



TECHNICAL NOTES on Brick Construction

1850 Centennial Park Drive, Suite 301, Reston VA 20191 | www.gobrick.com | 703-620-0010

Technical Note 45 - Brick Masonry Noise Barrier Walls - Introduction

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Abstract: Because our national highway system has grown significantly over the last few decades, public awareness of traffic noise on neighborhood communities has increased. Neighborhood associations and governmental bodies look for ways to reduce traffic noise without adversely affecting the surrounding environment. A solution to this problem lies in brick masonry noise barrier walls. Brick masonry noise barrier walls can easily blend into the environment and give residential communities protection from unwanted highway noise.

Key Words: acoustics, brick, noise barrier walls.

INTRODUCTION

Continued growth of our national highway system combined with an increase in public awareness of environmental issues has focused on a need to evaluate the impact of traffic noise associated with highway systems on neighboring communities. When noise levels exceed acceptable limits, community action generally alerts governmental bodies to the problem or potential problems. Governmental bodies then investigate measures to prevent or alleviate noise problems.

The severity of the noise and the stage at which the problem is identified determine the measures available to reduce the impact of highway noise. Measures to alleviate highway noise include traffic controls and regulations, modification of the highway configuration, land-use planning and zoning, and brick noise barrier walls.

When new highway systems are in the planning and design stages, a comprehensive analysis of and consideration to noise abatement measures can be given. However, when existing highway systems are renovated or if restrictions are placed on the routing of new highway systems or use of adjacent land, the most practical solution to noise control may be the use of noise barrier walls to isolate the highway noise sources from the surrounding communities.

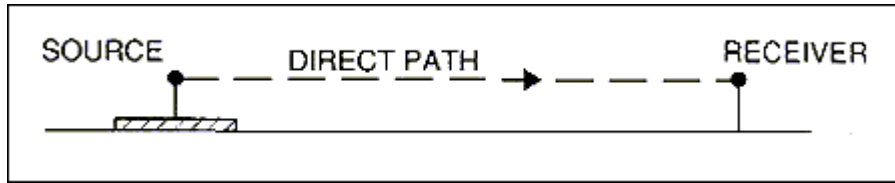
Three major types of noise barriers are currently being used in the United States: earth berms, walls and berm-wall combinations. Of these three, the noise barrier wall is typically the most common means of achieving noise abatement and is the primary topic of this *Technical Notes*.

This *Technical Notes*, the first in a series, addresses acoustical, visual, structural, construction, detailing and maintenance considerations of brick masonry noise barrier walls. The other *Technical Notes* in this series addresses the structural design of brick masonry noise barrier walls.

ACOUSTICAL CONSIDERATIONS

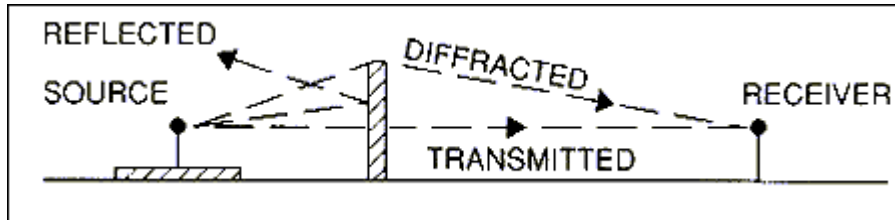
To understand the function of a noise barrier wall or how the wall reduces the noise level perceived by a receiver, it is necessary to discuss some of the fundamental principles involved in sound propagation and noise reduction.

When there are no obstacles or barriers between highway noise sources and receivers, sound travels in a direct path from the source to the receiver (Figure 1). When a noise barrier wall is placed between the noise source and the receiver, the barrier disperses the sound along three paths: a diffracted or bent path over the top of the wall, a reflected path away from the receiver and a transmitted path through the wall (Fig. 2).



Direct Noise Path

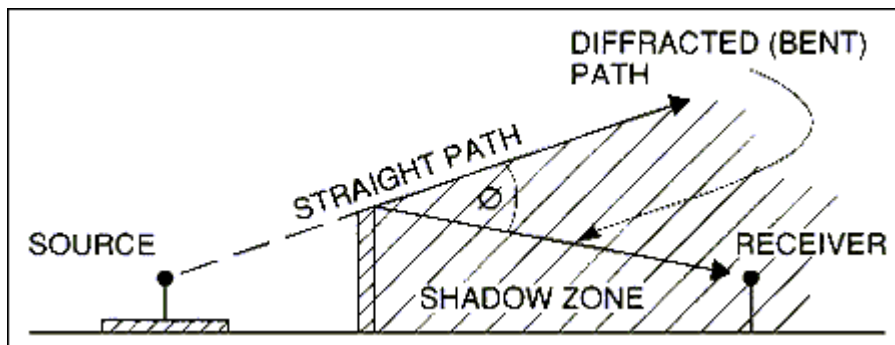
FIG. 1



Noise Path With Barrier Wall

FIG. 2

Diffraction of sound over the top of the wall produces a shadow zone behind the barrier. The boundary of this shadow zone is outlined by a straight line drawn from the noise source over the top of the barrier wall (Fig. 3). All receivers located within the shadow zone will experience some degree of sound attenuation. The amount of reduction or attenuation is directly related to the diffraction angle θ . As this angle increases, the barrier attenuation increases. Thus, barrier attenuation is a function of the wall height and the distances between the source, barrier and receiver. Two other factors also affect the amount of attenuation: the sound transmission characteristics of the material from which the barrier is constructed and the length of the barrier.



Noise Barrier Shadow Zone

FIG. 3

The sound transmission characteristics of a material are related to its weight, stiffness and loss factors. The sound transmission characteristics of materials can be assessed and compared by means of transmission loss values. The sound transmission loss is related to the ratio of the incident noise energy to the noise energy transmitted through the material. Typically, transmission loss values can be expected to increase with increasing square foot surface weights of barrier materials. Table 1 lists the transmission loss values at a frequency of 550 hertz (Hz) for materials commonly used in noise barrier wall construction. 550 Hz is the accepted frequency used to determine the transmission loss of highway noise barrier wall materials. As a general rule for design, the transmission loss value should be a minimum of 10 decibels (dB) above the attenuation resulting from the diffraction over the top of the barrier. The transmission loss values for brick masonry are at the higher end of the range and sound transmission through a brick barrier will not significantly affect the attenuation. However, when less massive materials are used, the transmission loss values may not be adequate and the noise reduction provided by the barrier can

be severely affected.

¹ Grouted cavity is 2 3/4 in.

The actual acoustical design of a barrier system to determine the length and height requirements are beyond the scope of this *Technical Notes*. A detailed discussion of noise barrier acoustical design procedures and considerations can be found in Reference 1.

VISUAL CONSIDERATIONS

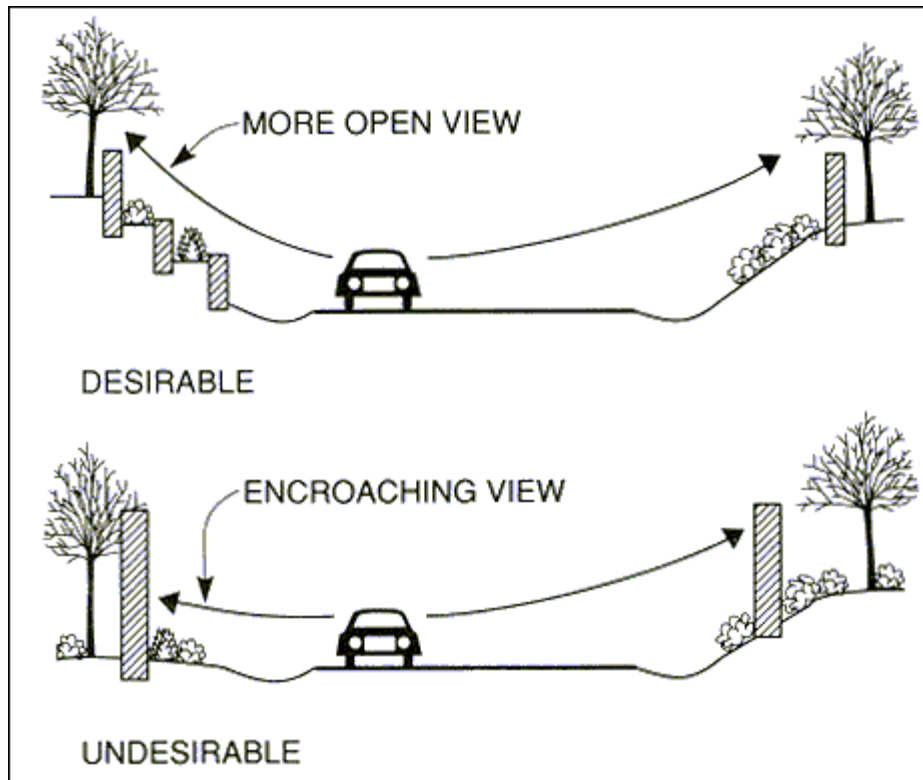
General

Highway noise barriers tend to dominate the visual environment adjacent to roadways (Fig. 4). They are often thousands of feet long and can be as high as 25 ft (7.6m) above the road surface. When noise barrier walls higher than 16 ft (4.9m) are acoustically required, visual consideration of surrounding features should be evaluated. Exceptionally high walls can have an unsightly impact on the aesthetic features of the territory and can give the driver a claustrophobic feeling. For safety reasons, the designer should reduce the visual impact of the noise barrier wall. The motorist must pass the barrier with as little visual disruption as possible. The primary attention of the driver should be on the road ahead and adjacent traffic conditions. This can be achieved by doing one of several things.



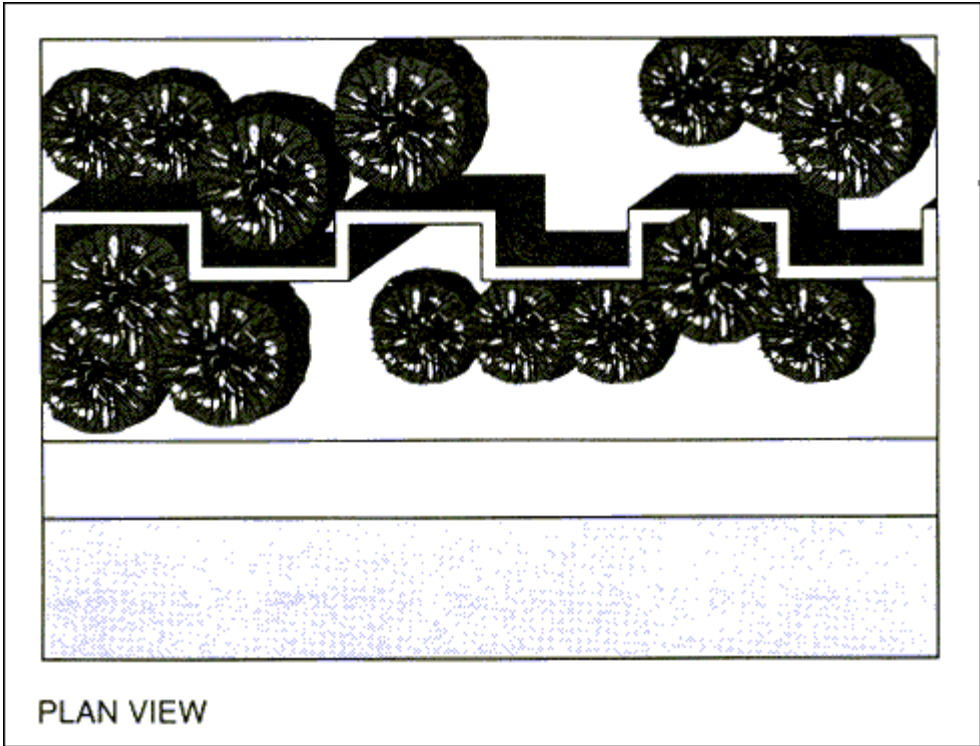
Brick Noise Barrier Wall
FIG. 4

For relatively low walls, the line of the noise barrier should reflect similar lines of the surrounding environment. For instance, in rolling terrain, a straight line will be out of place and attention will be drawn to that line. However, in a flat terrain where the horizon is visible as a straight line, a straight line in a noise barrier wall may not appear to be visually dominant. The introduction of vertical lines, such as with pilasters, placed along relatively low walls is recommended to achieve visual balance. Plantings such as columnar trees can emphasize vertical lines in a noise barrier wall. Further, shrubbery can be used to soften the transition between ground and wall intersection. Wherever possible, the wall should step back to open up the view for the motorist (Fig. 5). However, this can only be practically achieved in rolling or hilly terrain. In an urban environment where the horizon is composed of alternating heights of buildings, an appropriate wall may vary in height as a reflection of the city's profile.

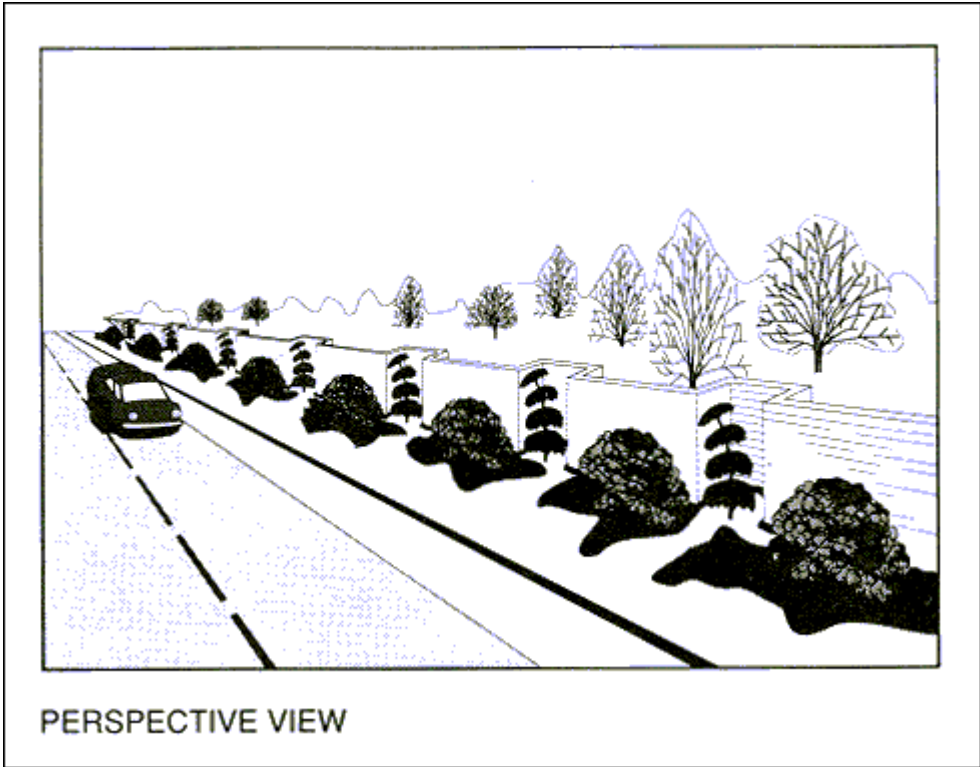


Effect of Wall Placement on Sight Lines
FIG. 5

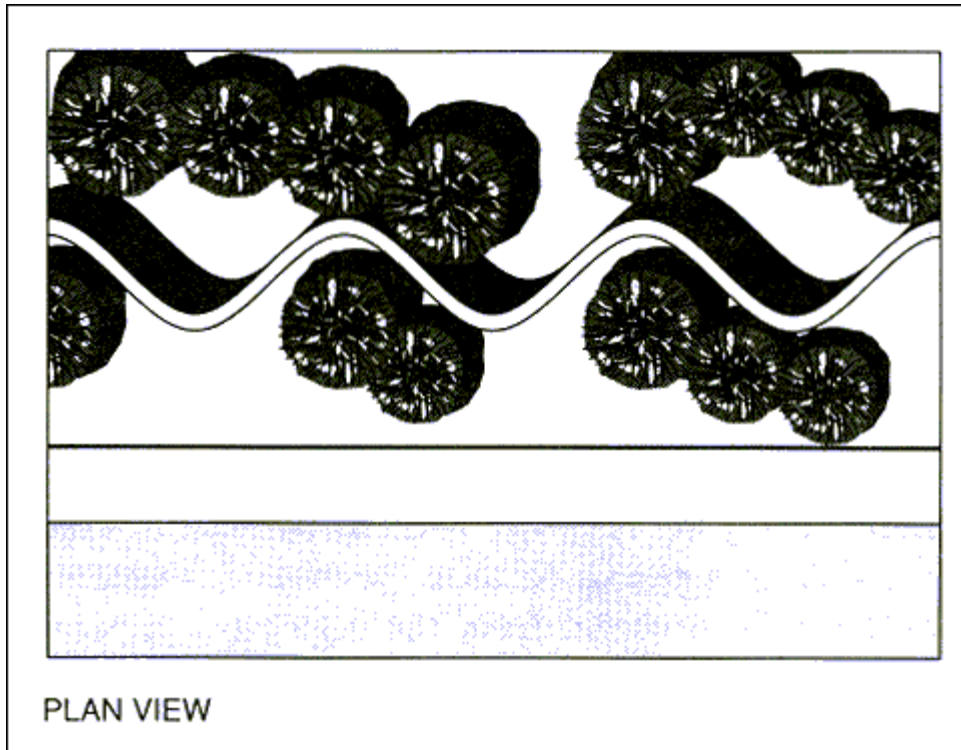
Another way to reduce the visual impact on the environment is through changes in height and location of the wall. A wall with offsets can break the monotony of a straight wall and create pockets which can be used for plantings (Fig. 6). These transitions may further be used as areas for change in texture, color or wall height. A serpentine wall can create the same visual interest as a wall with offsets (Fig. 7). Moreover, due to their geometry, both of these walls have the added advantage of being more resistant to seismic and wind forces than their straight counterparts.



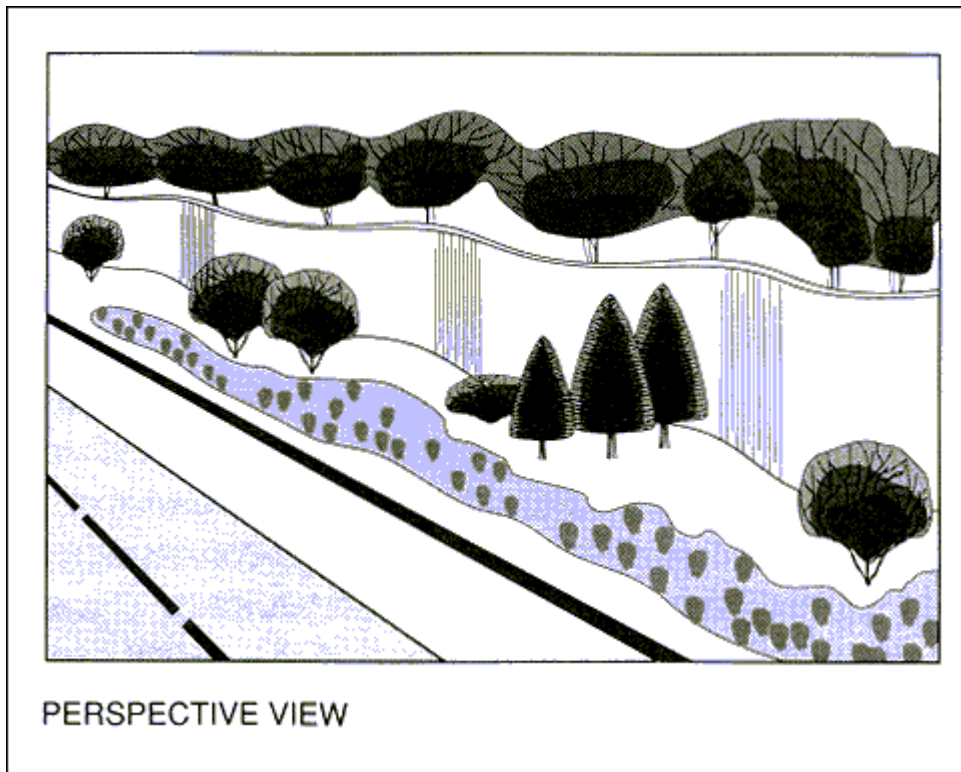
Offset Wall
FIG. 6a



Offset Wall
FIG. 6b



Serpentine Wall
FIG. 7a



Serpentine Wall
FIG. 7b

Regardless of the shape, noise barrier walls should not begin or end abruptly. The best transition of beginning and end is to tie the wall into a natural hillside or a man-made earth berm. If no natural hills or berms are available, the wall termination should taper down and angle away from the

roadway. Not only is this visually pleasing, it is also functional. This transition can effectively reduce the amount of noise traveling around the end of the wall as a result of approaching traffic.

Access through noise barrier walls may be needed in certain instances. Maintenance personnel may require doors for equipment or service. Firefighters may require access to hydrants or water sources on the opposite side of the barrier wall. The appropriate highway and emergency agencies should be consulted regarding access locations and requirements. Openings through noise barrier walls must not reduce the acoustic or structural performance of the noise barrier.

Larger openings are best located at offsets in the wall, or with piers or pilasters at the jamb of the opening. This geometry provides an easier means of accommodating loads and reducing sound penetration. Openings in straight wall sections change the load distribution and this influence must be considered. Loose steel lintels or reinforced masonry beams should be used to span over the openings.

Texture

A change of texture on noise barriers helps to create a pleasant variety for motorist, adjacent residents and pedestrians. The requirements of each are different, however, and must be treated separately. Since motorists usually drive at high rates of speed, they have little opportunity to examine details. To be effective, textures along the highway need to be bold or coarse and visible at a glance because the motorists' attention should not be diverted from the highway. However, textures on the opposite of the highway should be more detailed. The residents and pedestrians on this side view the barrier at much slower speeds and at closer distances. Bold textures can be overbearing and monotonous to them and, therefore, should not be used.

Unlike other materials, masonry can be adapted to create the bold textures for the motorist and the subtle, more detailed textures for those on the other side. Because of its versatility, the possibilities for brick masonry are almost limitless. Bold textures can be created by offsetting brick in random patterns which can cast varying textural shadows during the day. The use of pilasters, special shape brick and copings can also create bold textural interest. Further, brick sculpture can create detailed textures for residents (Fig. 8). Brick can be carved to portray a desired logo, mural or composition.



Brick Sculpture
FIG. 8
Color

Color

The color of the wall plays an important role in blending the wall into the surrounding environment. Since brick barrier walls are man-made structures placed in a natural environment, their color should not attempt to match the color of trees, grass, or shrubbery because they are not related to such natural features by form. Earthen colors, such as browns, grays, and rusts of varying tones, when

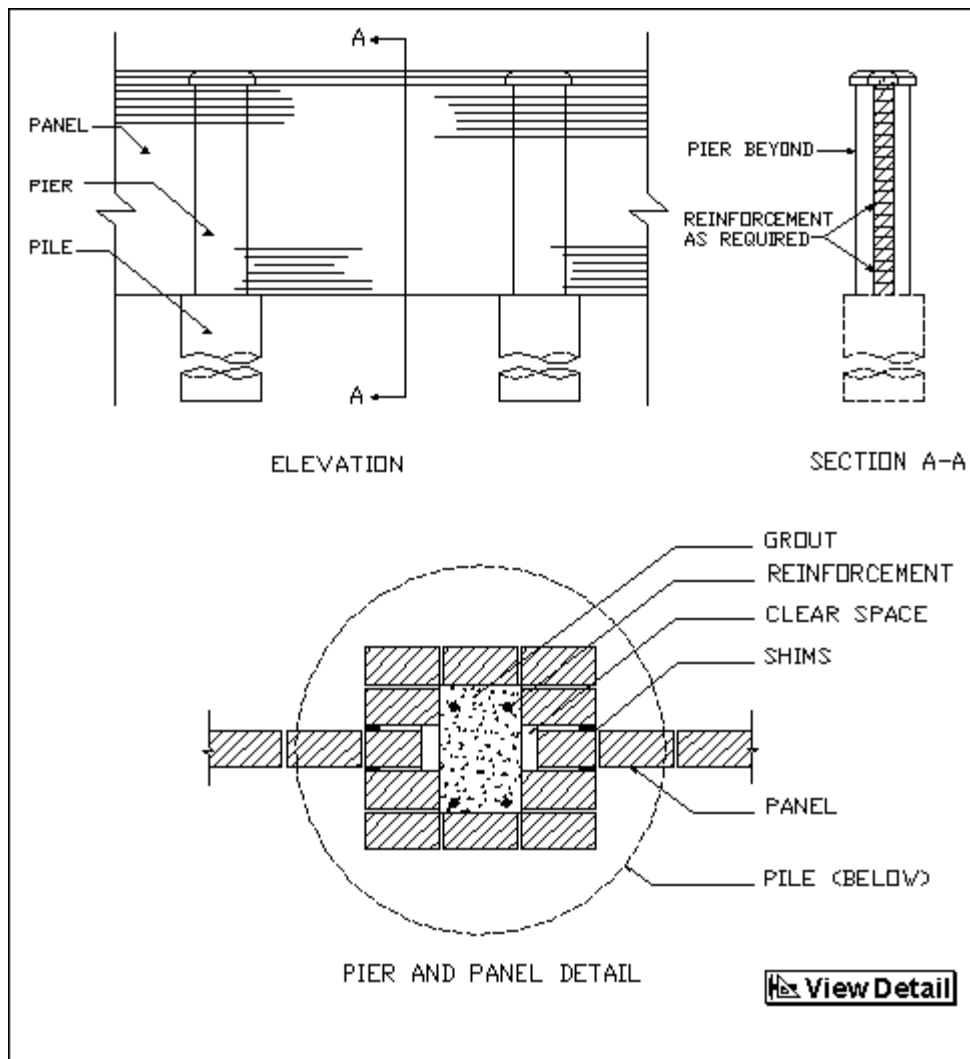
used on barrier walls help to blend the structures into their environment. Repetitious polychromatic patterns are not recommended on the highway side of the barrier. These types of patterns draw the motorists' attention away from the road ahead. However, they can be used on the side of the wall opposite of the highway. Moreover, placing units of different color in alternating bonding patterns can also easily create visual interest. Further, color interest and variety may be achieved through the use of plants and trees. Foliage which changes color will impart a pleasing seasonal variation.

STRUCTURAL CONSIDERATIONS

Structurally, brick masonry noise barrier walls can be designed in various ways. The most popular designs though are the pier and panel, pilaster and panel, and the cantilever walls.

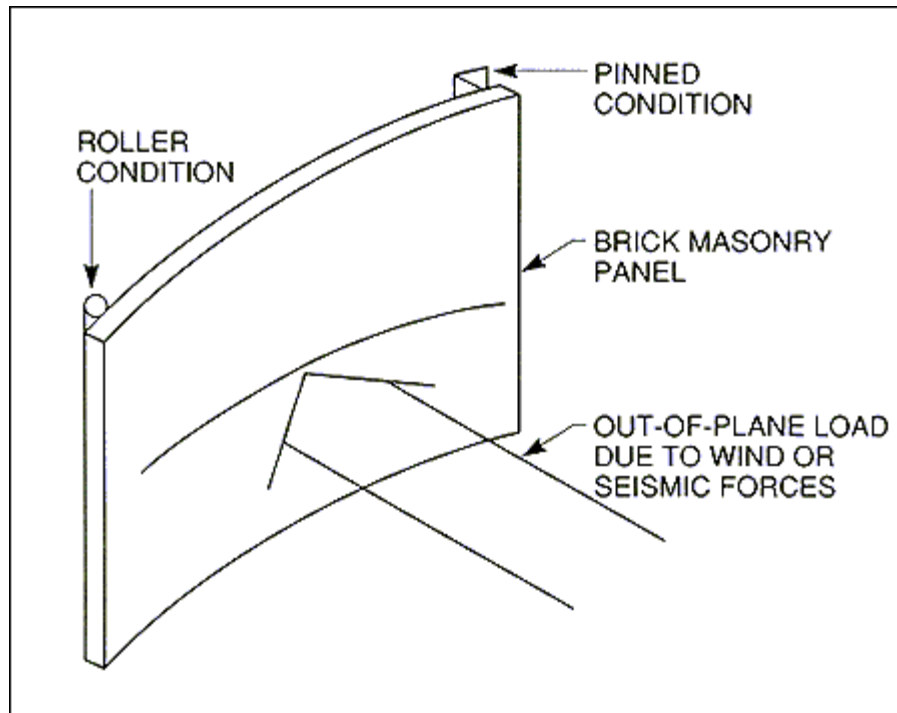
Pier and Panel Wall

The pier and panel wall is composed of a series of single-wythe panels, usually four inches in thickness. These panels are braced periodically by piers (Fig. 9). This type of wall is relatively easy to build and is economical due to the efficient use of materials. It is easily adapted to varying terrain and is acoustically adequate for a highway noise barrier. The pier and panel wall can also be built with returns of varying angles. However, the most easily constructed and economical return is one which is perpendicular to an adjacent panel. The panels, usually built from 8 to 20 ft long (2.4 to 6.1 m), are placed between piers of reinforced masonry, concrete, or steel. The panels can either be prefabricated or built in place and can be as high as acoustically or aesthetically necessary. However, any space left between the bottom of the wall and the ground must be adequately backfilled to prevent noise penetration underneath the wall.



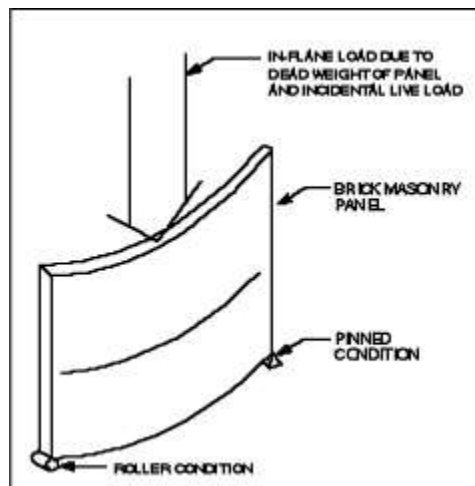
**Pier and Panel Assembly
FIG. 9**

The panels, supported on piles or clip angles attached to piers, essentially act as thin, simply supported beams. The panel, which spans horizontally between the piers, will develop flexural tensile stresses parallel to the bed joints due to out-of-plane wind and seismic loads (Fig. 10). Horizontal joint reinforcement is required if the calculated flexural stresses exceed the allowable stresses found in the local building code. If horizontal reinforcement is required, it must be distributed the full height of the panel.



Out-of-Plane Deflection of Panel in Pier and Panel Wall
FIG. 10

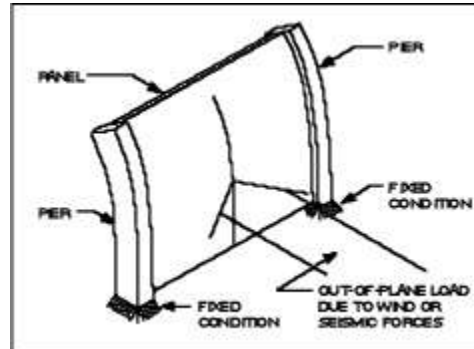
The panel also develops in-plane flexural stresses due to its own dead weight and any incidental vertical loading which may occur (Fig. 11). The in-plane bending will cause flexural tensile stresses at the bottom of the panel. Although the building codes do not now define allowable flexural tensile values for in-plane bending, the allowable flexural tensile stresses parallel to the bed joint for out-of-plane bending can conservatively be used. Both the in-plane and out-of-plane flexural tensile stresses must be calculated and added because the bottom of the panel is subjected to both maximum in-plane and out-of-plane moments. If the sum of the calculated stresses exceeds the out-of-plane allowable flexural tensile stress parallel to the bed joint the panel must be reinforced. This reinforcement is usually placed in the bottom two or three courses of masonry.



In-of-Plane Deflection of Panel in Pier and Panel Wall
FIG. 11

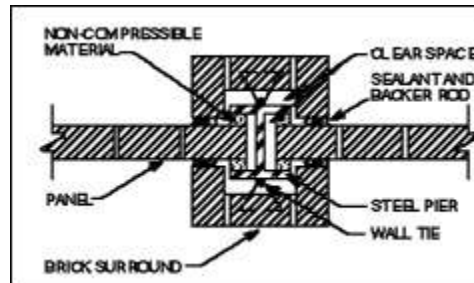
The piers, on the other hand, act as vertical cantilevers and must be designed to resist all lateral loads transferred from the panels. The piers are usually anchored to or embedded in reinforced concrete piles, which vary in depth due to local soil conditions. The piles must be designed to resist all shear and axial loads and the overturning moment caused by the panel due to out-of-plane wind and seismic forces (Fig. 12). Vertical reinforcement may be required in a panel if the out-of-plane

deflection of the pier exceeds the maximum allowable deflection of the panel. This maximum allowable deflection for an unreinforced panel is based on the allowable flexural tensile stress perpendicular to the bed joints. If vertical reinforcement is required, then hollow brick units can be used to facilitate the reinforcement and grouting process. However, it is recommended that the piers be stiff enough so vertical reinforcement in the panels is not necessary.



Out-of-Plane Deflection of Pier and Panel
FIG. 12

Due to the deflection requirements of the panel, the web length of the pier may be larger than the width of the panel, especially for piers made of steel. The space between the pier and panel must be filled with a non-compressible material, placed either uniformly or intermittently along the height of the pier. This non-compressible material ensures proper load transfer from the panel to the pier. However, if intermittent supports are used, a filler material must be placed between supports to block noise transfer around the end of the panel. Further, a clear space the entire height of the panel must be maintained between the end of the panel and the web of the pier. This space allows for the in-plane expansion and contraction of the brick panel (Fig. 13).



Steel Pier/Panel Detail
FIG. 13

When reinforced concrete or masonry piers are used, the flanges should be analyzed to ensure that the shear and bending forces imposed on them by the adjacent panel do not exceed allowable stresses. If for aesthetic reasons, an exposed steel pier is not desirable, brick can be built around the steel in the form of a pilaster (Figs. 13 through 15). Corrosion protection of the pier should be considered when steel piers are used.

Finally, the panels can bear directly on the pile or a steel clip angle which is attached to the pier. The bearing stress requirements of each material must be considered in the design.



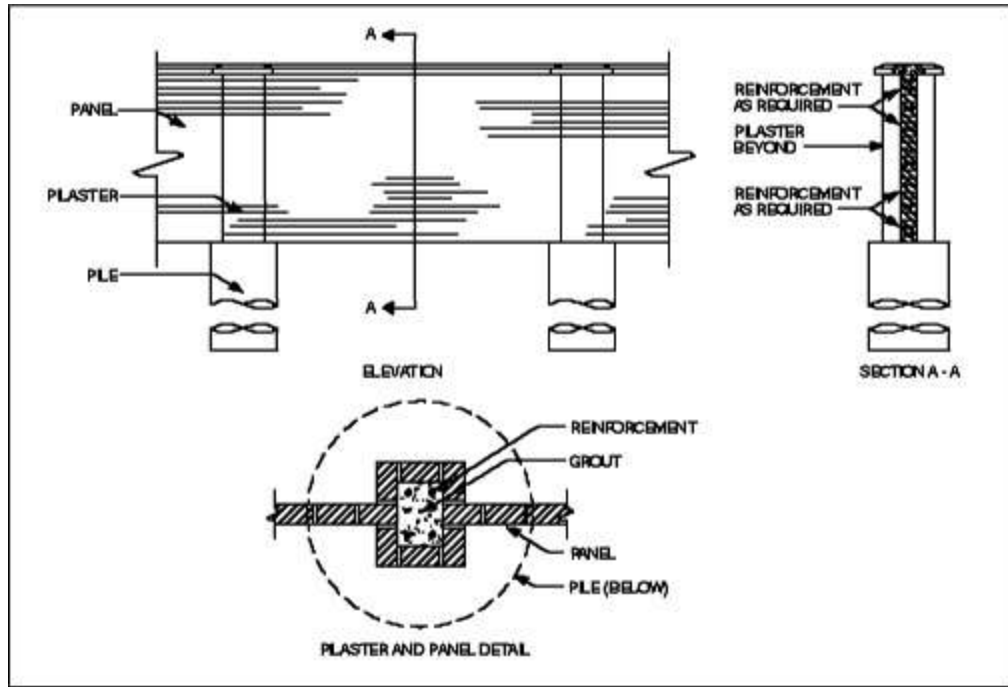
Steel Pier and Panel Wall
FIG. 14



Steel Pier and Panel Wall with Brick Surround
FIG. 15

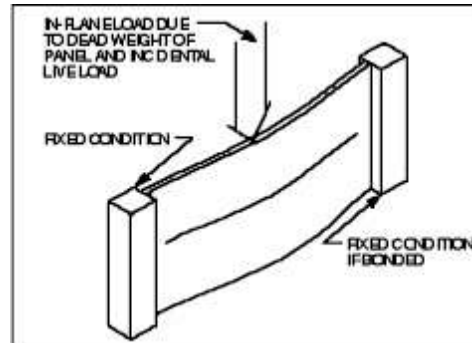
Pilaster and Panel Walls

The pilaster and panel and the pier and panel wall appear to be very similar. Both are composed of single-wythe panels periodically braced by vertical elements and both are equally adaptable to varying terrain and returns. However, there are some fundamental differences which must be carefully analyzed. First, unlike the pier and panel wall, the panel in the pilaster and panel wall is integrally bonded to the pilaster at most intersections (Fig. 16). This seemingly innocuous difference actually has a marked effect on the structural characteristics of the wall. The end condition of the panel in a pier and panel wall is considered simply supported while that in a bonded pilaster and panel is considered fixed. Because of the fixed-end condition, the designer must satisfy the negative moments which are generated at the pilaster (Fig. 17). Depending on the geometry of the wall, horizontal reinforcing steel may be required in both the top and bottom courses of brick due to vertical in-plane bending. If required, it must be fully developed and adequately anchored in the pilaster. The horizontal out-of-plane deflection of the panel will also generate negative moments at the pilaster (Fig. 18). Any horizontal reinforcement will help resist negative moments due to out-of-plane bending. However, the reinforcement must also be fully developed in the pilaster. The pilaster should be stiff enough so the allowable flexural tension developed in the panels due to the out-of-plane deflection of the pilaster is not exceeded. The pilaster must be rigidly attached to the pile below, and the pile must be designed to resist all shear and axial loads and overturning moments.



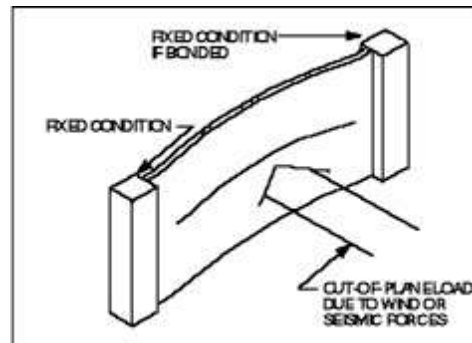
Pilaster and Panel Assembly

FIG. 16



In-Plane Deflection of Panel in a Pilaster and Panel Wall

FIG. 17



Out-of-Plane Deflection of Panel in a Pilaster and Panel Wall

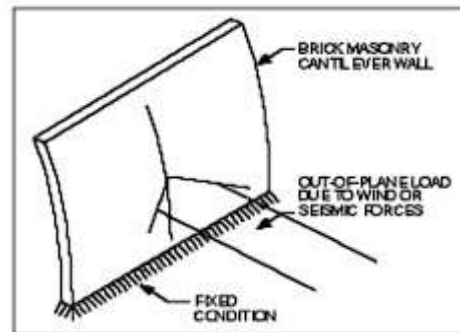
FIG. 18

Another difference between the pier and panel and pilaster and panel wall is the placement of expansion joints. Since the pier and panel are not bonded together, the in-plane horizontal movement can be accounted for at the end of each panel. However, this is not the case with the pilaster and panel wall because they are integrally bonded together. A vertical break provided by an expansion joint is necessary to permit horizontal expansion. The best location for an expansion joint is at the pilaster and panel intersection. The expansion joints should not be placed more than a maximum of 30 ft (9.1m) on center, and the pilaster must not restrict horizontal in-plane movement due to expansion. Further, the connection between pilaster and panel must be able to resist the out-of-plane loads imposed on it.

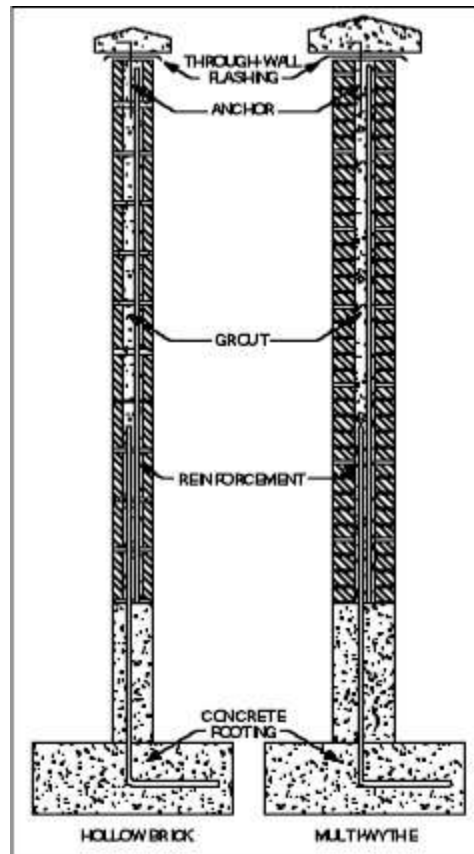
Finally, because the pilaster and the panel are bonded together, the pilaster and panel wall must be built in place. Forms or centering must support the panel during construction and can only be removed after the wall is adequately cured. However, a continuous footing running between the piles could be used to support the dead weight of the panel.

Cantilever Walls

The cantilever wall acts, as its name implies, like a vertical cantilever supported on a continuous footing. Unlike the panel walls, this type of wall is subjected primarily to out-of-plane bending (Fig. 19). The cantilever wall must be built of either reinforced grouted hollow or multi-wythe masonry (Fig. 20). To function properly this wall must be supported on a continuous foundation, usually made of reinforced concrete. The foundation must be designed to support the weight of the wall and be able to resist rotation caused by out-of-plane loads imposed on the wall. The reinforced masonry wall is anchored to the foundation by steel reinforcement placed in the cells of hollow masonry or between wythes in a multi-wythe wall. The steel reinforcement should be designed to resist the flexural tension developed in the wall and be fully developed in both the foundation and grouted masonry.

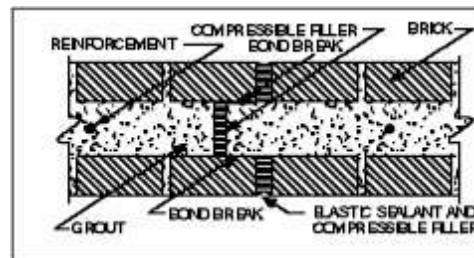


Out of Plane Deflection of Cantilever Wall
Fig. 19



Cantilever Wall Cross Sections
FIG. 20

Expansion joints should be placed at a maximum of 30 ft (9.1m) on center and may be detailed in a staggered fashion for multi-wythe construction (Fig. 21). This detail ensures that the sound from a highway cannot pass directly through the wall if the sealants fail.



Staggered Expansion Joint
FIG. 21

Other Load Considerations

Foundations. Additional stresses can be introduced in brick masonry noise barrier walls by differential settlement or rotation of the foundation system. Soil conditions should be evaluated to keep both differential settlement and differential rotation to a minimum in all wall systems. However, horizontal reinforcement can be used to resist in-plane loads resulting from differential settlement in pilaster and panel and in cantilever walls. Further, more frequent spacing of vertical expansion joints can reduce the effect of differential settlement in these walls.

Traffic Impact. The possibility of vehicles hitting a noise barrier wall must be considered. This is of special concern if the wall is immediately adjacent to the shoulder. Concrete deflector barriers are

recommended in this instance, and any time such devices are used traffic impact loads on the noise barrier walls need not be considered. If traffic can reach the noise barrier wall, then these additional loads must be considered. Horizontal and vertical reinforcement may be necessary in the brick noise barrier wall to add ductility and post-cracking integrity.

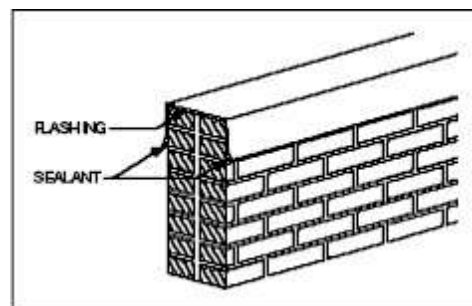
Due to the varying traffic and site conditions it is beyond the scope of this *Technical Notes* to evaluate traffic impact effects. Local highway officials should be consulted to establish these design parameters.

Seismic. If brick masonry noise barrier walls are built in Seismic Performance Categories C or D, they must be reinforced with a minimum amount of both horizontal and vertical reinforcement. These reinforcement requirements can be found in the *Building Code Requirements for Masonry Structures* (ACI 530 / ASCE 5 / TMS 402-02) or the local building codes. Moreover, an analysis should be made to ensure that sufficient reinforcement is present to resist the seismic forces.

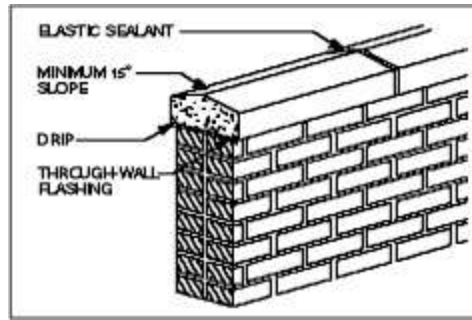
CONSTRUCTION AND DETAILING CONSIDERATIONS

Good workmanship and detailing are key to the success of all masonry assemblages, including noise barrier walls. Full head and bed joints and proper location and installation of reinforcement, ties, flashing and expansion joints are required for proper performance. Any unfilled joint will result in water penetration and will degrade the effectiveness of the noise barrier wall. Proper mixing and consistency between batches of mortar and grout is necessary. All spaces to be grouted must be completely filled, and grouting procedures found in the local building codes must be followed. Generally, Type S mortar as specified by proportion in ASTM C 270 Mortar for Unit Masonry is recommended for construction of noise barrier walls. Grout should conform to ASTM C 476 Specification for Grout for Masonry.

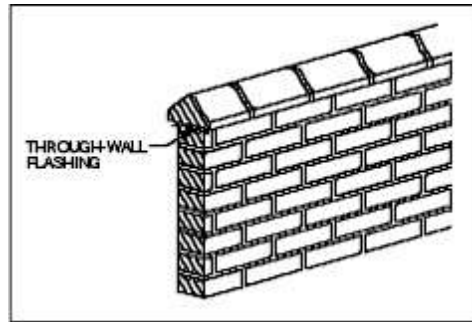
Two critical details in a noise barrier wall are the location and placement of copings and flashing. Copings should project beyond the faces of the wall a minimum of 1 in. (2.5 cm) on both sides. Stone or masonry copings should have a minimum slope of 15 degrees from horizontal and contain a positive drip to keep water from flowing down the face of the wall. It is important that the copings be anchored to the brick wall with metal anchors or bolts, especially in high wind and seismic areas. Natural stone, cast stone, terra cotta, metals, and brick are suitable for copings. If metal copings are used, they should extend down each side of the wall a minimum of 4 in. (10 cm). A sealant should be placed between the metal coping and the wall to prevent wind uplift and water penetration (Fig. 22). When stone or concrete copings are used, an elastic sealant should be placed between the head joints of the coping pieces (Fig. 23). If brick is used as a coping (Fig. 24), it may be prudent to use units which have the same physical requirements as brick pavers. ASTM C 902 Standard Specifications for Pedestrian and Light Traffic Paving Brick is the specification for these units. However, brick units that have been used successfully as a coping in the past, should be adequate.



Metal Coping
FIG. 22



Stone Coping
FIG. 23



Brick Coping
FIG. 24

Through-wall flashing is required directly under the coping. The flashing should extend beyond the faces of the wall to form a drip. All penetrations through the flashing made by the anchors must be adequately sealed with a compatible material.

Brick in noise barrier walls should not be in direct contact with the ground. Salt laden ground water could be absorbed into the brick causing efflorescence or possible spalling in the lower courses. In some instances it may be visually and functionally necessary to have the base of the wall in contact with the ground. In these cases, gravel instead of earth should be placed in contact with the wall. The gravel not only keeps ground water from being absorbed by the brick masonry but also keeps the lower courses free from staining by rain splashed earth.

MAINTENANCE CONSIDERATIONS

Brick masonry walls maintain their aesthetic appeal and remain virtually maintenance free throughout their life. The expansion joint sealant and any sealants used in conjunction with copings are the only elements in the wall which will require intermittent inspection and maintenance.

In some areas the noise barrier wall may be subjected to graffiti. In such an instance, an anti-graffiti coating should be considered. However, some coatings may reduce the durability of clay brick. Also, to remain effective, these materials may have to be re-applied.

Further, sufficient rights-of-way should be established where possible to allow for accumulations of snow on the leeward side of the wall. The location and alignment of noise barriers should be analyzed in order to prevent or reduce problems of drifting snow across roadways.

SUMMARY

Because our national highway system has grown significantly over the last few decades, public awareness of traffic noise on neighborhood communities has increased. Neighborhood associations and governmental bodies look for ways to reduce traffic noise without adversely

affecting the surrounding environment. A solution to this problem lies in brick masonry noise barrier walls. Brick masonry noise barrier walls can easily blend into the environment and give residential communities the protection from highway noise.

The information and suggestions contained in this *Technical Notes* are based on the available data and the experience of the engineering staff of the Brick Industry Association. The information contained herein must be used in conjunction with good technical judgment and a basic understanding of the properties of brick masonry. Final decisions on the use of the information contained in this *Technical Notes* are not within the purview of the Brick Industry Association and must rest with the project architect, engineer and owner.

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