in order not to restrict the movement of the bridge expansion joints.

Bridge-mounted sound barriers stiffen the supporting bridges 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...
Where post-and-panel construction is utilized, posts shall be placed on either side of any expansion joint in, or at the ends of, the deck.

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 barriers prone to vehicular collision, relative deflection between the sound barriers on either side of an expansion joint shall be restricted.

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 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 installing sound barriers on existing bridges, the effects of the sound-barrier forces on existing bridge components shall be investigated. The stiffening effect of added sound barrier may be ignored.

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.

Existing bridges where sound barriers are added need to be reanalyzed to determine their load rating taking into account the dead load of sound barriers.
15.8 LOADS

15.8.1 General

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

15.8.2 Wind Load

Except for as modified below, the provisions of Article 3.8.1 shall apply.

Wind load shall be applied to the entire surface of sound barriers as a uniformly distributed load. Where post-and-panel construction is utilized, the wind load effects on the posts shall be determined by applying the resultant wind loads from the uniformly loaded panels as concentrated loads to the posts at the mid-height elevation of the exposed portion of the sound barrier.

Base design wind velocity, $V_b$, for sound barriers shall be taken 1.07 times the wind velocity at the sound barrier location determined from Figure 15.8.2-1.

For sound barriers, Table 3.8.1.1-1 shall be replaced with Table 15.8.2-1.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Coastal</th>
<th>Open Country</th>
<th>Sparse Suburban</th>
<th>Suburban</th>
<th>City</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_0$ (mph)</td>
<td>7</td>
<td>8.20</td>
<td>9.4</td>
<td>10.90</td>
<td>12.00</td>
</tr>
<tr>
<td>$Z_0$ (ft.)</td>
<td>0.025</td>
<td>0.23</td>
<td>0.98</td>
<td>3.28</td>
<td>8.20</td>
</tr>
</tbody>
</table>
Figure 15.8.2-1 Isotach .02 quantiles, in miles per hour: Annual extreme-mile 30.0 ft. above ground, 50 years mean recurrence intervals.
15.8.3 Seismic Load

The provisions of Article 3.10 shall apply.

For the design of the sound barrier wall panels, seismic loads shall be applied to the entire elevation area of the sound barriers as a uniformly distributed lateral load. Where post-and-panel construction is utilized, in lieu of a more refined analysis, seismic loads shall be applied to the posts at a point located no less than 0.7 the exposed height of the wall panels measured from the base of the panels. For the purpose of determining the point of application of seismic loads on the posts, the base of the panels shall be taken as:

- For ground-mounted sound barriers: the ground surface adjacent to sound barrier, and
- For structure-mounted sound barriers: the bottom of the lowest wall panel

15.8.4 Earth Load

The provisions of Article 3.11 shall apply.

15.8.5 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.

In lieu of crash-testing, vehicular collision forces may be applied to sound barriers located within the clear zone as follows:

Case 1: For sound barriers mounted 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 mounted 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.

Case 3: For sound barriers mounted behind a crashworthy

C15.8.3

The point of application of seismic loads may be calculated by dividing the post base moment by the post base shear. Trial analysis of post-and-panel sound barrier systems that are 10.0 and 20.0 ft. high and are constructed in highly active seismic zones indicated that the location of the point of application of the seismic load on the posts, measured from the bottom of the wall, varied between 0.62 and 0.72 the wall height.

C15.8.4

Article 3.11.5.10 contains specific requirements for the determination of earth pressure on sound-barrier foundations elements.

C15.8.5

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 barriers part of such systems. 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 the specifications for the stand-alone railings; including the height and resistance requirements.

Crash Test Level 3 and lower are performed using small automobiles and pick-up trucks. Crash Test Levels 4 and higher include single unit and/or tractor trailer trucks. The difference in height of the two groups of vehicles is the reason the location of the collision force is different for the two groups of sound barriers.

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.
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 mounted with a sound barrier setback more than 4.0 ft.: vehicular collision forces need not be considered.

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.

The setback of the sound barrier, S, shall be taken as shown in Figure 15.8.5-1.

![Sound barrier setback distance](image)

Figure 15.8.5-1 Sound barrier setback distance
Collision forces shall be applied as a line load with a length equal to the longitudinal length of distribution of collision forces, \( L_t \), specified in Article A13.2 for the design test level of the traffic railing and sound barrier system.

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 in Cases 1 through 3 above.

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.

15.8.6 Ice and Snow Drifts Load

Potential of snow drifts and ice accumulation on the surfaces of sound barriers shall be investigated. Forces from the weight of ice and pressure from snow drifts shall be considered in the design and shall be approved by the Owner.

C15.8.6

The thickness of ice accumulation and height of snow drifts and the equivalent hydrostatic pressure of snow drifts should be based on historical records at the site. The selected values should be approved by the Owner before design.

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, 10.7 for driven piles, and 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.

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 principals specified in this section and Sections 10 and 11.

Sound barriers shall be investigated for excessive vertical and lateral displacement, and overall stability 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, \( \phi \), specified in Articles 10.5.5.2 or 11.5.6.

15.9.5 Resistance Factors

The resistance factors for geotechnical design of foundations are 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 11.5.6-1 for permanent retaining walls.

If methods other than those prescribed in these Specifications are used to estimate geotechnical resistance, are used, the resistance factors chosen shall provide equal or greater reliability than those given in Tables 10.5.5.2.2-1, 10.5.5.2.3-1, 10.5.5.2.4-1, and 11.5.6-1.

15.9.6 Loading

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

15.9.7 Movement and Stability at the Service Limit State

15.9.7.1 Movement

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

15.9.7.2 Overall Stability

The provisions of Article 11.6.2.3 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 11.8.4 using the earth pressure diagrams provided in Article 3.11.5.10.

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.
REFERENCES


Additions to Section 3: All-new Article 3.11.5.10.

3.11.5.10 Lateral Earth Pressures for Sound Barriers Supported on Discrete and Continuous Vertical Embedded Elements

For sound barriers supported on discrete vertical wall elements embedded in granular soil, rock, or cohesive soil, the simplified lateral earth pressure distributions shown in Figures 1, 2, and 3, respectively, may be used. For sound barriers supported on continuous vertical elements embedded in granular soil or cohesive soil, the simplified earth pressure distributions shown in Figures 4 and 5, respectively, may be used. For sound barriers supported on retaining walls, the applicable provisions of Section 11 shall apply.

Where discrete vertical elements are used for support, the width, \( b \), of each vertical element shall be assumed to equal the width of the flange or diameter of the element for driven sections and the diameter of the concrete-filled hole for sections encased in concrete.

The reversal in the direction of applied lateral forces on sound barriers shall be considered in the design.

C3.11.5.10

Earth pressure on foundations of sound barriers is similar to that on nongravity retaining walls discussed in Article 3.11.5.6 except that the soil elevation on both sides of the wall is often the same or, if there is a difference, does not reach the top of the wall on one side. The provisions of this article are applicable to the foundations of any wall that is not primarily intended to retain earth, i.e. there is no or little difference in the elevation of fill on either side of the wall.

In Figures 1 and 3, the width, \( b \), of discrete vertical elements effective in mobilizing the passive resistance of the soil is based on a method of analysis by Broms (1964a, 1964b) for single vertical piles embedded in cohesive or granular soil. Additional information on the background of the earth pressure on discrete vertical elements is presented in Article C3.11.5.6.

The main applied lateral forces on sound barriers are wind and seismic forces; both of them are reversible. When the ground surface in front and/or behind the sound barrier is not flat or the ground surface is not at the same elevation on both sides of the sound barrier, the design should be checked assuming that the lateral force is applied in either direction. The effect of the direction of ground surface slope, i.e. toward the barrier or away from the barrier should be considered in earth pressure calculations for both directions of lateral loads. The earth pressure diagrams shown in Figures 1 through 5 correspond to the lateral load direction shown in these figures. A lateral load in the opposite direction will result in reversing the earth pressure diagrams shown.
Figure 3.11.5.10-1 Unfactored Simplified Earth Pressure Distributions for Discrete Vertical Wall Elements Embedded in Granular Soil.

Figure 3.11.5.10-2 Unfactored Simplified Earth Pressure Distributions for Discrete Vertical Wall Elements Embedded in Rock.
Figure 3.11.5.10-3 Unfactored Simplified Earth Pressure Distributions for Discrete Vertical Wall Elements Embedded in Cohesive Soil.

Figure 3.11.5.10-4 Unfactored Simplified Earth Pressure Distributions for Continuous Vertical Elements Embedded in Granular Soil Modified After Teng (1962).
Figure 3.11.5.10-5 Unfactored Simplified Earth Pressure Distributions for Continuous Vertical Wall Elements Embedded in Cohesive Soil Modified After Teng (1962).
Revisions to existing Article 3.8

Proposed additions to Article 3.8 are shown in underlined, bold type font

3.8 WIND LOAD: WL AND WS

3.8.1 Horizontal Wind Pressure

3.8.1.1 General

Except for sound barriers, pressures specified herein shall be assumed to be caused by a base design wind velocity, \( V_B \), of 100 mph. For sound barriers, base design wind velocity, \( V_{B0} \) shall be determined in accordance with Article 15.7.2.

Wind load shall be assumed to be uniformly distributed on the area exposed to the wind. The exposed area shall be the sum of areas of all components, including floor system, railing and sound barriers, as seen in elevation taken perpendicular to the assumed wind direction. This direction shall be varied to determine the extreme force effect in the structure or in its components. Areas that do not contribute to the extreme force effect under consideration may be neglected in the analysis.

For bridges or parts of bridges more than 30.0 ft. above low ground or water level, the design wind velocity, \( V_{DZ} \) should be adjusted according to:

\[
V_{DZ} = 2.5V_0 \left( \frac{V_{30}}{V_B} \right) \ln \left( \frac{Z}{Z_0} \right) \quad (3.8.1.1-1)
\]

where:

- \( V_{DZ} \) = design wind velocity at design elevation, \( Z \) (mph)
- \( V_{30} \) = wind velocity at 30.0 ft. above low ground or above design water level (mph)
- \( V_B \) = base wind velocity of 100 mph at 30.0 ft. height, yielding design pressures specified in Articles 3.8.1.2 and 3.8.2
- \( Z \) = height of structure at which wind loads are being calculated as measured from low ground, or from water level, > 30.0 ft.
- \( V_0 \) = friction velocity, a meteorological wind characteristic taken, as specified in Table 1, for various upwind surface characteristics (mph)
- \( Z_0 \) = friction length of upstream fetch, a meteorological wind characteristic taken as specified in Table 1 (ft.)

The purpose of the term \( C \) and exponent \( \alpha \) was to adjust the equation for various upstream surface conditions, similar to the use of Table 1. Further information can be found in Liu (1991) and Simiu (1973, 1976).

The following descriptions for the terms “open country,” “suburban,” and “city” in Table 1 are paraphrased from ASCE-7-93:

- **Open Country**—Open terrain with scattered obstructions having heights generally less than 30.0 ft. This category includes flat open country and grasslands.

- **Suburban**—Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family or larger dwellings. Use of this category shall be limited to those areas for which representative terrain prevails in the upwind direction at least 1,500 ft.
City—Large city centers with at least 50 percent of the buildings having a height in excess of 70.0 ft. Use of this category shall be limited to those areas for which representative terrain prevails in the upwind direction at least one-half mile. Possible channeling effects of increased velocity pressures due to the bridge or structure’s location in the wake of adjacent structures shall be taken into account.

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>OPEN COUNTRY</th>
<th>SUBURBAN</th>
<th>CITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_0$ (mph)</td>
<td>8.20</td>
<td>10.90</td>
<td>12.00</td>
</tr>
<tr>
<td>$Z_0$ (ft.)</td>
<td>0.23</td>
<td>3.28</td>
<td>8.20</td>
</tr>
</tbody>
</table>

$V_{30}$ may be established from:

Fastest-mile-of-wind charts available in ASCE 7-88 for various recurrence intervals,

Site-specific wind surveys, and

In the absence of better criterion, the assumption that $V_{30} = V_B = 100$ mph.

### 3.8.1.2 Wind Pressure on Structures: $W_S$

#### 3.8.1.2.1 General

If justified by local conditions, a different base design wind velocity may be selected for load combinations not involving wind on live load. The direction of the design wind shall be assumed to be horizontal, unless otherwise specified in Article 3.8.3. In the absence of more precise data, design wind pressure, in ksf, may be determined as:

$$P_D = P_B \left( \frac{V_{oz}}{V_B} \right)^2 = P_B \frac{V_{oz}^2}{10,000} \quad (3.8.1.2.1-1)$$

$P_B = \text{base wind pressure specified in Table 1 (ksf)}$

The wind force on the structure shall be calculated by multiplying the design wind pressure, $P_D$, calculated using Equation 1, by the exposed area, including the area of sound barriers, if existing, regardless of the design wind pressure used in designing the sound barriers themselves.

The wind pressure specified in Article 15.8.2 for the design of sound barriers is generally less than that specified in this article for determining the wind force on bridge structures.

No other changes to end of Article 3.8.
SECTION 3

EXAMPLE OF SOUND BARRIER DESIGN FORCES
Example
Sound Barrier Design Forces

Determine the loads on the sound barrier shown in Figure 1 assuming the following:

Wall Location: Seattle area
Wall height (h): 20 ft above ground surface in the vicinity of the wall
Sound barrier setback: 2 ft. behind a crashworthy traffic barrier (Test Level 4 Traffic Barrier)
Site Class E
Setting Urban setting

Materials:
Wall Panels:
- Pre-cast concrete Panels 8 inch thick
- 28 days compressive strength = 4 ksi
- Each wall panel is made in 2 Sections 10 ft. high each

Posts:
- Steel H sections 10 x 57
- Post flange width 10.225 in.
- Spacing = 15 ft.
- E = 29000 ksi = 4176000 ksf
- Stiffness = 294 in.^4 = 0.0141782 ft.^4

Foundations:
Sound barrier is supported on 2.5 ft. diameter concrete drilled shafts
Drilled shafts extend 10 ft from the surface

Figure 1. General Sound Barrier Dimensions
1. Dead Load

Unit weight of panels = 0.15 k/cu.ft.
Dead load of panels = 0.10 ksf
For a 20 ft high panel, dead load = 2.00 kips/ linear ft of wall
Dead Load (for seismic load on post) = 1.557 kips/ ft of wall height (including weight of post)
Mass = 0.048 kilo slugs/ ft of wall height
Dead load per drilled shaft = 31.14 kips (including weight of post)

2. Seismic Load

Peak Ground Acceleration (PGA) = 0.4 From LRFD Specifications figure 3.10.2.1-1 for Seattle area
Horizontal Response Spectral Acceleration Coefficient at Period of 0.2 Seconds (S_d) = 1.0 From LRFD Specifications figure 3.10.2.1-2 for Seattle area
Horizontal Response Spectral Acceleration Coefficient at Period of 1.0 Seconds (S_s) = 0.3 From LRFD Specifications figure 3.10.2.1-3 for Seattle area
Site Class E

Site Factors
Site Factor at Zero-Period on Acceleration Spectrum (F_0z) = 0.9 For Site Class E from LRFD Specifications Table 3.10.3.2-1 for PGA = 0.4
Site Factor for Short-Period Range of Acceleration Spectrum (F_s) = 0.9 For Site Class E from LRFD Specifications Table 3.10.3.2-2 for S_s = 0.9
Site Factor for Long-Period Range of Acceleration Spectrum (F_l) = 2.8 For Site Class E from LRFD Specifications Table 3.10.3.2-3 for S_s = 30

Calculated Quantities

\[ A_s = PGA \times F_{psf} = \] 0.36
\[ S_{DS} = S_s \times F_s = \] 0.9
\[ S_{D1} = S_i \times F_i = \] 0.84
\[ T_s = S_{D1} / S_{DS} = \] 0.933333
\[ T_0 = 0.2 \times T_s = \] 0.186667

Wall Ht (ft) | 20
---|---
Mass per foot of post height (kilo slug) | 0.0484
E (ksf) | 4176000
I (ft^4) | 0.01417824

Modal Periods

For a uniformly loaded cantilever

\[ T_1 = \left( \frac{3.516}{h^2} \times \frac{E^* I^*}{mass \ per \ ft} \times 0.5 \right)^{0.5} = 0.65 \text{ Sec.} \]
\[ T_2 = \left( \frac{22.03}{h^2} \times \frac{E^* I^*}{mass \ per \ ft} \times 0.5 \right)^{0.5} = 0.10 \text{ Sec.} \]
\[ T_3 = \left( \frac{61.71}{h^2} \times \frac{E^* I^*}{mass \ per \ ft} \times 0.5 \right)^{0.5} = 0.04 \text{ Sec.} \]
\[ T_4 = \left( \frac{120.9}{h^2} \times \frac{E^* I^*}{mass \ per \ ft} \times 0.5 \right)^{0.5} = 0.02 \text{ Sec.} \]

Elastic Seismic Response Coefficient (C_{sm})

Using LRFD Article 3.10.4.2
- For periods less than or equal to \( T_0 \):
  - For mode \( m \), the elastic seismic response coefficient = \( C_{sm} = A_s + (S_{DS} - A_s) \left( \frac{T_m}{T_s} \right) \)
- For periods greater than \( T_0 \) and less than or equal to \( T_s \) : \( C_{sm} = S_{DS} \)
- For periods greater than \( T_s \) : \( C_{sm} = S_{D1} / T_m \)
For Mode 1: \( C_{sm1} = 0.900 \)

For Mode 2: \( C_{sm2} = 0.658248 \)

For Mode 3: \( C_{sm3} = 0.466489 \)

For Mode 4: \( C_{sm4} = 0.414346 \)

Modal and Total Responses

For mode \( m \), base shear = \( c_1 \times \text{Mass per foot of post height} \times h \times C_{sm} \times 32.2 \)

where, for a cantilever, \( c_1 = 0.613 \) for Mode 1
\( = 0.188 \) for Mode 2
\( = 0.065 \) for Mode 3
\( = 0.033 \) for Mode 4

For mode \( m \), base moment = \( c_2 \times \text{base shear from mode } m \times h \)

where, for a cantilever, \( c_2 = 0.726 \) for Mode 1
\( = 0.209 \) for Mode 2
\( = 0.127 \) for Mode 3
\( = 0.090 \) for Mode 4

Total base shear and total base moment are determined by calculating the Square Root of Sum Squares (SRSS) for modal base shears and modal base moments, respectively.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Mode 1 Base Shear (kips)</th>
<th>Mode 2 Base Shear (kips)</th>
<th>Mode 3 Base Shear (kips)</th>
<th>Mode 4 Base Shear (kips)</th>
<th>SRSS (kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17.180</td>
<td>3.854</td>
<td>0.944</td>
<td>0.426</td>
<td>17.64</td>
</tr>
<tr>
<td></td>
<td>249.453</td>
<td>16.108</td>
<td>2.398</td>
<td>0.766</td>
<td>249.98</td>
</tr>
</tbody>
</table>

Equivalent location of seismic force above post base =

\[ \text{Post base moment / post base shear} = 14.17 \text{ ft.} \]

3. Wind Load

From the map in Figure 15.8.2-1, annual extreme mile wind velocity at Seattle area is 80 mph

Base wind velocity 30 ft above ground = 1.07 annual extreme mile wind speed (Article 15.8.2) = 85.6 mph

For urban setting:

\( V_0 = \text{friction velocity} = 10.9 \text{ mph} \)

\( Z_0 = \text{friction length} = 3.28 \text{ ft} \)

From Article 3.8.1.1, Design wind velocity, \( V_{DZ} = \)

\[ V_{DZ} = 2.5V_0 \left( \frac{V_0}{V_B} \right) \ln \left( \frac{Z}{Z_0} \right) \]

\( Z = \text{height of structure} > 30.0 \text{ ft.} = 30 \text{ ft} \)

\( V_B = \text{base wind velocity} = 100 \text{ mph} \)

\( V_{30} = 85.6 \)

\( V_{DZ} = 51.63 \text{ mph} \)

Base wind pressure, \( V_B \), on large surfaces = 0.04 ksf (Table 3.8.1.2.1-1)

Design wind pressure, \( P_D \):\n
\[ P_D = P_B \left( \frac{V_{DZ}}{V_B} \right)^2 = P_B \frac{V_{DZ}^2}{10,000} \]

\( P_B = 0.0107 \text{ ksf} \)
Wind pressure is applied to the entire surface of the panels.

Assuming panel are simple spans

\[
\begin{align*}
\text{Panel spans length} & = \text{post spacing} - \frac{1}{2} \text{post flange width} = 14.57 \text{ ft.} \\
\text{Maximum wind moment on one panel} & = 2.8 \text{ k.ft for 10 ft. high panel}
\end{align*}
\]

For posts, the resultant of wind forces is applied at mid height of the panels above ground.

\[
\text{Intermediate post wind force} = \text{wind pressure} \times \text{wall height} \times \text{post spacing} = 3.21 \text{ kips}
\]

Assuming post base elevation is at ground surface, intermediate post wind moment at post base = 32.1 k.ft

4. Vehicular Collision Force

Sound barrier is mounted behind a Test Level 4 traffic barrier

Sound barrier setback is 2 ft. For collision force calculations, the applicable case from Article 15.8.5 is Case 3 (setback between 1 and 4 ft.) which requires interpolation between collision forces for Case 1 (setback no more than 1.0 ft.) and Case 2 (setback = 4.0 ft)

For Case 1 (setback no more than 1.0 ft.):
  \[
  \text{Collision force} = 54 \text{ kips} \\
  \text{Application point} = 6 \text{ ft above ground surface}
  \]

For Case 2 (setback = 4.0 ft.):
  \[
  \text{Collision force} = 4 \text{ kips} \\
  \text{Application point} = 14 \text{ ft above ground surface}
  \]

By interpolation for Case 3 with setback 2 ft.
  \[
  \text{Collision force} = 20.67 \text{ kips} \\
  \text{Application point} = 8.67 \text{ ft above ground surface}
  \]

Collision forces shall be applied as a line load with a length equal to the longitudinal length of distribution of collision forces, \(L_t\), specified in Article A13.2 for the design test level of the traffic railing and sound barrier system.

For Test Level 4 (TL4), collision length distribution length = 3.5 ft.

The point of application of collision forces will vary for different components. For maximum moments in the panels, the collision line load should be positioned at midspan of the panels between posts (see Figure 2). For maximum load on the posts, collision load should be centered at the post (see Figure 3).

Collision line load = collision force/distribution length = 5.91 klf

Assuming panel span length = post spacing - 1/2 post flange width = 14.57 ft.

\[
\text{Maximum collision moment on panels} = 66.25 \text{ k.ft}
\]

For simplicity, the wall panels may be assumed as series of simple spans supported at the center of the posts.

\[
\begin{align*}
\text{Maximum post collision force} & = 19.46 \text{ kips} \\
\text{For point of application} & = 8.67 \text{ ft. above the base of the posts,} \\
\text{Maximum post base collision moment} & = 168.72 \text{ k.ft.}
\end{align*}
\]
Summary of unfactored forces:

Wall panels:

Shear:
Negligible for slabs

Moment:
Wind Load : 2.8 k.ft per panel
Vehicular Collision : 66.25 k.ft per panel

Posts:

Base shear:
Seismic Load : 17.64 kips
Wind Load : 3.21 kips
Vehicular Collision : 19.46 kips

Base moment:
Seismic Load : 249.98 k.ft.
Wind Load : 32.1 k.ft.
Vehicular Collision : 168.72 k.ft.

Drilled shafts:

At the top of the shaft:
Dead Load: 31.14 kips
Seismic load: 17.64 kips applied at 14.17 ft above post base
Wind Load : 32.1 kips applied at 10.00 ft above post base
Vehicular Collision : 19.46 kips applied at 8.67 ft above post base

Using the unfactored forces shown above, the factored loads for different limit states can be determined and different components may be designed using the same procedures used in the past by the owner agency.