Final Report

To Advance the Concept of Aesthetics and Constructability in the Design of Noise Barrier Walls Through the Design of models, Prototypes, Plans and specifications of the Bhavnani Design

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By the
NJIT Transportation Research Centre

Year 2

December 17, 1999
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To Advance the Concept of Aesthetics and Constructability in the Design of Noise Barrier Walls Through the Design of Models, Prototypes, Plans and Specifications of the Bhavani Design

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The project is an approach to create a more pleasing roadway environment for drivers as they pass through areas shielded by noise barrier walls by installing shadow creating fins which produce a dynamic shadow play on the wall surface.

The front and back panel to post attachment system and the shadow creating fins produce a varied and more pleasing roadway environment which responds to complaints by the public about the aesthetics of current noise walls.

A prototype wall 18 ft. high by 45 ft. long was built and erected and is available to planners, designer and contractors to look at in full scale.

The shadow creating fins can be attached to any new concrete panel wall at an estimated cost of $10/ft. of fin ($33/m. of fin) installed.

The front and back panel to post attachment system using T bolts is reliable, easy to install, provides for increased field post placement tolerances, and eliminates the need to caulk H post joints. This system (using stainless steel T bolts and channels) can be installed for an estimated additional cost of $2/sq. ft. ($21.50/sq.m.) of wall.

The prototype developed wall is viable and should be considered for use in limited stretches for visual relief and to highlight special locations. When used this way the prototype developed wall system could significantly improve aesthetics with little increase in the overall cost of a noise wall.
Acknowledgments

This research was based on a concept conceived by Ashok Bhavnani who proposed the use of fins to create an aesthetically pleasing shadowplay pattern on the roadside surface of noise barrier walls.

The project researchers would like to thank Ashok Bhavnani and all the members of the advisory committee for their interest, contributions and ideas which played a significant role in the development of the prototype wall design. We would also like to single out Mark Marsella and Dominick Billera of the NJDOT for their encouragement and project support.

The researchers also thank Dr. Louis Pignataro of the NJIT Transportation Research Center for his vision and commitment to the project.

Finally we would like to thank Concrete Safety Systems who cast and erected the prototype wall free of charge as their contribution to the research project and Bob Hess and Clarence Mauser who made important practical suggestions during the design, production and erection stages of the prototype wall.
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SUMMARY AND CONCLUSIONS

The project is an approach to create a more pleasing roadway environment for drivers as they pass through areas shielded by noise barrier walls by installing shadow creating fins which produce changing shadow patterns on the wall surface. The fin pattern is created by bolting individual fins on the panel surface. The horizontal fins creates a limitless variety of wall patterns. Depending on the sun’s angle and intensity the length and definition of the shadows change which adds to the visual variety.

A prototype wall 18 ft. high by 45 ft. long (5.5m high by 13.7m long) was built and erected and is available to planners, designer and contractors to look at in full scale.

The front and back panel to post attachment system and the shadow creating fins produce a varied and more pleasing roadway environment (Figs. 29-34, page 32-34) which responds to complaints by the public about the aesthetics of current noise walls.

The shadow creating fins can be attached to any new concrete panel wall at an estimated cost of $10/ft. of fin ($33/m of fin) installed.

The front and back panel to post attachment system using T bolts (Fig. 9-10, page 22) is reliable, easy to install, provides for increased field post placement tolerances, and eliminates the need to caulk H post joints. This system and channels can be installed for an estimated additional cost of $2/sq. ft. ($21.50/sqm) of wall over that of a conventional H post wall.

The prototype-developed wall is viable and should be considered for use in limited stretches for visual relief and to highlight special locations such as exits and rest areas. When used this way the prototype developed wall system could significantly improve aesthetics with little increase in the overall cost of a noise wall.

RECOMMENDATIONS

The prototype developed wall is viable and should be considered for use in limited stretches for visual relief. This could significantly improve aesthetics with little increase in the overall cost of a noise wall. It is recommended that 300m (1000 ft.) of a noise
barrier wall be selected and built following the prototype wall design of front to back panel to post attachment with stainless steel hardware and shadow creating fins. This field section would be used to evaluate aesthetics and public response, and roadway erection costs and procedures.

The metal shadow creating fins can be attached to any new concrete panel wall at an estimated cost of $10/ft. of fin ($33/m of fin). The cost could be reduced by the use of plastic fins, but the cost and reliability of plastic and other lower cost materials needs further study. Fins could also be attached to existing concrete panel noise barrier walls but at a higher cost.

The front and back T bolt panel to post attachment system hardware (channels, T bolts) costs are partially offset by panel erection cost savings. The channels and T bolts used in the prototype, however, were galvanized steel and would be subject to corrosion. Use of stainless steel channels and T bolts would eliminate the corrosion problem but would add an estimated $2/sq. ft. ($21.50/sq.m) of wall to the cost of the wall.

The exposed look of the bolt/washer/nut post to panel assembly on the surface of the panel (Figs. 10, 32, page 22, 33) as installed may be viewed as objectionable. A recessed slot cast in the panel to contain this assembly, which would be covered by a plastic plug or cement mortar, as well as other less noticeable options need to be considered.
INTRODUCTION

The purpose of the research conducted in the second year of the study was to demonstrate the feasibility of building a full scale prototype noise barrier wall that incorporated the aesthetic qualities developed in the design report Type II Noise Wall Study by Bhavnani. That proposed barrier design was developed for NJDOT to respond to complaints by the public about the aesthetics of barrier walls in current use.

The design incorporates the use of horizontally projecting shadow creating fins. The fins project 1 ft. (0.3m) from the wall panel face and are positioned at 2 ft. (0.6m) intervals with the first fin located 8 ft. (2.4m) from ground level. The lower 8 ft. (2.4m) finless section of the wall can be protected by landscaping and other anti-graffiti measures. The erection of panels into a wall segment with differently configured horizontal fins creates a limitless variety of wall patterns. A dynamic shadowplay is produced by sunlight casting the fin shadows on the wall plane surface. Depending on the sun's angle and intensity, the length and definition of the shadows change and adds to the visual variety (Figs. 29-34, page 32-34). The one-third scale model wall built at NJIT during the first year of the study used plastic fins to demonstrate the visual effect of the shadowplay. However, further studies on the present structural reliability of recycled plastics and the high cost of extruded virgin plastics required the use of metal powder coated fins for the prototype.

In addition to aesthetic considerations the research conducted by NJIT also focused on the attachment systems for panel to post connections. Currently used concrete H post and panel systems require precise vertical and horizontal positioning of posts which can lead to field erection tolerance problems. The goal was to develop a system that was reliable, easy to install and which increased post placement tolerances in the field.

STUDY PROCEDURE

The full scale prototype wall designed by NJIT consisted of 3 sections of wall panels producing a wall which was 45 ft. long by 18 ft. high (5.5m high by 13.7m long).
This length of wall was chosen to demonstrate the aesthetic possibilities of creating distinct visual shadow patterns and to gain an understanding of casting and field erection requirements. The fin pattern selected for the prototype was a butterfly shape (App. Dwg. 4, page 53). Numerous methods of creating the horizontal shadow casting fin projections were considered. Casting the concrete fin as an integral part of the concrete panel was one option. This option provided additional structural stiffness to the concrete panel with the possibility of having longer panels with a wider post spacing. Difficulties with concrete casting, shipping problems, and the need to cast many different panels each with a different fin size and location on the panel worked against this option. Another option was the use of extruded plastic fins which would be attached to the surface of the panel at the field site. This allowed for the use of standard concrete panels that would be used as a canvas on to which the fins would be attached to create a predetermined design pattern. That option was pursued and used in the 1/3 scale model built in 1997. The cost of using structurally reliable plastics, however proved to be prohibitive.

Recycled plastics were less expensive but were not structurally reliable in the thin shapes needed for the fins. Ultimately a steel fin with a baked powder coated finish was selected as the most reliable and cost effective method of producing the desired shadow pattern on the surface of the wall. The fins were bolted on the surface of the panel in the field to produce the designed fin pattern.

The panel post attachment system developed by NJIT and used in the 1/3 scale model had the face planes of succeeding wall segments offset and attached to the front or back of posts. The panels were lag bolted into plastic nailer embedded in the posts. In the response to lessons learned form the model and input form the advisory board additional panel to post attachment systems were evaluated. The use of a T bolt system attaching to an embedded steel channel in the post was selected for use in the full-scale prototype. A metal angle bolted attachment system being used for the first time on a NYSDOT noise barrier wall was also studied and evaluated during field panel to post installation.

On June 12, 1998 the NJIT noise wall team visited the site of a NYSDOT noise wall at exit 34 on the Northern State Parkway (NSP) on Long Island. The noise wall contractor and general contractor was Yonkers Construction. The noise wall contractor
And the general contractor was Yonkers Construction. The noise wall and the posts were supplied by Concrete Safety Systems (CSS). The concrete noise wall being erected used a front and back system (same as the NJIT prototype) attached to the posts by a newly developed bolted angle attachment system (Fig. 35A-D, page 35-38). The NSP wall had posts on 12 ft. (3.7m) centers with varying panel heights ranging up to 8 ft. (2.4m) high and with a standard panel length of 14 ft. (4.3m). Maximum wall heights was 16 ft. (4.9m) high.

The panels were lifted into position by a 35 ton hydraulic crane and attached by placing the galvanized angle into a slot in the post. The two bolts in the angle were then attached to two bolt anchors at the panel end (Fig. 39, page 40). Once both sides of a panel were attached by this method the panel became fixed on the posts. The sequence of erection for the NSP job is shown on the Figs. 36-47, (page 39-44). As reported by the Yonkers project manager a crew of 6 men was typically used to install the panels (1 crane operator, 1 labor foreman, 4 laborers). This crew after a break-in period could place 7 bays per day (14 panels) of the maximum size panels used of 8 ft. (2.4m) high. This produced a total of 1,568 sq. ft. (146 sqm.) of panel erected per day (7 hours). Both the prototype wall and NYSDOT metal angle bolted wall were studied to determine erection procedures and costs.

**RESULTS AND DISCUSSION**

**Prototype Design**

The reinforced, air entrained, 5,000 psi (34.47M Pa) concrete panels were designed to be 5 inches (12.7cm) thick, 17 ft. (5.2m) long and, 2 ft. (0.6m) or 4 ft. (1.2m) high (App., Dwg. 2, page 51). A 6-3/4 inch (17.1cm) long tapered slot hole was cast into the panel’s 1 ft. (0.3) from each panel end to accommodate the T bolt during panel erection. This slotted hole provides for a + or -3 inch (7.6cm) horizontal tolerance for misaligned posts.

The surface texture selected for the highway side (fin side) of the wall was a bush hammer finish. A fuzzy rake finish was selected for the residential side of the wall. The 4 ft. (1.2m) high panel shown in App. Dwg. 3, page 52 is intended for attachment to the
post from the highway side and as such has a 2 ft. (0.6m) wide flat buff finish on each end of the residential side surface to allow for the flush placement against the post. Not shown in the design drawings is the residential side attachment panel which requires a 2 ft. wide flat buff finish on the highway side with a full 17 ft. (5.2m) wide fuzzy rake finish on the residential side.

A horizontal row of 318 inch (1cm) diameter Fosroc plastic anchors with a working load of 1,300 lbs (5,782N) per anchor was cast into the panel surface at 1 ft. (0.3m) centers for fin attachment as shown in App., Dwg. 1 and 2, page 50 and 51. As designed it was envisioned that all highway side panels would have fin anchors installed even though no fins would be attached on the bottom 8 ft. (2.4m) of the wall.

The reinforced, air entrained, 5,000 psi (34.47M Pa) concrete posts measuring 18 inch by 18 inch (46cm by 46cm) and 24 ft. (7.3m) long were designed to be placed at 15 ft. (4.6m) centers to support the panels. The posts as built had a flat finish on all four sides. The side surfaces of the posts which are exposed to highway view could be manufactured with a textured surface to improve aesthetics. The top of post height was set 4 inches (10cm) below the top of the panels (as shown in App. Dwg. 5, page 54) to allow for a :t4 inch (10cm) tolerance in post or panel height placement, before the top of the post becomes visible above the top of the panels. Post foundations consisted of concrete encased posts. Shims were placed on top of the concrete post encasement to level out the bottom panel.

A 20 ft. (6.1m) long Halfen, 3817 HTA- HT 3100 anchor channel (App. page 59) was cast into the front and rear face of each post as shown ~ App. Dwg. 8, page 57. These channels provide the anchorage for the Halfen M16 <5/8 inch (16mm) diameter) T bolts which attach the panel to the post. The channel has an allowable pullout capacity of 1,375 lbs. (6,116N) which is well above the maximum design wind load of 40lb/sf (1.92k Pa) which produces a 700 lbs. (3,113N) loading per bolt.

The panel to post attachment is made by installing ,the T bolt through the slotted hole in the panel. The T bolt is then turned 90° which locks the T head in the channel. Steel washers and nuts are then screwed on the T bolts to make the connection. The possible need for an enlarged washer to more effectively transfer wind loads at the
bolt/washer/slot interface requires analysis and testing which were beyond the scope of the project. For the prototype all Halfen channels and bolts were made of galvanized steel. They are available in stainless steel.

The steel fins which attach to the plastic anchors in the panel face were made of 14 gauge steel with a powder coated tan color finish. The fins protrude 10-3/8 inches (26cm) from the surface of the panel and are attached to the panel by 3/8 inch (1cm) diameter stainless steel bolts. The fins were manufactured by Industrial Acoustics Company (IAC) as shown on App. Dwg. 330083-1, page 58.

**Panel and Post Casting**

The concrete panels and posts for the prototype wall were cast at the Concrete Safety Systems (CSS) plant in Pennsylvania. The CSS Company provided critical support to the project with their design advice and by casting and erecting the prototype wall free of charge.

The panels were cast in a horizontal position with standard bush hammer form liner on the bottom surface of the forms and with an open fuzzy rake finish on the top. Location of the plastic fin anchors on the bottom of the form was accomplished by using anchor plugs attached to the bottom of the form set at 1 ft. (0.3m) centers. This operation required little additional work during casting and went smoothly. There were a total of eight 4 ft. by 17 ft. (1.2m by 5.2m) and two 2 ft. by 17 ft. (0.6m by 5.2m) highway side and four 4 ft. by 17 ft. (1.2m by 5.2m) and one 2 ft. x 17 ft. (0.6m by 5.2m) residential side panels cast to make up the prototype wall.

The posts were also cast in a horizontal position using modified standard H post forms. There were four 24 ft. (7.3m) long posts cast for the prototype wall. All panels and posts were cast at the CSS plant in April and May of 1999. Details of the casting are shown in Fig. 1 through 6, pages 18-20.

**Post and Panel Erection**

The posts were erected at the rear of the CSS site and positioned so that the highway side of the wall faced east to catch the morning sun. Post erection followed the same
installation procedure as standard H post erection would require with; excavation, post positioning, and casting the post in the excavated hole in concrete.

Panels for the prototype wall were erected on June 3, 1999 by a crew of CSS maintenance employees, using a 20 ton hydraulic crane with an 80 ft. boom. The crew consisted of two men who attached the fins and who erected the panels and one crane operator.

Panels were pre-positioned near the wall location within reach of the crane and were lifted into position and T bolted in place on the posts. A typical 4 ft. by 17 ft. (1.2m by 5.2m) panel which required the attachment of 2 fins and placement of 4 T bolts took 15 minutes to install from start to finish. This broke down to 10 minutes to install the fins and 5 minutes to swing lift and install the panel.

A total of twelve 4 ft. (1.2m) panels and three 2 ft. (0.6m) panels (a total of 918 sq. ft. (85.3 sq.m) of panel) including the attachment of 136 lin. Ft. (41.5m) of fins took the 3 man crew 3-1/2 hours to complete. This was extremely fast especially considering the fact that the system was new and untried and the fact that the CSS maintenance crew does not normally do wall erection. One difficulty encountered was that some of the plastic fin anchors had some grout in them. This required them to be cleaned with a tap (Fig. 13, page 24). During actual production of this type of panel the plastic anchor holes would all be cleaned with a tap prior to shipment to the site. This cleaning requires 2 minutes for one man per 4 ft. (1.2m) panel. The sequence of wall panel erection for the prototype wall is shown in Figs. 7 through 26, pages 21-30.

A second problem which was observed during fin installation was fin edge warping (Fig. 18, 20, page 26, 27). This was caused by panel surface unevenness where the metal fin rear attachment edge sits on the concrete panel surface. However, the problem was not noticeable when viewing the wall from a driver’s perspective (Fig. 31, page 33). The problem could be eliminated by placement of a leveling gasket on the rear attachment edge of the fin.
Fins Aesthetics

Sound barrier walls combat noise pollution in adjacent neighborhoods, but also obscures the landscape we all enjoy viewing while driving. Existing walls are often perceived as having a monotonous unattractive appearance.

The fin wall design is based on a concept developed by architect Ashok Bhavnani in 1994 for the NJDOT. The design concept incorporates shadow creating fins. The erection of panels into wall segments with differently configured horizontal fins can create a limitless variety of wall patterns. A dynamic shadowplay is produced by sunlight casting the fin shadows on the wall plane surface. Depending on the sun's angle and intensity, the length and definition of the shadow changes and adds to the visual variety. The prototype wall butterfly fin design changing shadow pattern can be seen in photographs taken at 8:30 am Figs. 30-32, (page 32, 33) at noon Figs. 33-34 (page 34) and at 1:30 pm Fig. 29 (page 32). The wall has an eastern exposure on the fin side.

Horizontal and Vertical Alignment Changes

Horizontal alignment changes in the prototype design wall can be best accomplished by casting special angled columns which would then maintain the + or -3 inch (7.6cm) tolerance on horizontal post placement. This would produce full panel to post contact on the post surface, which would reduce any possibility of noise leakage at panel to post openings. An alternate method could employ plastic wedges washers on the panel face as shown in Fig. 48, page 45. The as built prototype was a straight section of wall and as such design and construction details for horizontal alignment changes could not be evaluated.

Vertical alignment changes would be accomplished at the top of wall by casting a slope at the top of a panel. Elevation changes of less than 9 inches (23cm) would be via a 2 ft. (0.6m) form. Elevation changes of up to 2 ft. – 9 inches (84cm) would be via a 4 ft. panel (1.2m) (Fig. 49, page 46).

Changes in vertical alignment at the bottom of the wall would be accomplished by 1 ft. (0.3m) or 2 ft. (0.6m) high panels (fig. 49, page 46).
Corrosion

Fins - The steel fins used in the prototype wall were manufactured with a baked on powder coating finish which provides the currently available best corrosion paint protection finish. Individual fins installed in the prototype wall experiencing corrosion could be replaced. The use of non corroding fins (e.g., plastic) needs to be further explored and developed. The fin anchors are plastic and do not corrode. The fins are attached to the plastic anchors by 3/8 inch (1cm) diameter stainless steel bolts and stainless steel washers and should not present a corrosion problem. Panel to Post Attachment - The Halfan channels and Halfan T bolts used in the prototype were both made of galvanized steel and will eventually corrode. Both channels and T bolts are available in stainless steel but at a cost of four times the cost of the galvanized steel.

Noise Abatement

In conventional H post and panel construction, tolerances must be provided on the H post slots so that the panels can be slipped in. This produces open noise paths which reduces the noise abatement effectiveness of the system. Typically backer material and caulk are used to seal these tolerance openings which add to the overall construction cost of the H post system. With thermal movement over time the backer material and caulk often come loose and need maintenance work.

The front and back bolted attachment system used in the NJIT prototype all provides flush contact between panel and post and eliminates the need to seal tolerance openings and by doing eliminates caulking costs.

Cost Analysis

It should be noted that due to the front and back attachment system used in the prototype wall the sq ft. area of the panels was 18 ft. x 17 ft1 (5.5m x 5.2m) x 3 = 918 sq ft. (85sqm), while the actual area of the wall was 18 ft. x 45 ft. (5.5m x 13.7m) = 810 sq ft. (75sqm). In comparing costs of the prototype wall to other walls it is important to know if $/sq. ft. of wall or $/sq. ft. of panel is being used in the comparison. The NSP wall contractor reported being paid by NYSDOT on a $/sq. ft. of panel basis.
The cost of the prototype system is examined in two separate categories Fin Costs and Post to Panel Attachment Costs.

**Fin Costs**
For the butterfly pattern used in the prototype wall the additional cost of all materials and construction site installation came out to be $1.91/sq. ft. ($20.55/sqm) of wall or $11.35/lin ft. of fin ($37.23/m) (Fig. 50, page 47). The fins can be attached to a conventional H post and panel system just as easily as they were attached to the prototype wall panels. It is estimated that to attach fins to any new concrete wall panel with reductions for mass production of fins, would cost $10/lin ft. of fin ($33/m) installed.

**Panel Attachment Costs**

The cost of panel to post attachment in the field for the prototype system is difficult to estimate due to the wide variety of conditions encountered in the field during installation.

The prototype wall erection work was done by a small, efficient crew on a short section of straight wall on flat terrain. For these conditions it is estimated that construction site erection costs for the panels would be $0.35/sq. ft. ($3.77/sqm) of wall (Fig. 51, page 48). More difficult site conditions with larger crew requirements could raise the figure to $1/sq. ft. ($10.75/sqm) of wall. This cost does not include post placement, nor panel unloading, storage or site movement. It is clear that the prototype attachment system is simple and fast and could significantly reduce panel erection costs by an estimated $1/sq. ft. ($10.75/sqm) of wall.

Additional cost savings for the prototype wall system would be gained due to the increased post placement tolerances of the system with a reduction of post misalignment problems and the elimination of the need to caulk the H post joints with estimated savings of $1/sq. ft. ($10.75/sqm) of wall.

The prototype wall system does require additional expenditure for hardware (channels and T bolts). The additional cost is $1/sq. ft. ($10.15/sqm) of wall (Fig. 51,
page 48). If stainless steel channels and bolts are used the cost is increased to $4/sq. ft. ($43/sqm) of wall. Therefore, with estimated erection and no caulking cost savings of $2/sq. ft. ($21.59/sqm) of wall and cost additions of $4/sq. ft. ($43/sqm) using all stainless steel hardware the prototype system can be installed for an estimated total additional cost of $2/sq. ft. ($21.50 sq.m) of wall. The cost is the added cost over that of a conventional H post and panel noise barrier wall.

The NSP noise wall panel field erection cost was $1.74/sq. ft. of panel. This figure does not include the cost of the 4 galvanized angles, 8 galvanized bolts and 8 bolt anchors needed per panel for that system. The cost of this hardware was not available.
Fig. 1  Bush hammer (highway side) form linear at bottom of horizontal form at CSS

Fig. 2 Bush hammer (highway side) 4 ft. panel with smooth end treatments which rest against the posts.
Fig. 3  Detail of Fig. 2 showing plastic fin anchor holes.

Fig. 4. Fuzzy rake finish on residential side of Fig. 2 panel.
Fig. 5  Fuzzy rake finish (residential side) of 4 ft. panel with smooth end treatments which rest against the posts.

Fig. 6  Concrete post – 24 ft. long with channel for T bolts cast in. Note: Halfan Channel on left.
Fig. 7 Prototype posts 4@ 15 ft. center at CSS yard.

Fig. 8 Panels stacked on rack ready for erection.
Fig. 9  Three 4 ft. bottom panels are in place.

Fig. 10  Detail of T bolt in Fig. 9. Note slot mark at end to show T is set in channel.
Fig. 11  Residential side bolting of panel.

Fig. 12  Detail of Fig. 11. T bolt.
Fig. 13 Grout filled plastic anchors needed tapping

Fig. 14 Fin attachment to panels
Fig. 15 Four ft. panel with four 2 ft. fins

Fig. 16 Panel fig.15 being bolted from the residential side with the bush hammer side to post
Fig. 17  Detail Fig. 16.

Fig. 18  6 ft. fin above 4 ft. fin shows some edge waviness.
Fig. 19 Same panel as Fig. 18

Fig 20 8ft. and 10 ft. fins being attached
Fig. 21 Checking panel edge for debris

Fig. 22 Panel being lifted into position
Fig. 23  Fig. 20 panel being lowered to posts.

Fig. 24  Fig 20 panel T bolt detail
Fig. 25 12 ft. fin (6ft.x 2) being attached

Fig. 26 2 ft. panel being bolted to post
Fig. 27 Detail of T bolts on residential side

Fig 28 Residential side completed.
Fig. 29 Butterfly fin pattern on highway side hazy sun at 1:30 P.M summer

Fig. 30 Bright sun at 8:30 A.M- summer
Fig. 31 Bright sun at 8:30 A.M- summer driver’s perspective right lane

Fig. 32 Detail Fig. 31
Fig. 33 Bright sun at 12 noon - summer

Fig. 34 Bright sun at 12 noon- summer drivers perspective right lane
0° CLIP DETAIL (PLAN)

10° CLIP DETAIL (PLAN)

SECTION B-B (SHOWN)
SECTION B'-B' (SIMILAR)
Fig. 36 NSP noise wall panel erection.

Fig. 37 Detail of angle and bolt post to panel attachment.
Fig. 38 Detail of Fig. 31.

Fig. 39 Detail of angle and bolt attachment.
Fig. 40 Detail of angle and bolt attachment.

Fig. 41 Angle attachment at bottom and top of panels.
Fig. 42 Note shims used between angle and panel.

Fig. 43 Panel bolt holes at lower right.
Fig. 44 Anchor bolts for post base plate.

Fig. 45 Post base plate set on anchor bolts with grout below. Note anchor bolt and panel angle interference.
Fig. 46 View of the highway side wall.

Fig. 47 Detail of post tops set below level of wall.
VERTICAL ALIGNMENT CHANGE

AT TOP

AT BOTTOM

BOTTOM

FOUNDATION

1' PANEL

BOTTOM
FIN ATTACHMENT COST FOR PROTOTYPE WALL

MATERIALS

Fins - 136 liner ft of metal fin @ \$8.94/lin ft = \$944
Fin Anchors - @ \$2.77/1,000 x 400 = \$91
Fin Bolts + Washers (55) @ \$0.10/100 x 400 = \$40

PRODUCTION

Fin Anchor Placement During Casting and Clean/Tap Anchors After Casting Labor @ \$30/hr. Casting Yard.

Fin Panel Area = 918 sq ft.

Time Needed at Yard to Place Anchors and Clean/Tap @ 140 sq ft/hr

918 sq ft / panel

140 sq ft / panel/hr

= 6.56 hr @ \$30/hr.

= \$197

Fin Attachment at Construction Site - Labor @ \$60/hr. Construction Site

60 lin ft of Fin / 2 man crew / hour

136 lin ft / fin

60 lin ft / hr

= 2.27 hr @ \$120/hr.

= \$272

Panel Area = 17 ft x 12 ft = 918 sq ft

Wall Area = 45 ft x 18 ft = 810 sq ft

Total = 1,728 sq ft

FIN COST

\$1,544

810 sq ft of wall

= \$1.91/ft² of wall

\$1,544 / 136 ft² = \$11.35/ft²
Panel to Post Attachment Cost for Prototype Wall at a Construction Site.

Panel Erection Cost:

Crew - 2 Laborers
1 Crane Operator

\[ \text{Crew cost} = \$180/h \times 2 = \$360/h \]

Equip - 20 Ton Crane

\[ \text{Equipment cost} = \$30/h \times 2 = \$60/h \]

Total Crew + Equip. Cost: \$210/h.

4' x 17' panel w/ 4 T bolts (680 ft² per panel)
Panel hook up, lift, ladder placement, T-bolt attachment.

Took on ave 6 min. or 680 ft² of panel/crew/hr.

\[ \frac{918 \text{ ft}^2 \text{ of panel}}{680 \text{ ft}^2 \text{ per crew/hr}} = 1.35 \text{ hr} \times \$210/\text{hr} = \$284 \]

\[ \frac{\$284}{810 \text{ sq ft of wall}} = \$0.35 / \text{sq ft of wall} \text{ (Panel Erection Cost Only)} \]

System Materials Cost:

(estimate for long wall - neglect end effects)

Halfen - HT 3100 - Gal. Chan. @ \$84/20'
6 Channels @ \$84/20' \[ \$504 \]
T Bolts, nuts, washers, Gal. Mig @ \$6/T-Bolt
54 T Bolts @ \$6/T-Bolt \[ \$324 \]

\[ \$828 \]

\[ \frac{\$828}{810 \text{ sq ft of wall}} = \$1.02 / \text{sq ft of wall} \]
APPENDIX

Design Drawings------------------------------------------------------------- Pages
5000 PSI CONC.
AIR ENTRAINMENT
COLOR SAMPLE TO
IN - G. FIFALLO
COLOR - LIGHT GRAY/TRAN.
RESIDENTIAL
FUZZY RAKE
F - L
HIGHWAY SIDE
BUSH HAMMER
POST ANCHOR SLOT HOLE
FIN ANCHOR
\[ \frac{3}{8}'' D @ 12'' C.M. \]

\#4 WIRE @ 6''
AS SHOWN.
60 KSI.

\#1 WIRE @ 12''
60 KSI.

FIN ANCHOR
\[ \frac{3}{8}'' D @ 12'' \]

SCALE 2'' = 1'

NJ IT-5'' CONC. PANEL
W.K. 1/30/98 Dwg. 2
14 GAUGE STEEL
Powder coated finish. Concrete Tan/Gray

TWO FOOT LONG FIN

FOR DWG 4 FIN LAYOUT

<table>
<thead>
<tr>
<th>NEED</th>
<th>ORDER</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x 12'</td>
<td>2 x 12'</td>
</tr>
<tr>
<td>2 x 10'</td>
<td>2 x 10'</td>
</tr>
<tr>
<td>2 x 8'</td>
<td>2 x 8'</td>
</tr>
<tr>
<td>2 x 6'</td>
<td>2 x 6'</td>
</tr>
<tr>
<td>2 x 4'</td>
<td>2 x 4'</td>
</tr>
<tr>
<td>9 x 2'</td>
<td>11 x 2'</td>
</tr>
</tbody>
</table>

98 LIN FT.
32 < 45° ICONS
136 LIN FT.

102 LIN FT.
42 X 45° ICONS
144 LIN FT.

NJSI - FIN DETAIL
WK 11/30/98 DWG-6
PANELS NEEDED FOR NJIT FIN WALL SHOWN ON PAGE 4

Need 6 panels with fin anchors 2 rows

Need 3 panels with fin anchors 1 row

Need 6 panels without fin anchors.

N.I.T.S.

NJIT 5" conc. panels
W.J. 1/30/98 DRG 7
HALFEN ANCHOR CHANNEL
3817 HTA - HT 3100 - 20° HDG.

SCALE 1" = 1'

DETAIL C

POST CONC.
5,000 PSI.

SCALE 1" = 1'

#3 @ 7'
BOTTOM IS 10 FT.
60 PSI

Top 14'

USE #3 @ 12'
60 PSI

RE BAIL PLACEMENT.

NJIT - TERMINAL POST
# 3817 HTA ANCHOR CHANNEL

## LOAD DATA AND PART NUMBERS

<table>
<thead>
<tr>
<th>Standard Short Pieces With 2 Anchors</th>
<th>Allowable Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Number</td>
<td>Channel Length (inches)</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>HT3506</td>
<td>6</td>
</tr>
<tr>
<td>HT3508</td>
<td>8</td>
</tr>
<tr>
<td>HT3110</td>
<td>10</td>
</tr>
<tr>
<td>HT3112</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standard Short Pieces With 3 Anchors</th>
<th>Allowable Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Number</td>
<td>Channel Length (inches)</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>HT3510</td>
<td>10</td>
</tr>
<tr>
<td>HT3512</td>
<td>12</td>
</tr>
<tr>
<td>HT3518</td>
<td>18</td>
</tr>
<tr>
<td>HT3114</td>
<td>24</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Long Lengths Up To 20 Feet. Anchors at Either 5° Or 10°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Number</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>HT3100</td>
</tr>
<tr>
<td>HT3500</td>
</tr>
</tbody>
</table>

## BOLTS AND LOCKING PLATES

Standard grade HALFEN Tee-head bolt type M12 (1/2") is recommended for use with this channel. Other diameters are available to special order. The following locking plates are available for use with regular Hex head bolts and threaded rods — 1/4", 5/16", 3/8", 1/2". Tensile Tee-head bolts are used. Allowable longitudinal load available (3:1 Safety Factor): 1700 lbs.

Please refer to pages T-13 & T-14 for full bolt details.
HALFEN TEE-HEAD BOLTS

General

Halfen Tee-head bolts are the economical alternative to a stud nut. They offer high security because they are manufactured in one piece.

Fig. 1 Hammer Head Bolt
Fig. 2 Hook Head Bolt
Fig. 3

Sizes, Finishes, and P/Ns

Two types of Tee-head bolts are supplied, the hammer head bolt (Fig. 1) for channels 2815 & 3817, and the hook head bolt (Fig. 2) for channels 4022, 4930, 5030, 5234, and 7248. Both types are available in HALFEN Standard and High Tensile grades. In all cases the length of the bolt is figured from the head, so projection length from the concrete face can be calculated by subtracting the thickness of the channel lips.

Electroplated and stainless steel finishes are readily available. Galvanized finishes are provided to order. For ordering, please use the base part number given in the following table. Add a 1, 2, 3, or 4 to the end of the base part number depending on the finish required. Other bolt sizes can be supplied. Please consult HALFEN for details.

Electroplated to ASTM B-633 — Add '1' Example: BC2311
Hot dip galvanized to ASTM A-153 — Add '2' Example: BC2312
Stainless steel to AISI 304 — Add '3' Example: BC2313
Stainless steel to AISI 316 — Add '4' Example: BC2314

Standard Grade Tee-Head Bolts

<table>
<thead>
<tr>
<th>Channel Size</th>
<th>Thread Size</th>
<th>1/4&quot;</th>
<th>3/8&quot;</th>
<th>1/2&quot;</th>
<th>5/8&quot;</th>
<th>3/4&quot;</th>
<th>1&quot;</th>
<th>1-1/4&quot;</th>
<th>2&quot;</th>
<th>2-1/8&quot;</th>
<th>2-1/2&quot;</th>
<th>3&quot;</th>
<th>4&quot;</th>
<th>Base Part No.</th>
<th>Extra Nuts</th>
<th>Special Bolt Sizes</th>
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<tbody>
<tr>
<td>2815/3017</td>
<td>M10</td>
<td>BA231</td>
<td>BB231</td>
<td>BC231</td>
<td>BD231</td>
<td>BF231</td>
<td>BH231</td>
<td>BL231</td>
<td>BP231</td>
<td>HN231</td>
<td>M10</td>
<td>M10</td>
<td>M10</td>
<td>Add '1'</td>
<td>BC2311</td>
<td></td>
</tr>
<tr>
<td>4022/4930</td>
<td>M12</td>
<td>BB441</td>
<td>BD441</td>
<td>BF441</td>
<td>BH441</td>
<td>BL441</td>
<td>BM441</td>
<td>BM51</td>
<td>BP51</td>
<td>HN51</td>
<td>M10</td>
<td>M10</td>
<td>M10</td>
<td>Add '2'</td>
<td>BC2312</td>
<td></td>
</tr>
<tr>
<td>5030/5234</td>
<td>M16</td>
<td>BB551</td>
<td>BD551</td>
<td>BF551</td>
<td>BH551</td>
<td>BL551</td>
<td>BM551</td>
<td>BM61</td>
<td>BP61</td>
<td>HN61</td>
<td>M10</td>
<td>M10</td>
<td>M10</td>
<td>Add '3'</td>
<td>BC2313</td>
<td></td>
</tr>
<tr>
<td>7248/316</td>
<td>M20</td>
<td>BB771</td>
<td>BD771</td>
<td>BF771</td>
<td>BH771</td>
<td>BL771</td>
<td>BM771</td>
<td>BM81</td>
<td>BP81</td>
<td>HN81</td>
<td>M10</td>
<td>M10</td>
<td>M10</td>
<td>Add '4'</td>
<td>BC2314</td>
<td></td>
</tr>
</tbody>
</table>

Pullout & Shear Loads

![Graph showing pullout and shear loads](image)

<table>
<thead>
<tr>
<th>Bolt Diameter</th>
<th>M6</th>
<th>M8</th>
<th>M10</th>
<th>M12</th>
<th>M16</th>
<th>M20</th>
<th>M24</th>
<th>M27</th>
<th>M30</th>
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</thead>
<tbody>
<tr>
<td>Load</td>
<td>485</td>
<td>980</td>
<td>1405</td>
<td>2045</td>
<td>3815</td>
<td>5950</td>
<td>8550</td>
<td>11,130</td>
<td>13,600</td>
</tr>
<tr>
<td>Recommended Torque (R-105)</td>
<td>2</td>
<td>6</td>
<td>11</td>
<td>19</td>
<td>44</td>
<td>88</td>
<td>147</td>
<td>220</td>
<td>295</td>
</tr>
</tbody>
</table>
High Tensile Grade Tee-Head Bolts

HALFEN high tensile grade bolts have greater strength than the standard grade range of bolts. They may be used for the channel sizes indicated below, but care should be taken to ensure that the load applied does not exceed the capacity of the channel.

**Slip Loads**

It is recommended that if high slip loads are required (the load being applied longitudinal to the channel) that HALFEN channel 4122 HZA is used with toothed HALFEN bolts. Alternatively high tensile Tee-head bolts can be used in any of the HALFEN channels to achieve an increased slip load. Details of loads and torques are given below.

<table>
<thead>
<tr>
<th>Channel Ref.</th>
<th>Thread Size</th>
<th>1/3&quot; (35 mm)</th>
<th>1 1/2&quot; (40 mm)</th>
<th>1 3/4&quot; (45 mm)</th>
<th>2&quot; (50 mm)</th>
<th>2 5/16&quot; (60 mm)</th>
<th>2 3/4&quot; (70 mm)</th>
<th>3&quot; (75 mm)</th>
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</thead>
<tbody>
<tr>
<td>2815HTA</td>
<td>M10</td>
<td>BF232</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3817HTA</td>
<td>M16</td>
<td>BJ352</td>
<td>BL352</td>
<td></td>
<td></td>
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<td></td>
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<td>4022HTA</td>
<td>M16</td>
<td>BF452</td>
<td>BJ452</td>
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<td></td>
<td></td>
<td></td>
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<td>4930HTA</td>
<td>M16</td>
<td>BJ552</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>5030HTA</td>
<td>M16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5234HTA</td>
<td>M20</td>
<td>BG562</td>
<td>BJ562</td>
<td>BM562</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7248HTA</td>
<td>M24</td>
<td>BM772</td>
<td>BJ242</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4122HZA</td>
<td>M12&quot;</td>
<td>RH942</td>
<td></td>
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</tr>
<tr>
<td>4122HZA</td>
<td>M16&quot;</td>
<td>RH942</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Available in Standard Grade ASI 304 & 316
Preferred Finish Galvanized
Preferred Finish Electroplated

Before applying very high torques, ensure the face of the channel is level with the surface of the concrete, and that a substantial plate washer is used under the nut to resist crushing the component. See page T-2.

Using Tee-head Bolts

The study of the Tee-head bolts and their matching nuts have metric dimensions. The table gives recommended clearance hole sizes in components to be anchored, and appropriate wrench sizes for tightening nuts. Although it is good practice to use a torque wrench for tightening nuts it is not essential, unless the load is being applied longitudinally to the channel. Tightening with a wrench in a normal manner is usually all that is required. If a metric wrench is not available an adjustable wrench may be used for the smaller bolts. Metric wrenches are available from HALFEN on request.

<table>
<thead>
<tr>
<th>Bolt Thread Ref.</th>
<th>M6</th>
<th>M8</th>
<th>M10</th>
<th>M12</th>
<th>M16</th>
<th>M20</th>
<th>M24</th>
<th>M27</th>
<th>M30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt Diameter in Millimeters</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>16</td>
<td>20</td>
<td>24</td>
<td>27</td>
<td>30</td>
</tr>
<tr>
<td>Equivalent Diameter in inches</td>
<td>0.236</td>
<td>0.315</td>
<td>0.394</td>
<td>0.472</td>
<td>0.630</td>
<td>0.787</td>
<td>0.945</td>
<td>1.063</td>
<td>1.181</td>
</tr>
<tr>
<td>Recommended thru Hole Size in Component to be Anchored (mm)</td>
<td>1/4</td>
<td>11/32</td>
<td>13/32</td>
<td>1/2</td>
<td>21/32</td>
<td>13/16</td>
<td>1</td>
<td>1 3/16</td>
<td>1 1/4</td>
</tr>
<tr>
<td>Metric Wrench Size (mm)</td>
<td>10</td>
<td>13</td>
<td>17</td>
<td>19</td>
<td>24</td>
<td>30</td>
<td>36</td>
<td>41</td>
<td>46</td>
</tr>
</tbody>
</table>

HALFEN WASHERS

**General**

HALFEN washers are available in metric sizes to suit the range of Tee-head bolts. Washers are supplied to order.

Sizes, Finishes, and P/Ns

Electroplated and stainless steel finishes are readily available. Galvanized finishes are provided to order. For ordering, please use the base number given below. Add a 1, 2, 3, or 4 to the end of the base part number depending on the finish required as described in the Tee-head bolt section (Pg. T-13).

<table>
<thead>
<tr>
<th>For Bolt Size</th>
<th>Washer Base P/N</th>
<th>Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M6</td>
<td>HW061</td>
<td>D=7/8, d=1/4, T=5/64</td>
</tr>
<tr>
<td>M8</td>
<td>HW081</td>
<td></td>
</tr>
<tr>
<td>M10</td>
<td>HW101</td>
<td>1</td>
</tr>
<tr>
<td>M12</td>
<td>HW121</td>
<td>1 3/16</td>
</tr>
<tr>
<td>M16</td>
<td>HW161</td>
<td>2 11/16</td>
</tr>
<tr>
<td>M20</td>
<td>HW201</td>
<td>2</td>
</tr>
<tr>
<td>M24</td>
<td>HW241</td>
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<td>M27</td>
<td>HW271</td>
<td>2 3/4</td>
</tr>
<tr>
<td>M30</td>
<td>HW301</td>
<td>2 3/16</td>
</tr>
</tbody>
</table>

All sizes with Base P/N are available electroplated & S/S AISI 304 & 316