

Optimization of Glare Block Spacing

Swapan Kumar Bagui¹⁾ and Ambarish Ghosh²⁾

¹⁾ Dept. of Civil Engrg., Bengal Engrg. and Science University, Shibpur, Howrah – 711 103, INDIA. E-Mail: swapanbagui@gmail.com

²⁾ Professor, Dept. of Civil Engrg., Bengal Engrg. and Science University, Shibpur, Howrah – 711 103, INDIA. E-Mail: ambarish@civil.becs.ac.in

ABSTRACT

Glare screen barrier is an important element in highway safety engineering. Height and spacing of glare screen barrier block are important parameters in highway design, since vehicles of different driver eye heights with different head light heights are plying on highways. Selection of spacing of glare block is a complex problem. A model has been proposed to determine optimum spacing of glare block for horizontal alignment. Glare block can be placed perpendicular to the road or inclined by a certain angle to obtain optimum cost. It is found that spacing is optimal when the sum of inclination angle(x) and degree of curvature (θ) is 70° ; i.e., $x + \theta = 70^\circ$.

KEYWORDS: Glare screen spacing, Model analysis, Optimization, Cost optimization.

INTRODUCTION

Average speeds of vehicles have increased in the order of 80 to 100 kmph or more in the recently completed 5600 km four/ six lane roads in India (NHAI, 2008). With the increase of speed, accidents on the roads have also increased. Several accident black spot studies (MOST, 1997) as well as major and minor junction improvement projects were carried out in India with the financial assistance of the World Bank (WB), the Asian Development Bank (ADB) and the Ministry of Surface Transport and the Government of India (GOI). Various improvement measures have been also recommended in the form of: geometric design of sharp curves, junctions, partial realignment of the existing road, as well as provision of traffic signs, traffic signals and road markings; but unfortunately very limited improvements have been reported for providing glare screen barriers to improve the night speed and reduce the number of accidents caused by

glare.

Glare causes approximately 50% of the night accidents and 25% of the total accidents (NCHRP 66, 1979). The provision of glare screen barriers is justified to reduce glare and ensure a comfortable night journey. This is also helpful for safe driving at night, since the driver can drive safely at night with high speed. Night speed reduces too much for the cases of single, intermediate and two-lane as well as multi-lane undivided carriageways, because of glare caused by the head lights of opposite coming vehicles.

Types of Glare Screens

Generally, the following three types of glare screens are used in practice.

Type I: This type of glare screen is continuous, so that it is essentially opaque to light from all angles.

Type II: This type is a continuous screen of an open material that is opaque to light at angles from 0° to about 20° and increasingly transparent to light at angles beyond 20° .

Type III: This type is composed of an individual element positioned to block light at angles from 0° to about 20°; visibility is clear among the glare blocks.

Fig. 1 illustrates the plan and elevations of the above-mentioned three types of glare screen barriers.

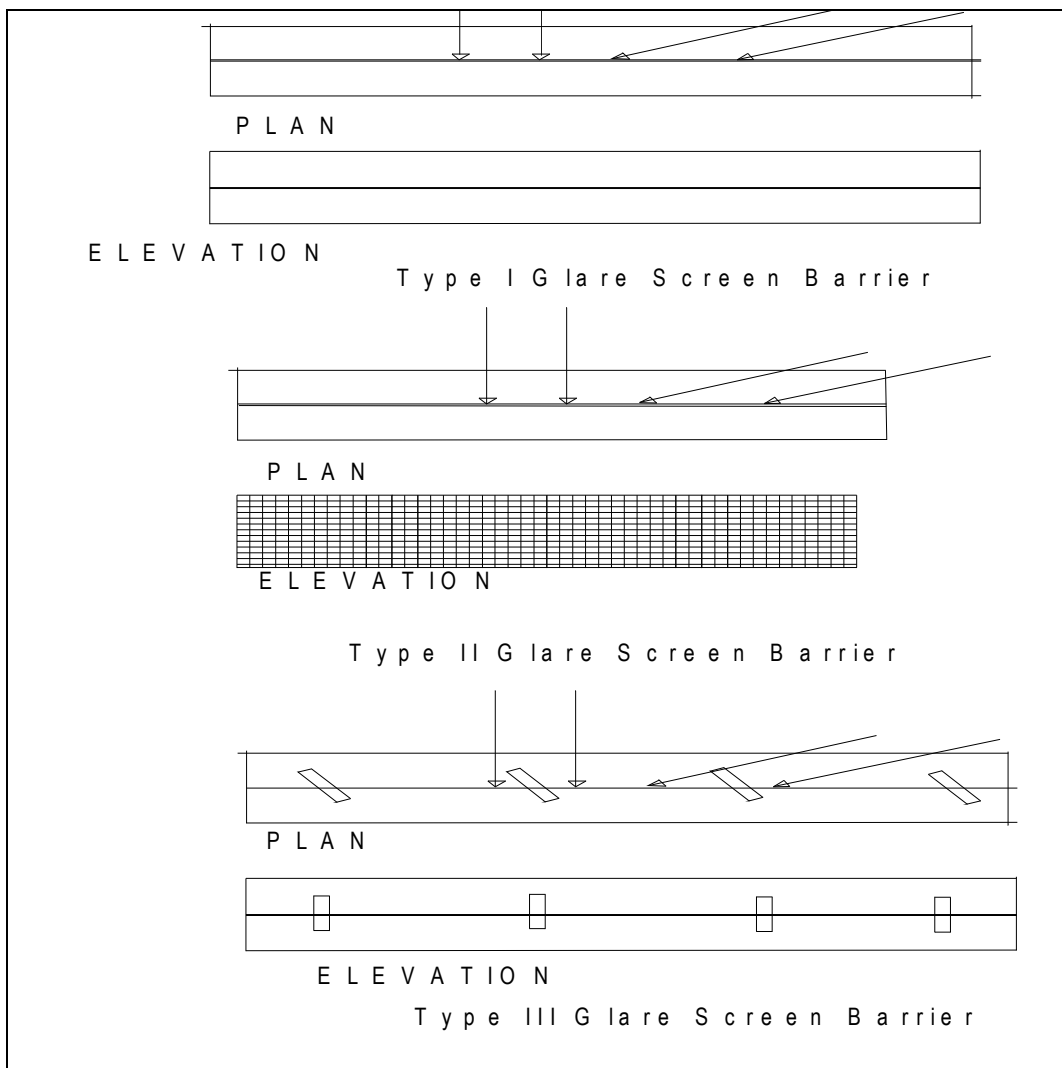


Figure 1: Plan and elevations of glare screen types I, II and III

Causes of Headlight Glare

Illuminance from the glare source is determined by the photometric intensity distribution of the oncoming headlamps, the aiming and height of these lamps, whether high beam or low beam is used, as well as the distance of the glare source from the observer. The greater the intensity directed toward an observer, the

greater the illuminance reaching the observer’s eyes (more than 6 lux).

Intensity of head light varies from 60,000 to 150,000 candle power (NCHRP 66, 1979).

From field investigations (Copenhaver and Zones, 1992), it is found that illumination resulting from two light sources of different intensity levels is a function

of the distance from the sources. This study found that illuminance is maximized when the distance between the two vehicles is 30 meters.

Accident History

Driving at night is more hazardous and more difficult than driving in the daytime. This is demonstrated by higher accident rates. It is generally very difficult for older drivers to travel at night. Headlight glare reduces the visibility of vehicles or other objects on the roadway and causes driver fatigue. Glare logically appears to be a causative factor in accidents and is recognized as a discomfort to all who ride the highway.

Reduction of accidents after the installation of glare screen barriers has been reported in several studies. An accident percentage of 35.3% reported before the installation of antiglare screen barriers has been reduced to 21.6% after the installation of glare screen barriers on US -22 in New Jersey. Percentage of accidents due to traffic flow, horizontal and vertical alignment, side friction, weather conditions... etc. before and after installation of barriers was 88.4% before installing and 64.7% after installing the glare screen. In order to reduce glare from opposing traffic, an antidazzle screen was installed on the M 6 Motorway on the Midlands Link. After 19-km screen was installed, accident rates were categorized as non-injury or injury accidents and accidents were reduced after installing the glare screen barrier (Walker, 1980). Night accidents reduced from 4.12×10^7 Veh-km to 3.17×10^7 Veh-km.

LITERATURE REVIEW

This section presents a review of the published literature.

The highway offers an opportunity for planting under a wide variety of conditions. Right of way may vary from an extremely wide to a too narrow one. Plantation can be of considerable value in certain areas based on road alignment, ground forms, existing

vegetation and width of median separation. Planting should form a continuous screen and avoid intermittent glare (AASHTO, 1970).

The purpose of an antidazzle fence or screen is to cut off light from oncoming vehicle head lights. A screen may be made of an expanded metal mesh, knitted polyester matrix supported on posts and lock bars (TA 57/87).

Buffer planting shall occur along all freeways and major arterials in order to visually screen uses and provide noise reduction. This landscaping shall be in addition to screening requirements.

The essential purpose of planting on a median is to cut off headlight glare from traffic in the opposite direction. Flowering plants and shrubs are eminently suited for this purpose. These could be planted in a variety of ways, but a very effective method is to plant them in the form of baffles. Apart from relating the road to the landscape, baffles have the advantage of offering breaks in planting which is very desirable to ensure a penetration of view for drivers. However, if the median width is less than about 3 meters, baffle plantation will not be possible, and a continuous line of shrubs should be thought of [Indian Roads Congress, Special Publication (IRC: SP 21, 2009)].

Plantings can be very effective in screening headlight glare from oncoming vehicles. Blinding vision due to headlight glare can be a cause of accidents. In addition to curved median areas, headlight glare can also be a problem between interchange loops, service roads and parking areas. Shrub planting may help prevent head-on collisions in these conditions (Louisiana Department of Transportation and Development, 2000).

Design and construction of an innovative dual-purpose screen can block headlight glare while having an adequate height to determine pedestrian crossover. Antiglare screen barriers are used to shield drivers' eyes from the headlights of opposing traffic, which has shown to be detrimental when the glare is within an angle of 20° . Expanded metal mesh antiglare screen barriers require improvements in the design to simplify

the construction and to reduce maintenance costs. On the other hand, pedestrian deaths from highway crossings over barriers and antiglare screen barriers have warranted the construction of pedestrian fencing on highways in urban areas. The proposed system, called Combination Antiglare Screen Pedestrian Fence (CASPF), has the strength and stiffness to satisfy the structural and geometric requirements of a dual system, and its design is such that it is very easy to install and maintain (Saadeghvaziri et al., 2000).

Zwahlen and Oner (2006) determined the antiglare screen barrier height based on the lateral position of the vehicles and determined the height of the antiglare screen barrier based on the 95th percentile eye height of the different vehicles plying on roads for the optimization of antiglare screen barrier costs.

Glare increases on roadways that bear to the left, because the opposing head light is directed into the drivers' eyes in proportion to the degree of curvature. Thus, the antiglare screen barrier may be needed on the horizontal curve, if type III antiglare screen barrier is installed on the curves, and the spacing and width of the glare blocking unit must be adjusted proportional to the sharpness of the curvature and the cutoff angle which is defined as follows (NCHRP 66, 1979):

$$\text{Cutoff Angle} = 20^{\circ} + \text{Degree of curvature.}$$

IRC (2010) recommended that the cutoff angle is defined by the following equation:

$$\text{Cutoff Angle} = 18^{\circ} + \text{Degree of curvature.}$$

The utilization of nighttime work in highway construction and rehabilitation projects has been increasing in recent years throughout the United States. In this type of projects, construction planners are required to develop and submit a lighting plan that provides: (1) adequate illuminance levels for all planned nighttime construction tasks; (2) reasonable uniformity of light distribution in the work area and (3) acceptable glare levels to both road users and construction workers. In order to support construction planners in this vital and challenging task, this paper presents a lighting design model, named CONLIGHT, which is capable of considering the specific

requirements of nighttime highway construction operations. The model is developed to enable construction planners to evaluate the performance of various lighting plans and select a practical design that complies with all lighting requirements for the nighttime work being planned. An application example is analyzed to illustrate the use of the model and demonstrate its accuracy and capabilities in generating practical lighting plans for nighttime construction and rehabilitation projects (Khaled and Khaled, 2005).

When trees are planted along streets, trees have an aesthetic impact on the neighborhood, in addition to providing shade, anti-glare screening, as well as acting as traffic calming tools (Putnam Country Landscape Development Code, 2004).

Five decision variables are optimized in the present system; namely: number of lighting equipment (Khaled and Khaled, 2008), positioning, mounting height, aiming angle and *rotation angle*. The system is also designed to consider and satisfy all practical constraints that can be encountered in this lighting design problem.

Day Visual Cone Concept

With respect to road planting, trees are the main visual component in the vertical aspect of a road view, whereas the road itself defines the horizontal aspect. Trees can enhance the three-dimensional space so as to provide a positive impression on a driver. Scale of road planting must facilitate the traffic functions of the road and be suitable for travelers' perceptions. Road planting is different from that of parks or gardens, which are primarily designed for tourists for either walking or resting.

The most important factors in road design are:

- the ability of a driver to perceive things associated with the driving task;
- the order in which a driver sees these things; and
- the time that a driver has to respond to what they he/she sees.

The average normal human eye can detect visual stimuli, approximately 180° in the horizontal plane and 130° in the vertical plane. Focal vision is limited to one

thousandth of the visual field at any one moment, and this represents a 2°- cone of interest from the lens of the eye (Bagui and Ghosh, 2010).

The real size of an object can be determined up to a distance of 400 m from it. Beyond this distance, objects begin to appear smaller.

Driver's night vision is limited. Focal distance is limited to about 150 m; i.e., the distance illuminated by the vehicle's head lights, and night vision is further reduced by glare of oncoming vehicles. Visibility is also reduced during wet weather vision.

Vision at Speed

As speed increases, the eye's behavior will affect the driver's performance in the following manner:

- Concentration decreases;
- The field of concentration reduces;
- Peripheral vision diminishes; and
- Space perception becomes impaired.

Fig. 2 illustrates the cone of vision (Bagui and Ghosh, 2010).

Maximum elevation and minimum elevation of

glare screen height should be such that light does not shine over or under the barrier. Generally, the minimum glare screen barrier height should be a different height between maximum elevation and minimum elevation. Glare screen barrier costs can be determined based on the lateral placement of vehicle with a clearance of 0.3 m from the median side and 1.4 m from the road side. Several models have been developed (Bagui and Ghosh, 2012).

Night Vision Concept-Glare Block

Individual Tree/Bush Works as Glare Block at Night

Glare increases on roadways in horizontal curves, and this increase is proportional to the degree of curvature. Glare block is installed on the curve. The spacing or width of the glare screen units should be adjusted in proportion to the sharpness of the curvature. To make the cutoff angle comparable to the 20° value on the tangent, the cutoff angle is defined by:

Cutoff angle = 20° + degree of curvature of the curve at the centre.

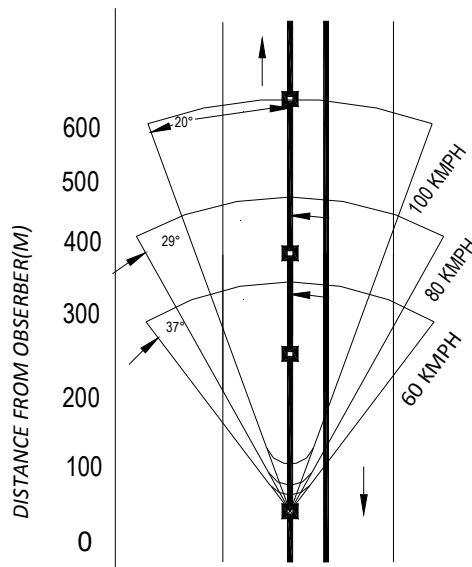


Figure 2: Vision cone

Degree of curvature is defined by:

$$\theta = 1746 / R; \tag{1}$$

where,

θ = Degree of curvature (degree);

R = Radius of curve (m).

Block is assumed to be placed perpendicular to the tangent of the curve, and the spacing of the block will be:

$$S = B / \tan (20^\circ + \theta) = B \times \cot (20^\circ + \theta); \tag{2}$$

where,

S = Spacing of glare block installed perpendicular to the road alignment (m);

B = Width of glare block (m); and

θ is the degree of curvature (degree).

Value of α is 20° , 29° and 37° for design speeds of 100,80 and 60 kmph.

Zwahlen and Oner (2006) developed an antiglare screen barrier height model based on the lateral position of the vehicle and evaluated the height of antiglare screen based on the 95th percentile eye height of the driver. The values apply for 95% of all adults.

For the eye distance to the antiglare screen barrier, it is assumed that the vehicle is driving in the center of a 3.66 m wide lane. Determination of antiglare screen barrier height is shown in Fig. 3.

$$\text{Height of antiglare screen barrier} = h + \frac{H - h}{a + b} b \tag{3}$$

where,

H = Height of driver's eye;

h = Height of headlamps of the oncoming vehicle;

a = Perpendicular distance of the driver's eye from antiglare screen barrier;

b = Perpendicular distance of headlamps of the oncoming vehicle from the antiglare screen barrier; and

A+B = Longitudinal distance between vehicles.

Considering that the angle of headlight is 1° upward and that glare occurs when the distance between the two vehicles is in the range of 30 to 90 m. Let C and W be the width of the main carriageway and the median width, respectively. Maximum headlight height is 1.2 m (Bagui and Ghosh, 2009).

Height of antiglare screen barrier is given by:

$$H = 1.2 + \sqrt{30^2 + (C + W / 2)^2} \tan 1^\circ . \tag{4}$$

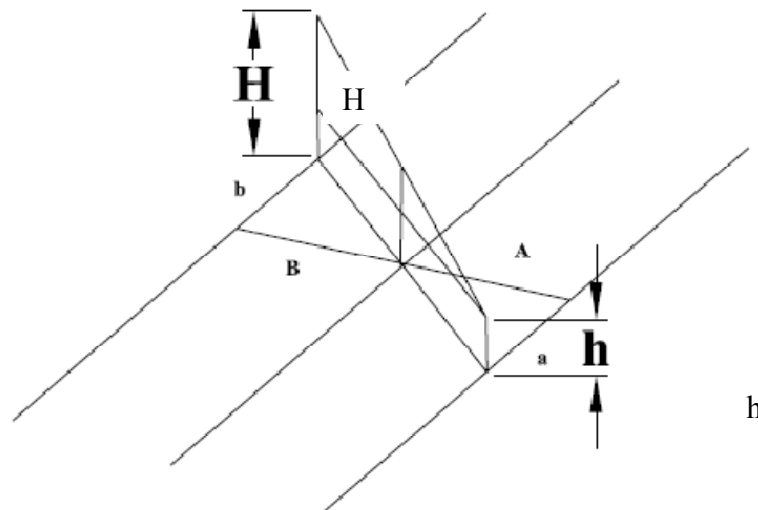


Figure 3: Determination of antiglare screen barrier height

Considering a median width of 5 m; 8.5 m for four-lane carriageway, 12 m for six-lane carriageway and 15.5 m for eight-lane carriageway, the heights of antiglare screen barriers are calculated as documented below.

For four lanes, height of antiglare screen barrier=1.76m.

For six lanes, height of antiglare screen barrier=1.78 m.

For eight lanes, height of antiglare screen barrier=1.81 m.

The following points may be highlighted herein:

- *There is paucity of standard guidelines to determine the spacing of trees or antiglare screen barrier block on horizontal alignment;*
- *Spacing of antiglare block unit is proportional to the sharpness of the curvature;*
- *Median tree plantation may partially/ completely work as antiglare screen barrier;*
- *Cutoff angle varies from 20° to 22°;*
- *Simplified model has been used to determine the height of antiglare screen barrier block, which varies from 1.76 m to 1.81 m.*

LEAD FROM PAST STUDIES

It has been found from literature survey that very limited works have been carried out earlier to determine the optimum spacing of the glare block.

OBJECTIVE AND SCOPE

Based on available literature and gap/limitation of previous research works, the following objectives and scopes are identified.

- Determination of horizontal spacing of glare block.
- Cost optimization of glare block considering glare cost.

Based on the present need as revealed from the literature, the following two aspects are to be investigated:

- Development of a model for the optimization of horizontal spacing of glare screen barriers.
- Quantity/cost calculation.

DEVELOPMENT OF MODELS FOR HORIZONTAL SPACING OF ANTI-GLARE BLOCK

Glare increases on roadways along horizontal curves, and this increase is proportional to the degree of curvature. If type III antiglare screen barrier (antiglare block) is installed on the curve, the spacing and width of the antiglare screen barrier units should be adjusted proportional to the sharpness of the curvature. To make the cutoff angle comparable to the 20° on the tangent, the cutoff angle is defined as (NCHRP: 66, 1979):

Cutoff angle = 20° + degree of curvature of the curve at the center.

Degree of curvature is given as:

$$\theta = 1746 / R; \quad (5)$$

where,

θ = Degree of curvature in degrees; and

R = Radius of curve in meters.

The following two approaches are used for computing the spacing of antiglare blocks:

- Antiglare block perpendicular to the road; and
- Antiglare block inclined to the road.

Antiglare Block Perpendicular to the Road

Spacing of antiglare block perpendicular to the road has been calculated as shown below:

$$Shv = B / \tan(20^\circ + \theta) = B \times \cot(20^\circ + \theta) \quad (6)$$

where,

Shv = Spacing of antiglare block in meters;

B = Width of antiglare block in meters; and

θ = Degree of curvature in degrees.

Antiglare Block Inclined to the Road

Spacing diagram has been illustrated in Fig.4 for antiglare block inclined to the road.

It is found that:

$$\frac{Shi}{Shv} = \frac{B[Cot(x) + Cot(20^{\circ} + \theta)]}{B[Cot(20^{\circ} + \theta)]}$$

$$Shi = Shv[1 + \frac{Cot(x)}{Cot(20^{\circ} + \theta)}] \quad (8)$$

From equation 8, it is found that the spacing of inclined antiglare unit block depends on the inclination angle 'x'. It is minimum when Cot (x) = 0; i.e., x = 0° and maximum (infinite) when x = 90°.

Minimum spacing, Shi = Shv = B × Cot (20° + θ).

Maximum spacing = infinite; i.e., antiglare screen barrier block should be placed continuously.

Economical Design Considerations

Let us consider that the antiglare screen barrier is to be provided to Z kilometers of the road. The number of blocks required has been calculated for the above-mentioned two cases.

Antiglare Block Installed Perpendicular to Road

$$Shv = B \times Cot(20^{\circ} + \theta)$$

$$\text{No. of blocks required, } N1 = [(Z \times 1000)/Shv + 1]$$

Total length(L1) required of antiglare screen block for Z km road for perpendicular placement, L1=BN1.

Antiglare Block Installed Inclined to Road

$$Shi = B[Cot(x) + Cot(20^{\circ} + \theta)]$$

$$\text{No. of blocks required, } N2 = [(Z \times 1000/Shi) + 1]$$

Total length (L2) required of antiglare screen block for Z km road for inclined placement = [B/Sin(x)] x N2.

Hence,

$$\frac{L1}{L2} = \frac{BN1}{BN2} \frac{Sin(x)}{Sin(x)} = \frac{N1}{N2} \frac{Sin(x)}{Sin(x)} \quad (9)$$

$$\frac{L2}{L1} = \frac{BN2}{(BN1)Sin(x)} = \frac{(\frac{Z \times 1000}{Shi} + 1)}{(\frac{Z \times 1000}{Shv} + 1)Sin(x)} = \frac{Shv}{Shi \times (Sin(x))} \text{ (Approx)}$$

$$\frac{L2}{L1} = \frac{B[Cot(20^{\circ} + \theta)]}{B[Cot(x) + Cot(20^{\circ} + \theta)]Sin(x)}$$

$$= \frac{Cos(20^{\circ} + \theta)}{Cos(x)Sin(20^{\circ} + \theta) + Cos(20^{\circ} + \theta)Sin(x)}$$

$$= \frac{Cos(20^{\circ} + \theta)}{Sin(x + 20^{\circ} + \theta)} \quad (10)$$

L2 is minimized when Sin(x+20°+θ) is maximized; i.e., 1=Sin (90°), Hence;

$$x + 20^{\circ} + \theta = 90^{\circ},$$

$$x + \theta = 70^{\circ}. \quad (11)$$

Eqn. 11 is the basic relation between x and θ for optimum spacing of antiglare screen barrier block.

Consider the special case, when the spacing of antiglare screen barrier block is B, 2B and 3B when the block is inclined. From equation 8, it is found that:

$$Shi = B[Cot(x) + Cot(20^\circ + \theta)] = B, 2B, \text{ or } 3B,$$

Hence;

$$Cot(x) + Cot(20^\circ + 0) = 1 \text{ or } 2 \text{ or } 3. \tag{12}$$

Typical economical spacing of antiglare screen barrier block for straight alignment ($\theta=0^\circ$) has been calculated and presented in Table 1.

Inclination angle for different radii of the curves is shown in Chart 1 which is developed using equation 11. From Chart 1, it is noticed that with increasing the inclination angle of the block, the radius of the curve is also increased and *vice versa*. Economical length of antiglare screen barrier block per kilometer length is also shown in Chart 2. From Chart 2, it is found that with the increase of the radius of the curve, the length of the block decreased. Therefore, a curve with a larger radius shall be beneficial from the viewpoint of consideration of antiglare screen barrier costs.

Illustrative Numerical Example

Calculate the length of antiglare screen barrier block with 1 m width on straight alignment for the following cases:

- Block to be placed perpendicular to the road;
- Block to be placed inclined to the road.

Solution

For straight alignment, $\theta = 0$ and the value of x varies from 0° to 90° , and the lengths of antiglare screen barrier block are shown in Table 1. From Table 1, the length of block for an inclination angle of 0° is 365 m, and the economical length of the screen barrier is found to be 343.67 m for 1 m wide antiglare block placed at an inclination angle of 70° . Alternatively, this can be calculated as:

$$Shv = 1/\tan(20^\circ) = 2.75 \text{ m.}$$

$$L1 = \text{Length required in one km road} = 1 \times (1000/2.75 + 1) = 365 \text{ m (Say).}$$

$$L2 = \text{Economical length} = 365 \times \text{Cos}(20^\circ) = 343.1 \text{ m (say).}$$

Table 1. Economical Spacing of Antiglare Screen Barrier Block (Straight Alignment) for 1.0 m Wide Antiglare Screen Barrier Block

x (Deg)	Shv(m)	Sin(x)	B'(m)	Shi(m)	N1	N2	L1(m)	L2(m)
0	2.75	0.00	infinite	infinite	365	1	365	1000.00
5	2.75	0.09	11.47	14.17	365	72	365	825.78
10	2.75	0.17	5.76	8.42	365	120	365	690.78
15	2.75	0.26	3.86	6.48	365	155	365	598.64
20	2.75	0.34	2.92	5.49	365	183	365	534.85
25	2.75	0.42	2.37	4.89	365	206	365	487.25
30	2.75	0.50	2.00	4.48	365	224	365	447.84
35	2.75	0.57	1.74	4.17	365	241	365	420.02
40	2.75	0.64	1.56	3.94	365	255	365	396.58
45	2.75	0.71	1.41	3.75	365	268	365	378.89
50	2.75	0.77	1.31	3.58	365	280	365	365.41
55	2.75	0.82	1.22	3.45	365	291	365	355.15
60	2.75	0.87	1.15	3.32	365	302	365	348.63
65	2.75	0.91	1.10	3.21	365	312	365	344.18
70	2.75	0.94	1.06	3.11	365	323	365	343.67
75	2.75	0.97	1.04	3.01	365	333	365	344.70
80	2.75	0.98	1.02	2.92	365	343	365	348.26
85	2.75	1.00	1.00	2.83	365	354	365	355.33
90	2.75	1.00	1.00	2.75	365	365	365	365.00

Note: L1, L2, Shv... etc. are already defined.

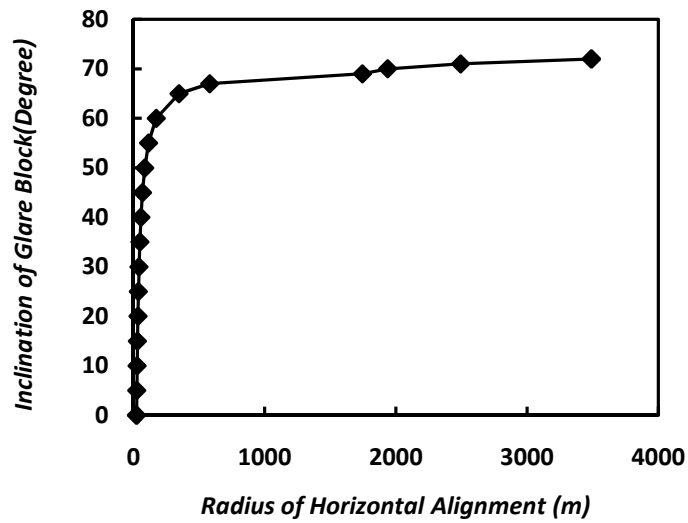


Chart 1: Optimization of inclination angle for various radii of the curve

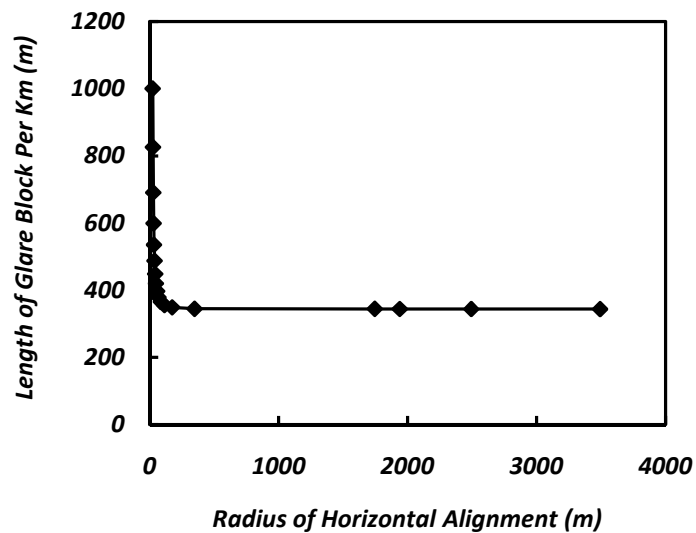


Chart 2: Economical length of antiglare screen barrier block per km length

Example

Determine the economical spacing of glare block for a width of the glare block of 1.0 m on straight alignment.

Solution

Spacing depends on inclination angle x as shown in Fig. 4.

Minimum length is found when $x = 70^\circ$.

Optimization of glare cost is also calculated using equation 6.

$$Shv = B \times \cot(20^\circ + \theta) = 1 \times \cot(20^\circ) = 2.75 \text{ m.}$$

No. of blocks required for one km of road length, $N1 = (1000/2.75 + 1) \approx 365$.

$$\text{Length required, } L1 = B \times N1 = 1 \times 365 = 365 \text{ m.}$$

From equation 10, it is found for straight alignment:

$$L2 = L1 \times \cos(20^\circ) = 343 \text{ m (approximately).}$$

[Putting $\theta = 0$ and $x = 70^\circ$ in equation 6), cost has been calculated]:

Cost per km for the case - glare screen is placed perpendicular to the road = USD 37,250.

Cost per km for the case - glare screen is placed inclined to the road = USD 35,000.

CONCLUSIONS

Following conclusions may be drawn from the above-mentioned analysis.

Antiglare screen barrier block can be placed on the

median perpendicular/inclined to the median. Spacing depends on the width of the block, the degree of the curvature, θ , and the inclination angle of the block, x . Optimum length of the block is achieved when the following relationship is satisfied:

$$x + \theta = 70^\circ.$$

Spacing of the block depends on the inclination angle of the block to the road. It is found that with the increase of the inclination angle, width and spacing of the glare block decrease, and the total length of block for a known length also decreases. This is found for a value of $x = 70^\circ$. Beyond 70° , the total length increases.

Glare block may be placed inclined to optimize the glare cost and ultimately the project costs.

Height of antiglare screen barrier block may be determined using a simplified model as shown in this paper for multilane divided carriageways.

Economical aspect of antiglare screen barriers has been considered, and it is found that cost optimization may be achieved using inclined placement of the block.

REFERENCES

- AASHTO. 1970. Guidelines for Highway Landscape and Environmental Design, 21-35.
- Bagui, S.K. and Ghosh, A. 2009a. Development of Guidelines for Median Tree Planting as Median Barrier, Antiglare Screen and Antiglare Screen Height for Unsymmetrical Curve. *Journal of Indian Highways*, 37 (4): 33-49.
- Bagui, S.K. and Ghosh, A. 2010. Visual System and Glare. Published in: *Indian Highways*, 39 (6): 20-29.
- Bagui, S. K. 2012. Geometric Design, Economic Analysis and Financial Analysis for Antiglare Screen Barrier. Unpublished PhD Thesis, Bengal Engineering and Science University, Under Guidance of Dr. Ambarish Ghosh.
- Copenhaver, M.J. and Jones, Jr., R. E. 1992. Measurement of Headlamp Aim and the Electrical and Photometric Performance Characteristics of Rear Lighting Systems. DOT HS 807 930, U.S. Department of Transportation, National Highway Traffic Safety Administration, Washington, DC, 34-45.
- Department of Transport Highway and Traffic, HMSO. 1987. Advice Note TA 57/87, "Roadside Features".
- Indian Roads Congress, Special Publication, I R C SP: 21. 2009. Manual for Landscaping for Road Works. New Delhi, India.
- I.R.C. 2010. Development of Expressway Manual. Government of India, New Delhi, India.
- Khaled, E. and Khaled, H. 2005. CONLIGHT: Lighting Design Model for Nighttime Highway Construction. *Journal of Construction Engineering and Management*, ASCE, 132 (4):467-478.

- Khaled, E. and Khaled, H. 2008. Optimal Lighting Arrangements for Nighttime Highway Construction Projects. *Journal of Transportation Engineering, ASCE*, 135 (11): 432-437.
- Louisiana Department of Transportation and Development. 2000. Policy for Roadside Vegetation Management.
- Ministry of Surface Transport (MOST). 1997. Accident Black Spot Study of Selected Sections of National Highway of India.
- National Co-operative Highway Research Programme (NCHRP). 1979. No. 66. Effect of Glare in Night Driving.
- Putnam County Landscape Development Code. 2004. Article 7: Development, Design and Improvement Standards.
- Saadeghvaziri, M.A., MacBain, K. and Ersoy, S. 2000. Combination Glare Screen Pedestrian Fence Using Recycled Plastics. *Pract. Periodical on Structural Design and Construction*, 5 (40): 150-156.
- Walker, A.E. and Chapman, R.G. 1980. Assessment of Anti-dazzle Screen on M6. Sponsored by: Transport and Road Research Laboratory, Department of the Environment, Department of Transport, Accident Investigation Division/ Safety Department.
- Zwahlen and Erdnic Oner. 2006. Improved Work Zone Design Guidelines and Enhanced Model of Travel Delays in Work Zones. Ohio Department of Transportation.