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Combination Glare Screen Pedestrian Fence for Center Barrier

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16. Abstract

Glare screens are used in the median of divided highways to shield drivers from the headlight of oncoming traffic. Headlight glare has been shown to be detrimental when the glare is within an angle of approximately 20 degrees. A comprehensive review of previous studies indicates that expanded metal mesh glare screen suffered the least criticism. However, it is evident that further effort is needed to simplify and improve existing designs. Improvements are needed with regard to simplifying mounting procedures and reducing maintenance cost. Furthermore, pedestrian deaths from highway crossings over barrier and glare screen installation have warranted the construction of pedestrian fencing on highways in urban areas. This report presents the design and construction of a new design that addresses these problems. The new design, which is called a Combination Glare Screen Pedestrian Fence (CGSPF) uses recycled plastics sheets and is easily installed. Due to inherent characteristics of plastics it is expected that maintenance cost will be significantly reduced compared to existing designs. Thus, the advantages of the new design are lightweight, low cost, and ease of attachment. Furthermore, the color and texture can be controlled for aesthetic and safety purposes (e.g., as median delineator) and the use of recycled material is environmentally responsive. The report also presents the results of a literature survey on the subject conducted as a part of this study.

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psf – pound(s) per square foot.
kPa – kilo-pascal
N – Newton(s)
mm – millimeter(s)
lb – pound(s)

SUMMARY

Glare screens are used in the median of divided highways to shield drivers from the headlights of oncoming traffic. Headlight glare has been shown to be detrimental when the glare is within an angle of approximately 20 degrees. A comprehensive review of previous studies indicates that expanded metal mesh glare screen suffered the least criticism. However, it is evident that further effort is needed to simplify and improve existing designs. Improvements are needed with regard to simplifying mounting procedures and reducing maintenance cost. Furthermore, pedestrian deaths from highway crossings over barrier and glare screen installation have warranted the construction of pedestrian fencing on highways in urban areas. This report presents the design and construction of a new design that addresses these problems. The new design, which is called a Combination Glare Screen Pedestrian Fence (CGSPF) uses recycled plastics sheets and is easily installed. Due to inherent characteristics of plastics it is expected that maintenance cost will be significantly reduced compared to existing designs. Thus, the advantages of the new design are lightweight, low cost, and ease of attachment. Furthermore, the color and texture can be controlled for aesthetic and safety purposes (e.g., as median delineator) and the use of recycled material is environmentally responsive. The report also presents the results of a literature survey on the subject conducted as a part of this study.

INTRODUCTION

Headlight glare is a long recognized driving hazard and the need to shield drivers' eyes from the headlights of oncoming traffic is well documented in the literature. Although no specific warrants for installation of glare screens have been established, there are many factors that can be considered in determination of the need for a glare screen. (1)* Among these factors are accident pattern (day-night ratio, age of drivers in night accidents, etc.) high night time traffic volume, comments from the public, measurement of veiling brightness (disability glare), and highway geometry.

There are two forms of headlight glare known as disability glare and discomfort glare. (1,2) Disability glare is defined as causing a decrease in visual acuity, while discomfort glare causes discomfort without necessarily impairing vision. Most drivers are familiar with situations where temporary blindness and/or extreme discomfort occur due to the sudden appearance of glare from oncoming vehicles. However, many drivers are probably not aware that glare from headlights can be disabling even when not discomforting. Studies and tests of driver vision have shown (1) that headlight glare is detrimental when the glare is within an angle of approximately 20 degrees to the driver's line of sight (roughly half the cone of vision). The amount of headlight glare affecting a driver is controlled by several vehicle and roadway factors. Among these factors are vehicle speed, road geometry (e.g., horizontal and/or vertical curvature), lateral separation of vehicles, and headlight height, aim, and intensity. Furthermore, high levels of background illumination will reduce or eliminate glare because the eye does not have to adapt to changes in brightness. In other words, the effect of glare is more serious when the intensity is varied sharply.

Planting, fencing, barriers, and glare screens are the common solutions to headlight glare. Another remedy would be to consider highway design (wide medians, uneven alignment, earth mounds). However, due to geometric requirements especially in urban areas where glare is more of a problem, the most widely used solution is the use of

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* References are found on pages 18-20.

glare screens. The following section includes a literature search on the design and evaluation of various glare screens. The general conclusion on the use of glare screens is that although they are very effective in eliminating glare, maintenance is a problem and further work is needed to develop higher performance glare screens.

In addition to the need for improvement in the design of glare screens, recent pedestrian deaths from highway crossings over barrier and glare screen installations have warranted the construction of pedestrian fencing in conjunction with the glare screen. In New Jersey this problem appears to be predominant in urban areas where businesses border the highway. Addressing this problem was one of the primary objectives of the New Jersey Department of Transportation's request for proposal, and the support of the work presented here. Other states also have similar problems with pedestrians crossing the freeway sometimes fatally. For example, the California Department of Transportation (CalTrans) has an exceptionally serious problem in the boarder region where illegal immigrants are crossing the freeways in order to elude the authorities[1].

Thus, a research and development effort was initiated to address these two problems. The main objective of the study was to design a new, dual-purpose screen system that can block headlight glare, while having adequate height to restrict pedestrian access. This report presents the results of that study.

In the following sections, the literature search conducted as a part of this study is described. Then the details of the proposed new design and the construction of actual prototypes are presented.

LITERATURE REVIEW

There are several options to address the glare problem. (1) These are:

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[1] Personal communication with CalTrans staff.

- Glare avoidance through highway design such as width of median, separate alignment, and earth mounds,
- Physical barrier or fencing such as guardrail, concrete barrier, plantings, and fencing, and
- Glare screens mounted on the center barrier such as expanded metal mesh, double reverse corrugated steel, knit polyester fabric, and paddles.

The first two options are often not possible for practical reasons (narrow median, harsh environment for planting, etc.). Among the several glare screens available, expanded metal mesh and plastic paddles have been most widely used. Reinforced concrete glare screens, which consist of extensions (about 10 inches high) to existing concrete barriers and belongs to the second category, have also gained popularity as an effective and low maintenance glare screen. Thus, the bulk of literature, although itself limited, is devoted to evaluation of these three types of glare screens. The review is organized chronologically by state.

California

In an experimental study performed by Rowhani, et al. [3, 4] two crash tests were performed on a retrofit concrete glare screen slipformed on top of an existing 32-inch high concrete median barrier. Both tests were successful and showed that a concrete glare screen can withstand the impact of both a pick up truck and a heavy passenger car and can satisfy the requirements of *NCHRP Report 230.* This study was done as part of an effort to use the concrete glare screen as a replacement for the current standard expanded metal mesh glare screen. Due to *excessive maintenance costs* and the potential of exposing maintenance personnel and the drivers to the hazard of traffic, a team of Caltrans experts made the recommendation for replacement. [4] It is expected that because of greater strength and durability, thus possibly lower maintenance cost, the concrete glare screen is superior to metal mesh. Furthermore, it may even result in some safety enhancement. Plans for this retrofit glare screen can be accessed on the Internet at http://www.dot.ca.gov/hq/esc/oe/project_plans/HTM/stdplns-met-new99.htm.

Caltrans now uses only concrete glare screen on median barrier[2]. The standard combination barrier glare screen is Type 60G, which consists of a single-slope barrier that is 60-inch (1420 mm) high, 24-inch (610 mm) wide at the base and 6-inch (150 mm) wide at the top. Plans for this barrier, which has been crash tested and meets NCHRP Report 350 Criteria [(1)], can also be accessed at the above site (pp 31 of standard plans).

Disadvantages of concrete glare screens include higher initial cost and lack of visibility at larger angles to the traffic flow. The latter is important for surveillance purposes by law enforcement agencies. Another important shortcoming of the concrete glare screen is that it can not be used where other kind of median barriers (such as guardrail) are used.

Safety of glare screens is the subject of another work by Caltrans. [(5)] It emphasizes the success of the crash tests discussed and the maintenance problems associated with metal mesh glare screen. Details of an expanded metal mesh screen system are given in a Caltrans specification. [(6)]

Caltrans has developed a temporary wood glare screen (T4) that is used in construction zones. It is not used in comparative analyses in this study because it is not employed as a permanent glare screen. Furthermore, it is not porous and current design allows for only 24-inch (600 mm) height. It can not serve the dual purpose of glare screen and pedestrian fence. Taller height will require thicker plywood panels and stronger anchorage system making comparative evaluation based on the existing data meaningless.

Iowa

The multiple benefits of glare screens (e.g., improve safety, reduce noise, etc.) are presented in a paper published in 1973. [(7)]

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[2] Personal communication with CalTrans staff.

Michigan

The study performed by Hoffman, Lampela, and Gunderman [8] considers 2-ft high glare screen on top of a 2-ft and 8¾-inch guardrail. The study, considered the median barrier rather than the glare screen, found that cross-median accidents were eliminated and that reduced glare led to fewer accidents.

The feasibility of slipform construction for concrete glare screen is reaffirmed in a study performed by Arnold and Chiunti. [9] It is reported that metal mesh glare screens are expensive, subject to damage by plow-thrown snow, wind-blast vibrations, and vehicle impact, however, concrete glare screen should have long life and low maintenance.

In another study where a 19-inch high glare screen is used on a concrete barrier the concrete option is recommended in lieu of the expanded metal mesh. [10] This recommendation is based upon slightly lower installation cost and “the anticipated lower maintenance costs.”

The study conducted on glarefoils [11] concludes that they are not suitable for the locations studied. Among problems reported are damage by vehicles climbing the barrier, fatigue due to wind load, and vibrations. Glarefoils were chosen due to lightweight, simple installation, and favorable experience in other states. However, replacement of glarefoils with concrete glare screens was recommended.

In yet another study [12] the use of a concrete glare screen over metal mesh screens is recommended. The study consisted of two phases. Phase I consisted of construction and destructive testing of a short section of a concrete glare screen in the contractor’s yard. The second phase involved in-field evaluation of glare screens used on various construction projects, consisting of both concrete and metal mesh. A part of the evaluation was performed over a period of one decade (from the summer of 1973 to the spring of 1983). It recommended the continued use of concrete glare screens, and that all reinforcement be epoxy coated. If it is necessary to use a metal glare screen, the expanded steel mesh is recommended over aluminum.

New Jersey

Several types of mesh with slightly varying heights were evaluated during an experimental use of expanded metal mesh. [13] The glare screen was installed on a concrete median barrier and the report provides “a description of the designs, methods of installation, observation and accident statistics.” It is reported that the glare screen was effective in reducing glare and that it “did not act as a snow fence or collect litter.” Among the recommendations of this study are that the height of the glare screen should be 18-inch when installed on the top of the Department’s standard 32-inch concrete barrier (for a total height of 50-inch) and warrants for placement of glare screens need to be developed.

New York

For an in depth review of available literature and a comprehensive bibliography on glare screens the reader is referred to the work published by Capelli. [2] This research report indicates that glare screens are effective in eliminating glare and that some median plantings have also been effective. Chain link mesh with wood slats is deemed satisfactory while aluminum meshes are reported to have serious shortcomings. The latter is consistent with the experience of Michigan Department of Highways and Transportation. Expanded metal meshes are reported to be the most satisfactory. Note that this study does not cover concrete glare screen.

Ohio

The City of Columbus conducted a study on the effect of expanded metal mesh glare screen on accident statistics. [14] The test site was a six-lane freeway with horizontal curvature that carried 80,000 to 100,000 vehicles per day. The study was conducted over a period of twenty-one months, and it did reveal a statistically significant reduction in night accidents (61.5 percent reduction). Other conclusions were that the mesh allowed through vision of opposing lanes, did not cause drifting of snow, and that the maintenance cost was reasonable.

Pennsylvania

An original work by Hofer [15] discusses the details of how glare screens need to be designed and their geometric requirements to be effective. The study used human subjects.

Other reports, such as (16), on evaluation of expanded metal mesh installations by the Pennsylvania Department of Transportation indicate experiences similar to the State of Michigan. Steel is reported to be a superior metal for an expanded metal mesh anti-glare screen. However, there are two problems with this design. It cannot be used along sharp curves, and it can be damaged by material and objects extending beyond the side of trucks.

Due to maintenance difficulties, Pennsylvania Department of Transportation discontinued the use of its standard glare metal screen [17] in 1976. A system consisting of plastic airfoil-shaped paddles, which when mounted resembles a picket fence, was installed on a bridge reconstruction project and was monitored for five years. [17] The system is reported to be more effective than a metal mesh screen and have satisfactory performance with less than 5 percent replacement over a five-year period without maintenance. This is contrary to both the experience of the State of Michigan as discussed previously and the mixed conclusion reached by the State of Vermont as follows.

Vermont

The performance of SYRO Glarefoil glare screen system was also evaluated by the research and development division of the State of Vermont Agency of Transportation.[18] The glare screen system was installed on the top of a steel beam guardrail. The primary intention of the study was to evaluate the durability of the system in a severe winter environment. It is reported that the installation was time consuming and tedious. Although less costly to maintain than metal mesh glare screens the maintenance was time consuming. Snow plowing procedures were changed to improve durability of the SYRO Glarefoil.

Virginia

This work discusses the use of glare screens as part of the means used to delineate the median on a divided highway.[19] Three types of glare screens are considered: plantings, guardrails, and wire mesh. The author claims that "the most effective glare screen has been found to be a line of expanded metal mesh placed on the median, parallel to the Centerline."

Others

The advantage of concrete extensions of the median barrier for glare prevention over expanded metal mesh, particularly from maintenance considerations, is also highlighted in a report by FHWA.[20] It is reported that "based on observations of crash tests it would appear desirable to offset the concrete glare screen from the barrier top to inhibit vehicle tendency to climb the barrier." Of course, the synthesis by NCHRP [1] is of great value and usefulness to those seeking information on the use of glare screens.

Modular guidance system developed by Carsonite International (http://www.carsonite.com/) and Safe-Hit glare screen system by Safe-Hit Corporation (http://www.safe-hit.com/) are paddle type systems that use composite or high impact polymer. Based on review of manufacturer literature, the systems appear to be versatile and easy to install and maintain. However, there has been no study on their installation and long term performance. Furthermore, paddle type systems allow for easy access to highway, thus, they cannot be used as combination glare screen pedestrian fence.

The Temporary Highway Visual Barrier Fence by Advanced Barrier Technologies, Inc. (http://www.advancedbarriertech.com/) is designed for easy installation and removal. Compared to their wooden counter part they are claimed to have both better performance and lower life cycle cost. Since the system uses recyclable high-density polyethylene plastic. With regard to the objectives of this study, similar to the plywood option, this is a nonporous temporary glare screen, thus, not suitable for comparative evaluation to the proposed design.

Summary of Prior Experiences

Some salient points from the above discussions include: 1) The use of glare screens is the most practical option among various means to avoid glare of oncoming cars, 2) expanded metal mesh is more common of the several glare screen designs available though it is reported that maintenance is a problem. The concrete glare screen appears to be more suitable from maintenance point of view. Its shortcomings are that it is opaque and can not be installed on medians other than the standard concrete median, and 3) the mounting procedures must be simple to reduce both risk to the personnel and drivers. Furthermore, a modular system of erection is more desirable in order to limit damage when screens are struck and also to facilitate construction and maintenance.

PROPOSED DESIGN

The main objective of this study was to develop a new dual-purpose screen system that can block headlight glare while having adequate height to restrict pedestrian access. Wind load is not a major factor in the design of current glare screens because they are not high (about 10-inch to 18-inch) above the median barrier. Pedestrian fencing is much taller (typically about 48-inch), but, it too does not sustain much wind load because of the coarse meshing. However, the new design which is to serve both functions must have adequate strength and stiffness to sustain high wind loads since it can not be as porous as normal fences and it will be taller than current glare screens. Furthermore, the new design must be modular and easy to install and maintain and address other problems associated with existing designs as discussed in the previous section. The design considerations can be summarized as follow:

- Elimination of oncoming headlight glare,
- Deterrent to pedestrian cross over,
- Simple mounting procedures for attachment to both concrete median barrier and steel guardrail system,

- Resistance to damage from passing vehicles, vandalism, and environmental loads,

- Modular design for ease in construction and maintenance, and

- Economically competitive with or even superior to, current designs in terms of both initial and life cycle costs.

Of course, other factors such as esthetic and use of recycled materials for environmental reasons were also among important design considerations. Using these criteria, an innovative design called Combination Glare Screen and Pedestrian Fence (CGSPF) was developed. The design specifications and the construction of two prototypes are described in the following sections.

Specifications and Standard Details of CGSPF

The new design consists of a pair of sheet/plate where the top edges are joined together while the bottom edges of each side are spaced apart, i.e. forming an inverted V.[21] Both sides contain a plurality of spaced apart holes or slots. These apertures are sized and spaced so that the sides will shield lights of oncoming traffic, however, they permit one to see the opposite lane(s) when looking at an angle normal to the direction of traffic. Figure 1 (page 22) shows both types of openings, however, they can actually be of any shape.

Each module can be of any desired length and height. For example, the height would be higher if it is also used as pedestrian fence.

Two types of mounting are developed, and along with the connection details are shown in Figure 2 (page 23). These are called top mount and side mount connection. For the latter a clamp-type attachment is made by directly connecting each side of the CGSPF to the concrete barrier. For the top mount option, first a recycled plastic (or wood) plate is attached on the top of the concrete barrier to which the CGSPF can be attached (Figure 2). Note that for the side mount alternative the panel spacers (two per each module) are provided to facilitate installation. When top mount option is used the module temporarily rests on the concrete barrier until screws are inserted. Therefore, both types of connections can easily be made using only one person. An advantage of the top-mount option is that it can be flush with the concrete median barrier or even recessed.

To connect the CGSPF to a steel guardrail an anchor plate, similar to top mount option for concrete median barrier, is first attached between support posts as shown in Figure 3 (page 24). For ease of assembly anchor brackets can be attached to the anchor plate with slotted holes to allow for construction tolerances of post spacing. Since the spacing of posts is less than the length of each CGSPF module it can rest temporarily on two or more posts before screws are inserted.

Modules can be joined by either in-field heat weld at the top or with an interlocking key as shown in Figure 4 (page 25). As shown in the same figure, end treatments can be made for esthetic purposes. Various dimensions of the design are described in Table 1 (page 21) and suggested values are given.

The panels are preferably made of recycled thermoplastics such as PET (Polyethylene) or HDPE (High Density Polyethylene). These are readily available and resistant to weathering. A glare screen eight feet long made of recycled plastic with about 40% voids is quite light weighing less than 50 pounds. Thus, a single person can easily handle the panel. For additional information on the mechanical properties of recycled plastic used in development of CGSPF prototypes and its application in the design of a sound barrier the reader is referred to (21, 22).

Construction of Prototypes

To demonstrate the feasibility of constructing the proposed CGSPF, two full-scale models were constructed at NJIT during the summer of 1998. Both models were constructed using ½-inch thick recycled high-density polyethylene plastic sheets. Other design details are provided below. In addition to two prototypes of CGSPF, a modified concrete glare screen was also constructed for evaluation and comparative purposes.

One of the CGSPF has 2.75-inch diameter holes spaced at 3.375-inch center to center. As shown in Figure 5 (page 26), the side mount connection was used for this system. No preparation of the concrete barrier is required before placing the CGSPF on the barrier. Two people place the CGSPF module on top of the concrete median barrier although the lightweight (42 lbs. for the 8-ft long panel shown with circular voids) makes it possible for one person to handle. After the panel is placed on the concrete barrier, it can be attached with either screws or powder-actuated fasteners through the side of the panel into the concrete. To compare these methods of attachment, 0.145-inch diameter powder-actuated fasteners (X-NI by HILTI) were used on one side and ¼-inch diameter screw-type fasteners on the other side. Both fasteners were embedded 1-inch into the concrete. For both designs ½-inch thick recycled plastic sheets fastened together with ordinary wood screws were used.

A spacing of 32-inch for power-actuated fasteners will give a factor of safety of 4 for New Jersey design wind load although a smaller spacing was used for the prototype, mainly to further experiment with the ease of construction and consistency. Note that the 32-inch spacing is based on design wind load assuming the panels are not porous, which is a conservative assumption. Actual demand on the system, which also includes truck gust, is complex and difficult to quantify. To better assess the performance, an in-field installation should be made. Until the results of such study becomes available use of smaller spacing is recommended.

For screw fasteners, a factor of safety of 4 will require 36-inch spacing. Screw installation is a two-step procedure of pre-drilling a hole and driving the screw into the hole using the drill with screw bits. This fastener has the advantage of being easily removed. Based on this preliminary trial, the screw-type fastener appears to be the preferred choice. Thus, the installation procedure for the side-mount can be summarized as: i) place panel on barrier, and ii) attach the panel to the concrete barrier.

The second CGSPF was made of recycled plastic sheets with 2-inch wide vertical slots every 4-inch, and the top mount connection procedure was employed. This mounting, seen in Figure 6 (page 27), requires a separate anchor plate to be first attached to the concrete barrier, which both locates and provides a point of attachment for the CGSPF. The anchor plate, which is similar to the panels is made of recycled plastic, is attached to the concrete barrier with 3/16-inch diameter screw fasteners. Fasteners are spaced 6-inch apart and are embedded 1-inch into the pre-drilled holes in the barrier. Then, the CGSPF is placed on the top of the barrier and attached to the anchor plate with ¼-inch screws spaced 36-inch apart. Thus, the installation can be summarized as follows: i) attach anchor plate to the top of the median barrier (could be concrete barrier or steel guardrail), ii) place glare screen panel on top of the barrier over the anchor plate, and iii) attach glare screen to the anchor plate.

An objective of this study was to seek improvement to an existing design. As it was mentioned before, one criticism of concrete glare screen is that it is opaque. Thus, it was decided to modify and build a concrete glare screen with vertical slots as shown in Figure 7 (page 28). The slots are 2-inch wide and spaced 6-inch center to center. The glare screen could not be made any more porous due to the cover requirement for the vertical reinforcement between the vertical slots. This option is much heavier and required equipment to move and place it. The 5-ft long concrete glare screen is attached to the concrete barrier by drilling two holes into the barrier to accept the two reinforcing bars protruding from the bottom of the glare screen. Grout is placed in the holes and along the top of the barrier to secure it in place.

It became quite clear right after installation that the modified concrete glare screen is not a viable option. Because, its construction is time consuming and labor intensive and at the end it does not provide the degree of transparency desired. However, both types of the new combination glare screen pedestrian fence proved to be very easy to install and satisfy the design criteria and functional performance set forth.

Cost

Although cost was an important consideration in the development of the new designs, it was not within the scope of this study to perform a detailed cost analysis. Based on material cost it is anticipated that the proposed CGSPF will be competitive or even superior to current options such as concrete glare screen or expanded metal mesh.

For example, based on quotes from a vendor used by NJDOT, the manufacturing cost of 2-ft high solid concrete glare screen will cost $10.75 per lineal foot. It will be $12 for slotted concrete glare screen.

For the paddle type systems the material cost for 24-inch high glare screen is $9 to $10.5 per lineal feet, depending on anchoring hardware (zinc plated or stainless steel).

The recycled material cost for the prototype panels made under this study, which were also 2-ft high, was $5.5 per lineal foot. Note that this cost is based on *retail price* for the recycled plastic sheets, and they were solid sheets that had to be perforated. That is, essentially half of the material was discarded. So, under a production environment the actual material cost will be much lower.

Furthermore, due to the lightweight and the simplicity of mounting techniques, the transportation and labor costs for the CGSPF will be much lower than the concrete option.

It was difficult to make an updated cost comparison to metal glare screen. However, based on the available information in the literature (cost of $10 to $12 per lineal foot for projects in the 70s and the 80s) the initial cost of the new design will be competitive. It is expected that the life-cycle cost will be significantly lower since maintenance is reported to be a major problem with metal screens.

TESTS OF ATTACHMENTS

Of the two types of attachment proposed, the top-mount option is the weakest because of the smaller moment arm to resist the wind load. For the side-mount connection the moment arm is equal to (or more exactly slightly larger than) the top width of the concrete barrier. However, for the top-mount attachment the moment arm is half of the top width of the concrete barrier because the fasteners connecting the anchor plate to the top of the concrete barrier are located in the middle. Inspection of the prototype clearly indicated that indeed the side-mount connection is much stiffer. However, it was decided to test both types of connections to observe the actual performance of each attachment.

A 2-ft X 3-ft (610-mm X 914-mm) specimen was used for both tests, which were conducted in the Structures Lab at the Department of Civil and Environmental Engineering at NJIT. Shown in Figure 8 (page 29) is the top-mount specimen. Note that for the test specimen the fasteners connecting the top anchor plate were spaced apart 12-inch (305-mm) rather than 6-inch (152-mm) as recommended for actual design. This was done to see if the attachment could be tested to failure within the range of actuator's displacement limit. As it can be seen from Figure 8, the applied load was uniformly distributed along the top edge. Furthermore, the loading was monotonic and was applied at the rate of 0.4-inch (10-mm) per minute.

For New Jersey 33 psf (1.58 kPa) is a good estimate of wind pressure for most locations. As shown before, the actual CGSPF is not solid, however, if we assume a solid surface the total wind load will be 198 lb (881 N). The maximum moment caused by this uniformly distributed load over 24-inch (610-mm) high screen will be 2,376 inch-lb (294 N-m). Test results indicate that the attachment is quite adequate (even with 12-inch or 305-mm fasteners spacing) in resisting any practical level of wind load or truck gust. As seen from the load-deformation curve shown in Figure 9 a load of 420 lb (1868.8 N) was attained for the top mount case. This load corresponds to a moment of 8,610 inch-lb (973 N-m). This level of load was achieved without any failure or noticeable damage to attachment components. The test ended when the actuator reached its absolute limit of 5 inch (127-mm).

For the side-mount case, as expected, the capacity was significantly higher. The load attained at the displacement limit of the actuator was 1,700 lb (7564 N). From these tests and analysis of the connection assembly it can be concluded that both of the proposed attachment procedures are adequate for any practical demand. Note that determination of actual demand is difficult to quantify because of complex nature of truck gust. However, due to vibratory and cyclic nature of the demand and response a high margin of safety is recommended in order to reduce the adverse effect of fatigue. Therefore, dimensions as discussed before should be used in actual designs (see Appendix I, page 31, for standard drawings).

CONCLUSIONS

A new glare screen that can also be made high enough to serve as deterrent to pedestrian cross over has been successfully developed. Among the benefits of this combination glare screen pedestrian fence (CGSPF) are: lightweight, ease of attachment, ease of maintenance, lower initial and life-cycle costs, aesthetically pleasing, and environmentally advantageous by using recycled materials. Furthermore, another major advantage of CGSPF, which is associated with its use of extruded recycled plastic, is that the color and texture of the finished surface can be controlled. This is very important not only from aesthetic point of view but also for the fact that it allows the *use of CGSPF as delineator of the median both in highways and in work zones.* It is reported that state highway agencies have recognized deficiencies in the Manual on Uniform Traffic Control Devices (MUTCD) with regard to selecting and applying delineators on portable concrete safety-shaped barrier. [(23)] Some states are making “trial-and-error” efforts to improve practices of reducing the risk of work zone accidents. CGSPF of appropriate color (such as orange) and height can be used in work zones to reduce the risk of accidents and to improve traffic flow by eliminating driver distraction by shielding the work area.

The proposed CGSPF appears to be promising and a major advancement towards reducing risks associated with glare, pedestrian cross over, and work zone accidents. However, before its widespread application it is important to further demonstrate its constructability and structural performance under various traffic conditions through in situ projects.

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Table 1. Dimensions of proposed glare screen pedestrian fence*

Variable	Description	Dimension	Notes
L	Panel length	10-ft	All panels
H	Total panel height	24-inch – 48-inch	
w	Width of slots	2-inch	For vertical slotted panels
S_v	Spacing of slots	4-inch	
d	Diameter of holes	2-inch	For circular hole panels
S_h	Spacing of holes	2 ½-inch	
S_b	Anchor plate screw spacing	6-inch	For top mount
S_s	Side mount screw spacing	16-inch	
h	Overlap height	4-inch	For side mount
L_w	Length of weld	4-inch – 8-inch	For heat weld
L_k	Length of key projection		For interlocking key
H_k	Height of key	4-inch	

* Dimensions shown are suggested values and are probably conservative for lower total panel heights (H). Proposed design is flexible and actual values can vary depending on application.

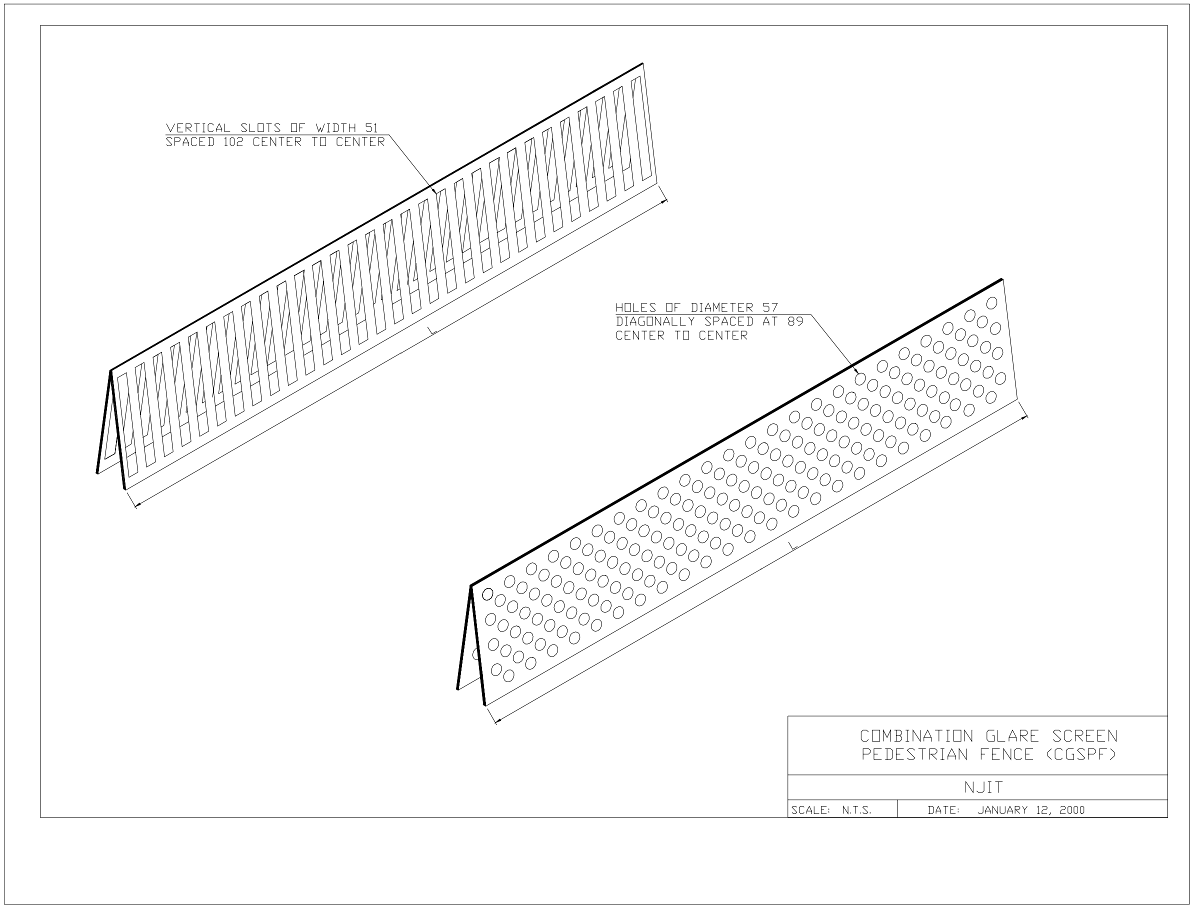


Figure 1. Perspective view and dimensions of CGSPF with circular and vertical slots.

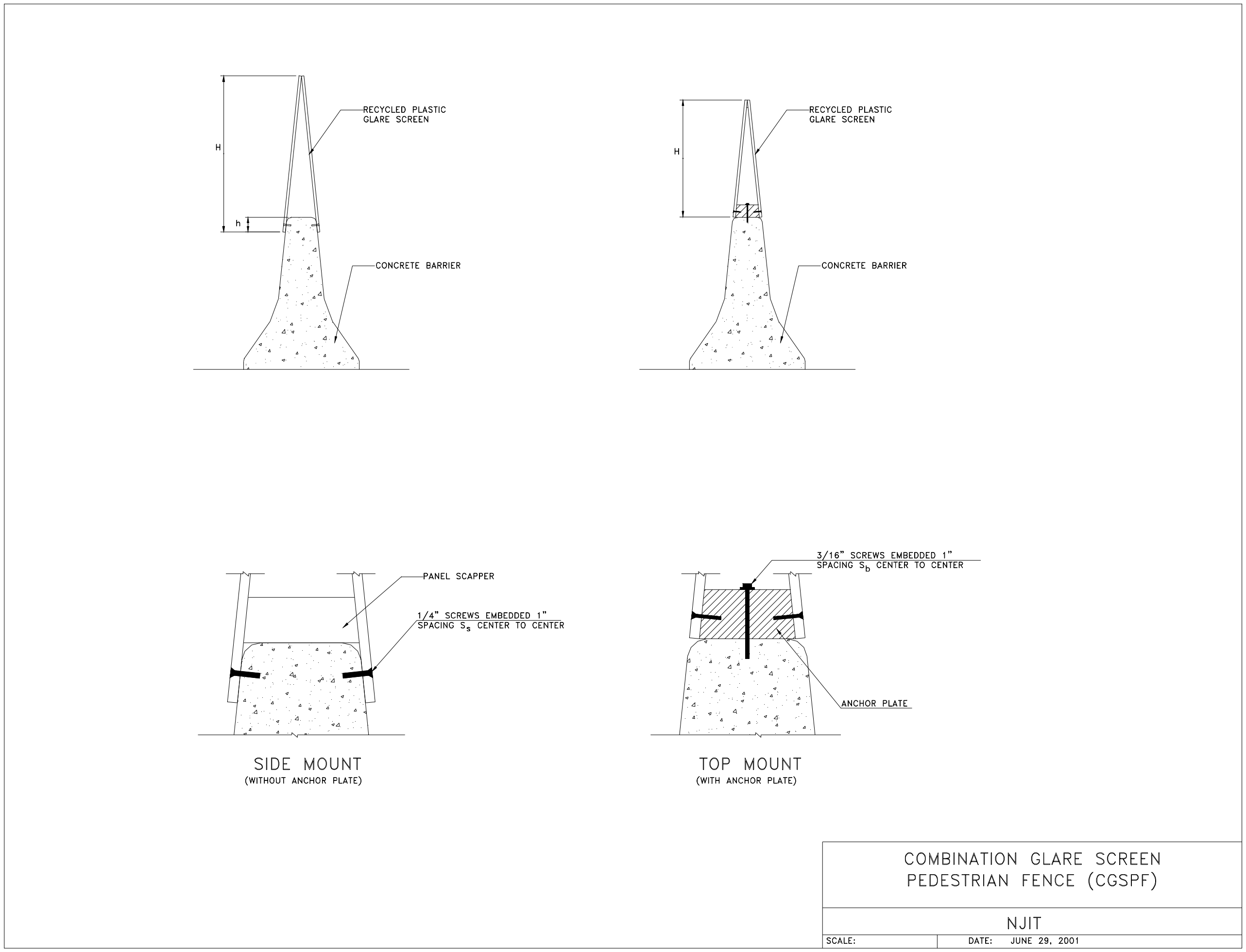


Figure 2. Cross-section, dimensions and details of the two mounting techniques.

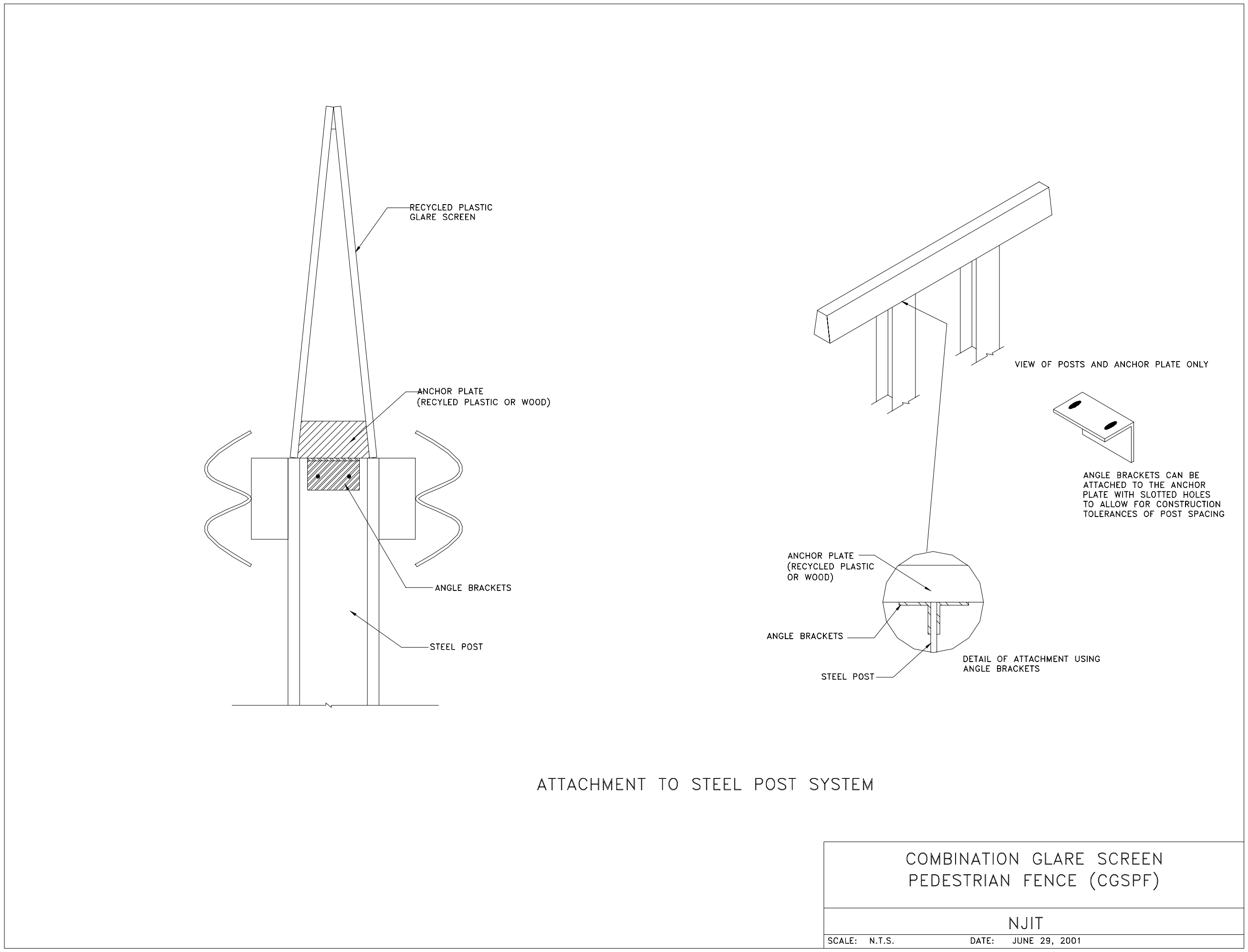


Figure 3. Details of attachment to steel guardrail system.

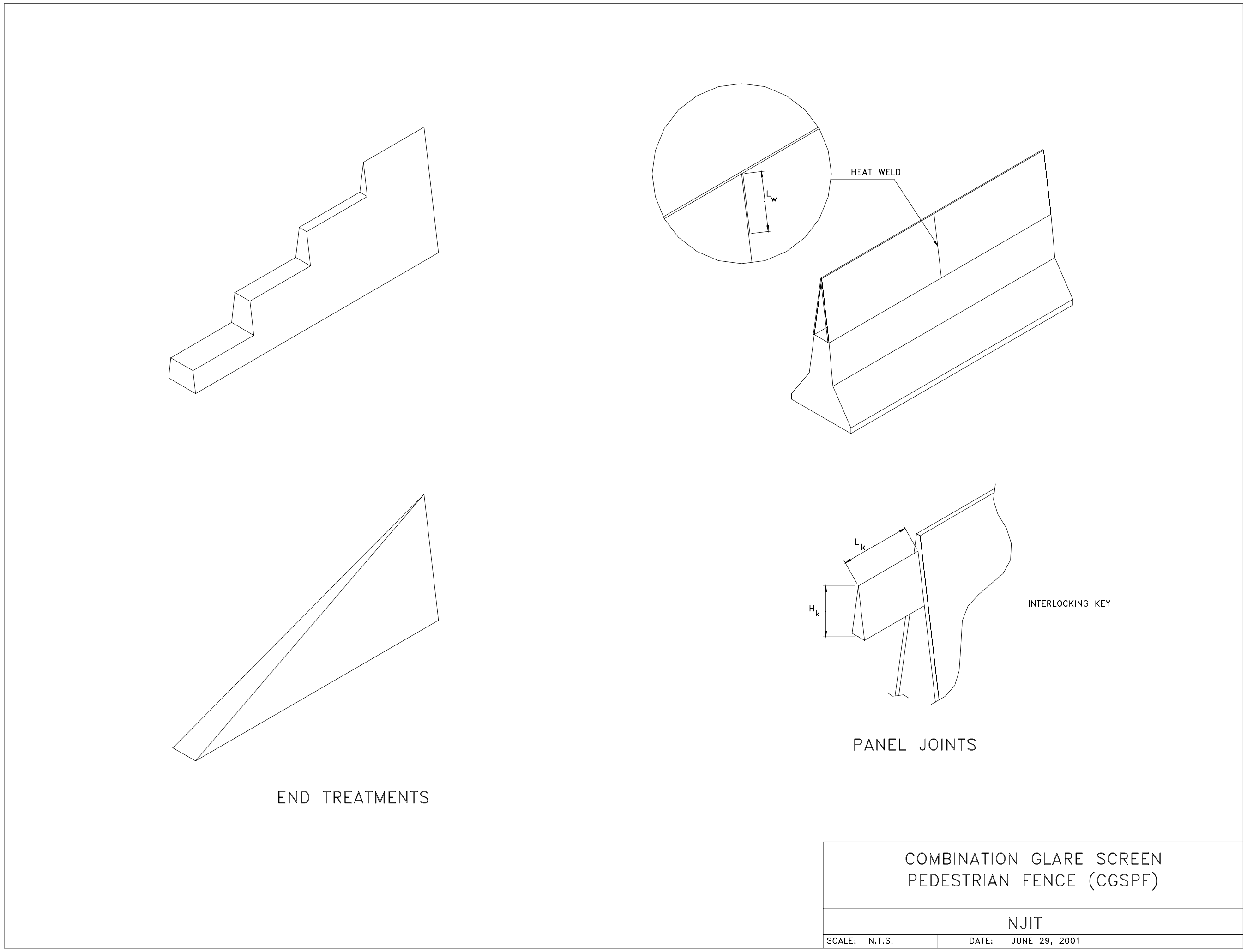


Figure 4. Details of joining two CGSPF modules and end treatment.

Figure 5. Prototype of side-mount CGSPF using recycled plastics

(Opening can be any shape or circular as shown; H = 24-inch, %void = 41%, Weigh = 5.3 lb/ft)

Figure 6. Prototype of top-mount CGSPF using recycled plastics

(Opening can be any shape or slotted as shown; H = 24-inch, %void = 41%, Weigh = 5.3 lb/ft)

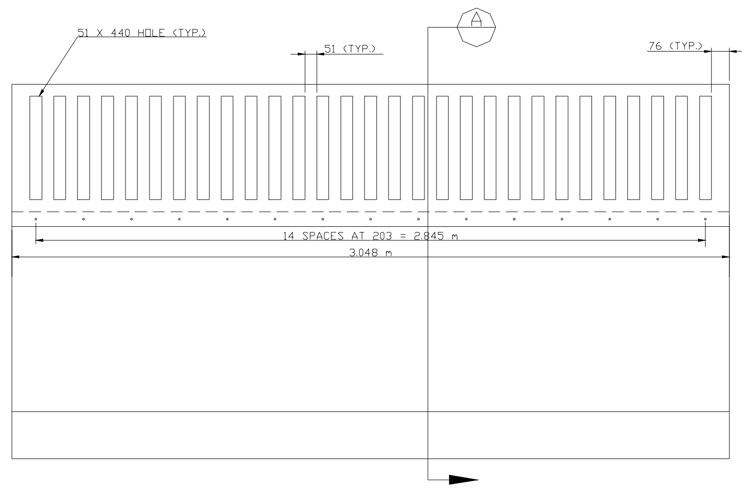
Figure 7. Modified concrete glare (H = 24-inch, %void = 26%, Weigh = 100 lb/ft).

Figure 8. Test specimen setup and performance during loading.

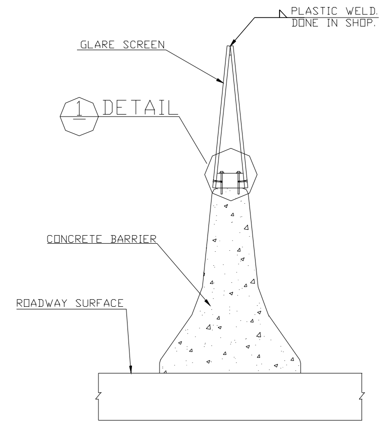
Figure 9. Load-deformation curve for top-mount connection.

APPENDIX I

Standard Drawings



ELEVATION



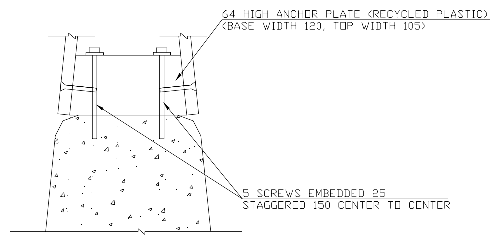
VIEW A
SECTION VIEW

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.
2. EACH MODULE WEIGHS ABOUT 23 KG.
3. ANCHOR PLATE IS ATTACHED TO CONCRETE BARRIER USING 6 X 102 SCREWS. SCREWS ARE INSTALLED USING HAMMER DRILL (HILTI TE-5) TO DRILL HOLES AND SET SCREWS (KWIK-CON II SYSTEM).
4. COMBINATION GLARE SCREEEN PEDESTRIAN FENCE (CGSPF) IS ATTACHED TO ANCHOR PLATE WITH 6 X 45 SCREWS.

CONSTRUCTION SEQUENCE:

1. ATTACH ANCHOR PLATE TO CONCRETE BARRIER. REFER TO NOTE 3.
2. PLACE CGSPF MODULE ON CONCRETE BARRIER
3. ATTACH CGSPF TO ANCHOR PLATE. REFER TO NOTE 4.

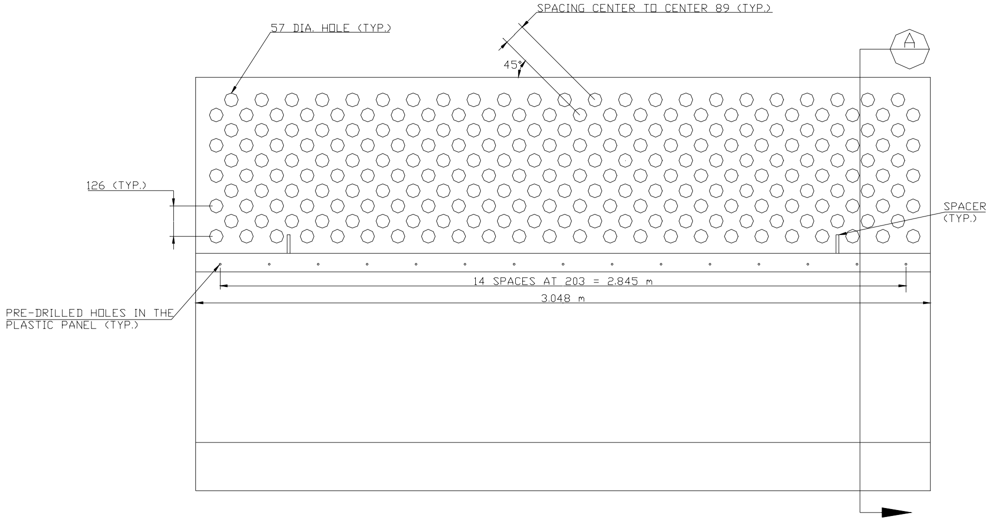


DETAIL 1

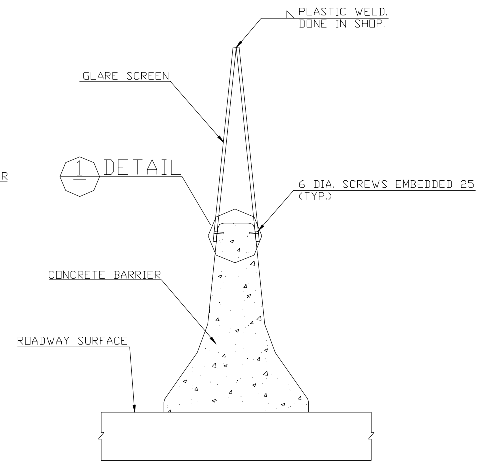
COMBINATION GLARE SCREEN
PEDESTRIAN FENCE (CGSPF)
TOP MOUNT

NJIT

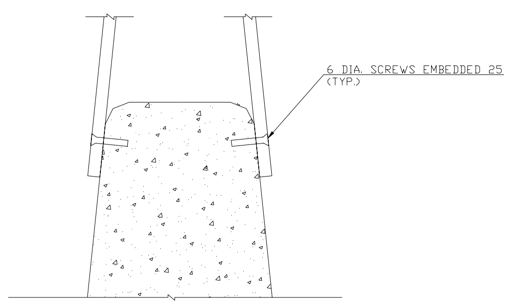
SCALE: N.T.S. DATE: SEPTEMBER 9, 1999



ELEVATION



VIEW A
GLARE SCREEN SECTION



DETAIL 1

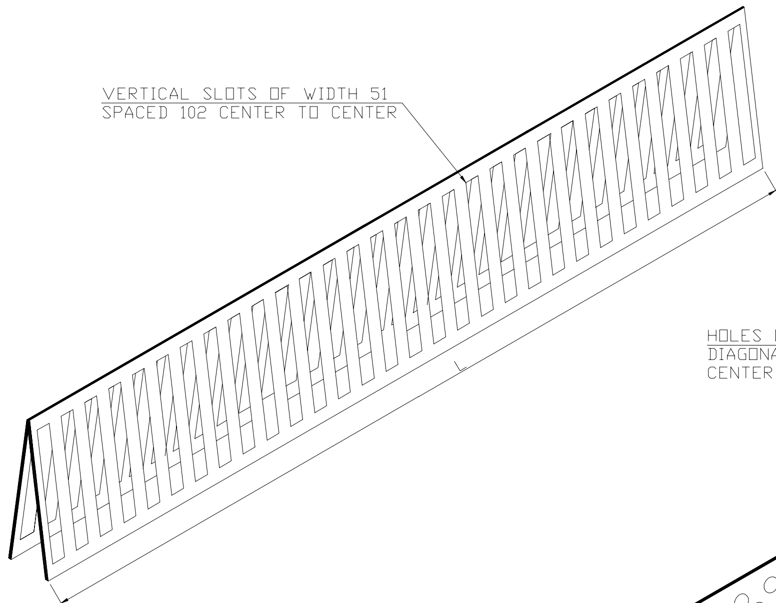
NOTES:

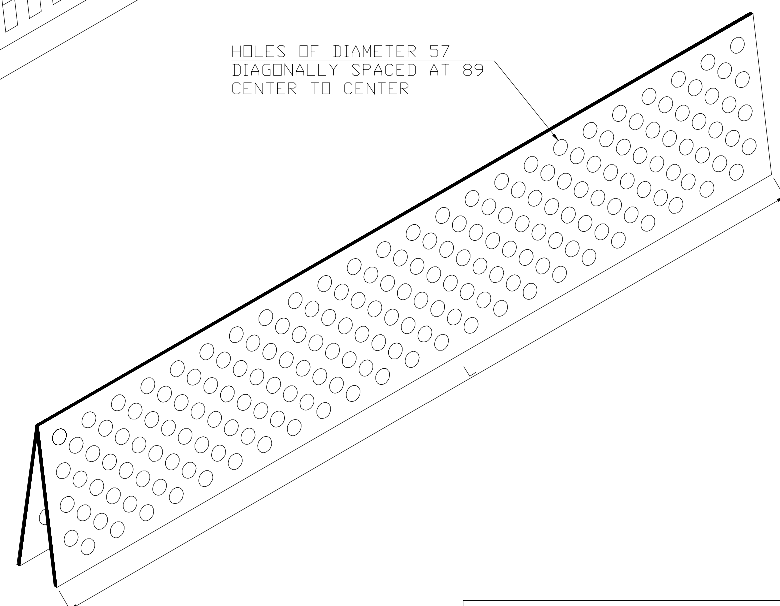
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE NOTED.
2. EACH MODULE WEIGHS ABOUT 23 KG.
3. COMBINATION GLARE SCREEN PEDESTRIAN FENCE (CGSPF) IS ATTACHED WITH 6 X 45 SCREWS. SCREWS ARE INSTALLED USING HAMMER DRILL (HILTI TE-5) TO DRILL HOLES AND SET SCREWS (KWIK-CON II SYSTEM).

CONSTRUCTION SEQUENCE:

1. PLACE MODULAR PANEL ON CONCRETE BARRIER
2. INSTALL SCREWS. REFER TO NOTE 3.

COMBINATION GLARE SCREEN PEDESTRIAN FENCE (CGSPF) SIDE MOUNT	
NJIT	
SCALE: N.T.S.	DATE: SEPTEMBER 9, 1999





COMBINATION GLARE SCREEN PEDESTRIAN FENCE (CGSPF)	
NJIT	
SCALE: N.T.S.	DATE: JANUARY 12, 2000