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Three-Dimensional Analysis for Determination of Anti-Glare Screen Barrier Height

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ABSTRACT

Few models are available to determine the height of anti-glare screen barrier based on two-dimensional analysis. Very limited research works have been carried out considering three-dimensional analysis. A model has been developed herein to determine the height of anti-glare screen barrier considering three-dimensional analysis. Height of anti-glare screen barrier has been determined considering plane, parabolic and spherical surfaces based on three-dimensional analysis. Height of anti-glare screen barrier has been found to be constant for plane surface, and it depends on the eye height of the driver and the height of vehicle head light only and varies for other surfaces. The model has also been modified for two-dimensional analysis and is reported herein. Height of anti-glare screen barrier obtained from two-dimensional analysis is also reported herein. There is no significant change in the height of anti-glare screen barrier in case of surface with large radius. Height of anti-glare screen barrier has been recommended as 1.85 m for Indian situation.

KEYWORDS: Anti-glare screen barrier, Anti-glare screen barrier height, Three-dimensional analysis, Two-dimensional analysis, Parabolic, plane and spherical surfaces.

INTRODUCTION

Traffic of various important National Highways (NH) and State Highways (SH) in India has increased rapidly in the past few years and exceeded the existing capacity of roads. Major roads were of two lanes, and speeds of vehicles reduced tremendously causing delays and traffic jams. In order to increase the capacity of roads and the speed of vehicles, the Government of India decided to widen the existing roads of two lanes to four lanes and roads of four lanes to six lanes based on capacity augmentation.

Average vehicle speed has been increased to be in the order of 80 kmph to 100 kmph or more in the completed four/six lane roads. Attending these speeds at night is difficult due to glare of head light of opposite vehicles. Accidents have also increased for several causes. One of the causes is glare of head light of opposite vehicles during night driving. The number of accidents may be minimized by providing an anti-glare screen barrier, and vehicle speed can also be increased during night time. Vehicles move safely from one place to another during the night by providing anti-glare screen barriers.

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Types of Glare Screens

Three types of glare screens are generally (NCHRP 66 1979) available. These are as follows:

Type I: This type of glare screen is continuous, which means 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 beyond 20°.

Type III: This type is composed of individual elements positioned to block light at angles from 0° to about 20°, and visibility is clear between the elements.

The plan and elevation of the three glare screen types are shown in Fig. 1.

LITERATURE REVIEW

Coleman and Sack (1967) carried out investigation on anti-glare screens. They found a height of glare screen of about 4.5 m for a vertical curve of 6% grade (3%+3%) and 200 m length curve. This was on the very higher side and ultimately wide median with bushes provided.

One of the best studies was carried out in Ohio (Musick, 1969). An expanded metal mesh was installed back to back guard rail and later replaced by a concrete barrier. The accidents were reduced by 35% (Musick, 1969).

Plastic paddles were installed on a concrete median for an 8.5 km section of a four lane freeway in Indiana. Glare screen height was 1.5 m (Venable, 1977).

Nihon Doro Kodan (1985) has established the height of glare screen as 1.4 m for National Expressway in Japan.

TA 57/87(Department of Transport, Highway and Traffic, HMSO, UK) recommended the minimum height of 1.75 m for glare screen to avoid glare of head light of all vehicles including large trucks.

Illuminence 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 and the distance of the glare source from the observer. The greater the intensity directed toward an observer, the greater the illuminence reaching the observer's eyes. Copenhaver and Jones (1992) found that the illumination resulting from two light sources of different intensity levels is a function of distance from the sources. Illuminence is maximum when the distance between the two vehicles is 30 meters.

Zwahlen and Erdnic (2006) developed a glare screen height model based on the lateral position of the vehicle and determined the height of glare screen based on 95 percentile eye height of the vehicles .They found the height of glare screen barrier as 1.78 m based on two-dimensional analysis.

Bagui and Ghosh (2009) developed a simplified model and found from the analysis that the anti-glare screen height varies from 1.76 m to 1.81 m for four and eight lane roads and 1.79 m for six lane divided highways.

The following points may be highlighted from the literature review on anti-glare screen barrier presented in the above section:

- *Two-dimensional analysis is used by various researchers to determine the height of glare screen barrier ;*
- *Height of glare screen varies from country to country;*
- *Glare is maximum when the distance between two vehicles is approximately30 m; and*
- *Very limited research works have been carried out to determine glare screen height based on three-dimensional analysis.*

Based on previous research works, it is revealed that very limited research works have been carried out to determine the height of screen barrier on vertical curves and plane surfaces considering three-dimensional analysis. The objective of the present work is to develop a model to determine the anti-glare screen height through three-dimensional analysis, and this model is also modified for two-dimensional analysis.

In two-dimensional analysis, vehicles are assumed moving on a single plane; i.e., two-dimensional coordinate system. Actually in real practice, it is not possible. Vehicles are moving in a varying three-dimensional coordinate system. Height based on three-dimensional analysis will give better results than those of two-dimensional analysis. Three-dimensional analysis will be preferable compared to two-dimensional analysis considering the head light a point sources.

Field Investigations

As part of the present study, field investigations have been carried out in India to determine drivers' eye heights and head light height of vehicles .Data collected for each type of vehicle in the range of 85-100 numbers and average values were used to determine the height of glare screen barrier. Field data can be found in Table 1.

Development of the Model

Three-dimensional analysis has been carried out for plane, parabolic and spherical surfaces and is presented herein.

Plane Surface

Let Ax+By+Cz = D be the equation of the plane on which road alignment passes.

Let, (x1, y1, z1) and (x2, y2, z2) be two points on the plane. These points are the locations of two vehicles moving in opposite directions.

Glare occurs when the distance between the two vehicles is 30m; hence:

$$[(x1-x2)^2+(y1-y2)^2+(z1-z2)^2]^{0..5}=30 \qquad (1)$$

Let, He and Hh are the eye height of the driver and head light height of two vehicles moving in opposite directions.

The coordinates of the eye height of the driver of the first vehicle and the head light of the second vehicle are:

- (x1, y1, z1+He)
- (x2, y2, z2+Hh)

The coordinates of the head height of the first vehicle and the eye height of the driver of the second vehicle are:

- (x1, y1, z1+Hh)
- (x2, y2, z2+He)

These are four points which form two lines in space. Glare screen barrier should be installed at the point of intersection of these two lines. Let (x, y, z) be the point of intersection of these two lines as shown in Fig.2.

The two points (x1, y1, z1) and (x2, y2, z2) lie on the plane; hence:

$$Ax1+By1+Cz1 = D \qquad (2)$$

$$Ax2+By2+Cz2 = D \qquad (3)$$

Let O(x,y,z) be the point of intersection of lines AB and CD as shown in Fig.2. Considering point O, the equations of the two lines AB and CD are:

$$\frac{x-x1}{x2-x1}=\frac{y-y1}{y2-y1}=\frac{z-(z1+He)}{(z2+Hh)-(z1+He)} \qquad (4)$$

$$\frac{x-x1}{x2-x1}=\frac{y-y1}{y2-y1}=\frac{z-(z1+Hh)}{(z2+He)-(z1+Hh)} \qquad (5)$$

From equations 4 and 5, it is found that:

$$\frac{z-z1-Hh}{z2+He-z1-Hh}=\frac{z-z1-He}{z2+Hh-z1-He}=\frac{He-Hh}{2(He-Hh)}=\frac{1}{2} \qquad (6)$$

Hence, the location of the point of intersection is computed as follows:

$\frac{x-x1}{x2-x1}=\frac{1}{2}$ or x2-x1=2x-2x1; hence:

$$x=(x2+x1)/2 \qquad (7)$$

Similarly,

$$y = (y2+y1)/2 \qquad (8)$$

$\frac{z-z1-He}{z2+Hh-z1-He}=\frac{1}{2}$ or 2(z-z1-He)=z2+Hh-z1-He;

hence:

$$z = (z2+z1)/2 +(He + Hh)/2 \qquad (9)$$

The coordinate of the upper elevation of glare screen barrier is given by:

- x=(x2+x1)/2;
- y =(y2+y1)/2 ;
- z=(z2+z1)/2 +(He + Hh)/2.

z elevation of the screen barrier (upper point) is to be calculated using Eq. 9.

Again it is already found that:

Ax1+By1+Cz1=D

Ax2+By2+Cz2=D

or

A(x1+x2)+B(y1+y2)+C(z1+z2)=2D

or

A(x1+x2)/2+B(y1+y2)/2+C(z1+z2)/2=D (10)

Equation 10 implies that the point [(x1+x2)/2, (y1+y2)/2, (z1+z2)/2] lies on the plane; .i.e., (z1+z2)/2 is the lowest elevation of the screen barrier.

So, the height of the glare screen barrier is given by:

(z1+z2)/2 + (He + Hh)/2 - (z1+z2)/2= (He + Hh)/2

$$\text{Height of glare screen} = \frac{He + Hh}{2} \qquad (11)$$

This equation implies that the height of glare screen barrier depends on the eye height of the driver, the height of head light of the vehicle and is independent on the distance between the two vehicles. Height of glare screen barrier for various vehicles is shown in Table 1.

Economical Anti-Glare Screen Barrier

Generally, anti-glare screen barrier is a solid section. Hollow section is proposed to reduce anti-glare screen barrier cost to be an economical anti-glare screen barrier. The cost of the proposed screen barrier is less than that of the traditional screen barrier.

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 height should be the difference in height between maximum elevation and minimum elevation. The most economical glare screen barrier can be designed considering maximum elevation and minimum elevation of the glare screen barrier. This can be obtained from the eye height and the head light of the highest truck and smallest (Maruti) car plying in India. An example is illustrated in the following section.

Example

The height of screen barrier is determined based on the height of the head light and the eye height of the truck. These are 1.200 m and 2.500 m for the maximum height for the truck vehicle.

Using equation 11, the upper limit of glare screen barrier is determined, and is shown as follows:

Upper height (maximum) of screen barrier is given by:

Upper Height (max) = (1.200 +2.500)/2=1.850 m.

Similarly, the lower height of the screen barrier is determined considering the head light height and the eye height of 0.600 and 1.050 m for the minimum height for the maruti car.

Lower height is given by:

Lower height (minimum) =0.5(0.600+1.050)=0.825 m.

A typical drawing of glare screen barrier is presented in Figure 3.

Paraboloid

Let the vertical curve be part of a paraboloid. The equation of the paraboloid is as follows:

$$\pm (x/a)^2 \pm (y/b)^2 = 2z \qquad (12)$$

There are two different cases in the expression of the left side of Eq. 12 (Jain and Ahmad, 2005) as mentioned below :

- Both terms are of the same sign; then the surface is called an elliptic paraboloid;
- Both terms are of opposite signs; the surface is called a hyperbolic paraboloid.

Let A and B be two points on the curve and x1, y1, z1 and x2, y2, z2 be the coordinates of these two points.

Hence, it can be found that:

$(x1/a)^2 + (y1/b)^2 = 2z1$ (13)

$(x2/a)^2 + (y2/b)^2 = 2z2$ (14)

Upper Elevation and Lower Elevation

The height of screen barrier is determined based on the height of the head light and the eye height of the truck. These are 1.2 m and 2.5 m for the maximum height for truck vehicles plying in India.

The coordinates of the point where the barrier is to be installed are (x1+x2)/2, (y1+y2)/2, zr

Upper Height=1.85+0.5(z1+z2)-zr for sag curve (15)

Upper Height=1.85 - 0.5(z1+z2)+zr for crest curve (16)

where, $zr = 0.5\,[\{(x1+x2)/2a\}^2 \pm \{(y1+y2)/2b\}^2]$ (17)

In equation 16, the positive sign shall be used for elliptic paraboloid; i.e., crest curve, and the negative sign shall be used for the hyperbolic paraboloid; i.e., sag curve.

Again, the distance between the two points is 30 m as mentioned earlier; .i.e.,

$$[(x1-x2)^2 - (y1-y2)^2 + (z1-z2)^2]^{0.5} = 30\text{m}.$$

Using the above six equations (Eq.12 to Eq.17), the optimum height of glare screen barrier can be determined.

Similarly, the lower height (minimum) of the screen barrier is determined considering the head light height and the eye height of 0.600 and 1.050 m for the smallest maruti car.

Lower elevation of screen barrier =
0.5(z1+0.600+z2+1.050)- zr
=0.825+0.5(z1+z2)- zr

where,
$zr = 0.5[\{(x1+x2)/2a\}^2 \pm \{(y1+y2)/2b\}^2]$.

Sample Calculation

Let $\dfrac{x^2}{15000^2} \pm \dfrac{y^2}{1000^2} = 2Z$ be the equation of the curve.

Let (147001,9011.2,7.419) and (147022.4,9033,7.237) be two points on the curve;

$$\frac{x^2}{15000^2} - \frac{y^2}{1000^2} = 2z.$$

Distance between the two points is found by using the following expression:

Distance=$[(147001-1470000)^2+(90011.200-9033)^2+(7.237-7.419)^2]^{0.5}$
=30.480=30.000 m (approximately).

The x and y coordinates of the glare screen barrier where it will be installed are:

x = (x1+x2)/2 = (147001+147022.400)/2 =147011.700;

y = (y1+y2)/2 = (9033+9011.200)/2 = 9022.100.

The z-coordinate of the surface where the screen needs to be installed may be determined from the following expression:

$$zr = 0.5 \times \left(\frac{147011.700^2}{15000^2} - \frac{9022.100^2}{1000^2}\right) = 7.237.$$

(z1+z2)/2 = (7.419+7.237)/2 =7.328.

The height of the barrier = 1.850+7.328-7.237=1.941 m.

Let (147001, 9011.200, 88.622) and (147022.400, 9033, 88.832) be two points on the ellipsoid, $\dfrac{x^2}{15000^2} + \dfrac{y^2}{1000^2} = 2z$.

Similarly, the height has been calculated and found to be 1.849.

Glare screen height has been found to be 1.849≈1.850m.

Table 1. Eye height, head light height and height of anti-glare screen barrier for various vehicles

Vehicle Type	Head Light Height (m)	Eye Height (m)	Height of Anti-Glare Screen Barrier	Traffic Composition	Weight Age Height(m)
Maruti car	0.60	1.08	0.825	0.02	0.017
Maruti van	0.85	1.40	1.125	0.03	0.034
Qualis	0.90	1.50	1.200	0.03	0.36
Jeep	1.00	1.50	1.250	0.05	0.063
Tata Indica	0.75	1.20	0.975	0.02	0.02
Taxi	0.75	1.20	0.975	0.04	0.034
L C V	1.20	1.80	1.500	0.05	0.075
Tata Sumo	0.95	1.55	1.250	.04	0.05
RTV	1.00	1.70	1.350	0.1	0.135
Mini bus	0.95	1.60	1.275	0.15	0.191
Standard bus	1.15	2.10	1.625	0.2	0.325
MCV	1.20	2.50	1.850	0.265	0.49
Auto (9 seated)	0.90	1.35	1.125	0.005	0.006

Recommended Weighted height=1.48m.

Table 2. Height of glare barrier

Values of Constants a and b		Height of Screen Barrier(m)	
a	b	Elliptic Paraboloid	Hyperbolic Parabolid
50	25	1.794	1.954
75	25	1.781	1.954
125	75	1.845	1.863
150	100	1.848	1.858
200	150	1.849	1.854
250	200	1.850	1.852
300	250	1.850	1.851
400	300	1.850	1.851
500	400	1.850	1.851
1000	500	1.850	1.850
1500	500	1.850	1.850

Earth

Earth is an ellipsoid. The semi-major axis a and the semi-minor axis b differ only 21 km. The dimensions a and b are 6378137 m and 6356752m, respectively. Let (637837, 635675, 1.000031) and (6378260, 6356874, 1.000038) be two points on the earth.

Distance between the two points is 31.8 m; i.e., 30m.

(x1+x2)/2 = 6378249 and (y1+y2)/2 = 6356863, (z1+z2)/2 = 1.000035, zr = 1.000035.

Using the above equations, the height of the glare screen is calculated and shown below:

Screen Height = 1.850000 + 1.000035 -1.000035 = 1.850000 m.

Some typical calculations are shown in Table 2.

Table 3. Maximum and minimum height of glare barrier

Radius (m)	Maximum Screen Height (m)	Minimum Screen Height(m)
500	1.60	0.57
1000	1.72	0.70
1500	1.77	0.74
2000	1.79	0.76
2500	1.80	0.77
3000	1.81	0.78
3500	1.81	0.78
4000	1.82	0.79
4500	1.82	0.78
5000	1.82	0.80
6000	1.83	0.80
7000	1.83	0.81
8000	1.83	0.81
9000	1.84	0.81
10000	1.84	0.81
20000	1.84	0.82
50000	1.85	0.82
100000	1.85	0.82
6400000	1.85	0.82

Spherical Surface

Semi-major axis a and semi-minor axis b of earth differ only 21.0 km. So, earth may be considered as a sphere with a radius of approximately 6400000 m. Spherical surface has also been considered for the calculation of height of anti-glare screen. Variation of height of screen barrier using larger values of a and b for paraboloc surface and larger radius for spherical surface will be negligible .So, spherical surface is considered for comparison purposes only.

Let the vertical curve be part of a sphere with a large radius; then the equation of the surface is mentioned as follows:

$$x^2 + y^2 + z^2 = a^2 \qquad (18)$$

Let A and B be two points on the curve, and x1, y1, z1 and x2, y2, z2 be the coordinates of these two points. Hence, the following expressions may be written:

$x1^2 + y1^2 + z1^2 = a^2$ (19)

$x2^2 + y2^2 + z2^2 = a^2$ (20)

Upper Elevation and Lower Elevation

The height of the screen barrier has been determined based on the height of the head light and the eye height of the truck. These are 1.2 m and 2.5 m for the largest truck vehicle.

The coordinates of the point where the barrier is to be installed are (x1+x2)/2, (y1+y2)/2, zr.

Maximum height of screen barrier = 0.5 (z1+ 1.2+ z2 + 2.45) – zr =1.825+ 0.5(z1+z2)- zr.

$zr=[a^2-\{(x1+x2)/2\}^2-\{(y1+y2)/2\}^2]^{0.5}$. (21)

Table 4. Height of glare screen barrier based on two-dimensional analysis

Surface Type	Equation of Surface	Coordinates of Two Points		Distance between Two Points (m)	Height of Glare Screen Barrier (m)
		First Point	Second Point		
Paraboloid	$y^2 = 10000z$	100.000,1.000	130.380,1.700	30.420	1.870
Circle	$x^2 + y^2 = 1000^2$	500.000,866.030	526.000,850.500	30.800	1.730
Circle	$x^2 + y^2 = 6400000^2$	3300000.000, 5483611.900	3300026.000, 5483596.300	30.350	1.849
Ellipse	$\frac{x}{10000^2}^2 + \frac{y}{15000^2}^2 = 1$	7072.140,10605.000	7088.74,10580.030	30.000	1.865
Ellipse	$\frac{x}{20000^2}^2 + \frac{y}{15000^2}^2 = 1$	14168.270,10586.960	14144.270,10605.000	30.000	1.858

The following expression may be stated considering the distance between two points as 30m:

$[(x1-x2)^2-(y1-y2)^2 + (z1-z2)^2]^{0.5} = 30m.$ (22)

Using the above five equations (Eq.18 to Eq.22), the upper elevation of the glare screen barrier can be determined.

For level surface, the radius of earth is assumed to be very large (6400 km), and the height of anti-glare screen is determined for different radii including the radius of earth as shown in Table 3.

Two-Dimensional Analysis

The model has been modified for two-dimensional coordinate system. Vehicles are assumed moving in an x-z coordinate system.

Let Ax+Cz = D be the equation of the road alignment which passes through the plane.

Let (x1, z1) and (x2, z2) be two points on the plane. These two points are the locations of two vehicles moving in opposite directions.

Glare occurs when the distance between the two vehicles is 30 m; hence:

$$[(x1-x2)^2+(z1-z2)^2]^{0..5}=30. \quad (23)$$

Let He and Hh be the eye height of the driver and the head light height of the two vehicles moving in opposite directions.

The coordinates of the eye height of the driver of the first vehicle and the head light of the second vehicle are:

- (x1, z1+He)
- (x2, z2+Hh)

The coordinates of the head light height of the first vehicle and the eye height of the second vehicle are:

- (x1, z1+Hh)
- (x2, z2+He)

These four points form two lines. Glare screen barrier should be installed at the point of intersection of these two lines. Let (x, y, z) be the point of intersection of these two lines.

The two points (x1, z1) and (x2, z2) lie on the plane; hence:

$$Ax1 + Cz1 = D \quad (24)$$

$$Ax2 + Cz2 = D \quad (25)$$

The equations of the two lines are:

$$\frac{x-x1}{x2-x1}=\frac{z-z1-He}{z2+Hh-z1-He} \quad (26)$$

$$\frac{x-x1}{x2-x1}=\frac{z-z1-Hh}{z2+He-z1-Hh} \quad (27)$$

From the two equations (26 and 27), it is found that:

$$\frac{z-z1-Hh}{z2+He-z1-Hh}=\frac{z-z1-He}{z2+Hh-z1-He}=\frac{He-Hh}{2(He-Hh)}=\frac{1}{2} \quad (28)$$

Hence, the location of the point of intersection may be computed as follows:

$\frac{x-x1}{x2-x1}=\frac{1}{2}$ or x2-x1=2x-2x1, hence:

$$x=(x2+x1)/2 \quad (29)$$

$\frac{z-z1-He}{z2+Hh-z1-He}=\frac{1}{2}$ or 2(z-z1-He)=z2+Hh-z1-He;

Hence:

$$z = (z2+z1)/2 + (He + Hh)/2. \quad (30)$$

The coordinates of the upper elevation of the glare screen barrier are given by:

- x=(x2+x1)/2;
- z=(z2+z1)/2 +(He + Hh)/2.

z elevation of the screen barrier (upper point) is to be calculated using Eq. 30.

Again, it is already found that:

Ax1+Cz1=D

Ax2+ Cz2=D

or

A(x1+x2)+C(z1+z2)=2D

or

$$A(x1+x2)/2 + C(z1+z2)/2 = D \quad (31)$$

Equation 31 implies that point [(x1+x2)/2, (z1+z2)/2] lies on the plane; .i.e., (z1+z2)/2 is the lowest elevation of the screen barrier.

So, the height of the glare screen barrier is given by:

(z1+z2)/2 + (He + Hh)/2 - (z1+z2)/2= (He + Hh)/2

$$\text{Height of glare screen} = \frac{He+Hh}{2} \quad (32)$$

Height of the glare screen barrier is the same as obtained from three-dimensional analysis mentioned in Equation 10.

Similar equations may be developed for parabolic and circular surfaces as shown below:

$(x/a)^2=2z$ for parabolic surface (33)

$x^2+y^2+z^2=a^2$ for circular surface (34)

$(x/a)^2+(y/b)^2=1$ for elliptical surface (35)

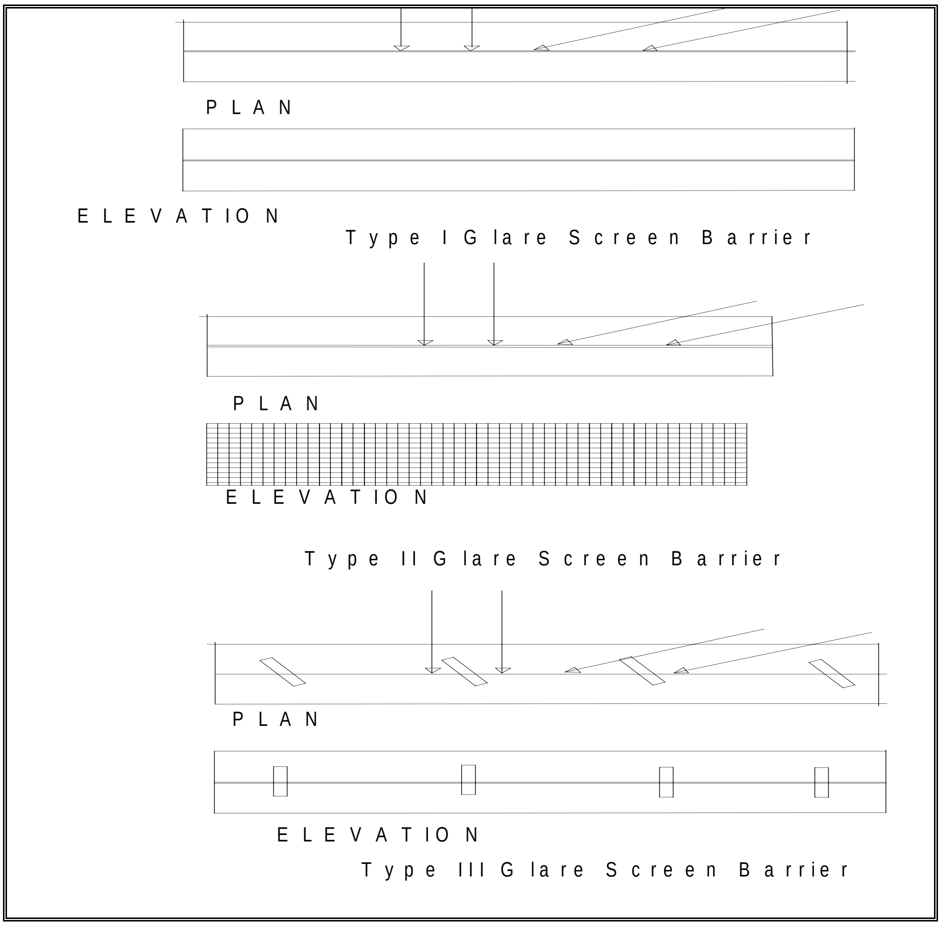

Figure 1: Plans and elevations of glare screen types I, II and III

Table 5. Comparisons of glare screen height with other models

Research Work/Practice	Height Proposed (m)	Source
UK	1.75	TA 57/87(Department of Transport, Highway and Traffic, HMSO, UK).
Japan	1.4	Nihon Doro Kodan, National Expressway Practices in Japan, 1985.
Zwahlen and Erdnic Oner	1.78 to 1.92	Zwahlen and Erdnic Oner, Improved Work Zone Design Guidelines and Enhanced Model of Travel Delays in Work Zone, Ohio Department of Transportation, January 2006.
Bagui and Ghosh	1.76 to 1.81	Bagui, S.K. and Ghosh, A. 2009. Glare Screen Height for Unsymmetrical and Unequal Vertical Curves, *Indian Highways*, 36 (4): 33-51.

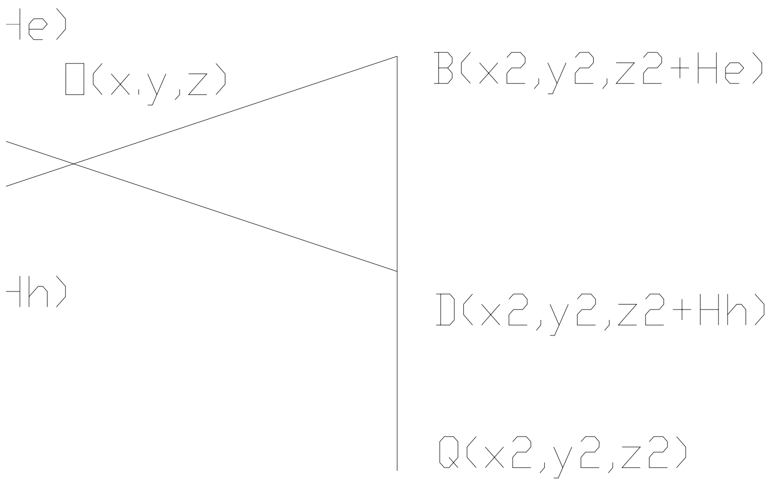

Figure 2: Position of vehicles in x,y,z coordinate system

Some typical calculations are shown in Table 4.

Comparison of the Model with other Models, and Recommendations

The height of glare screen barrier has been compared with other models and presented in Table 5.

Based on Table 4 and practices of other countries, anti-glare screen height of 1.85 m is proposed for Indian conditions. Economical glare screen barrier as shown in Fig. 3 can be proposed on the median. Height of median kerb is approximately 0.2 m. The actual height of screen barrier may be reduced to 1.65 m where kerb is provided on median.

CONCLUSIONS

The following conclusions may be drawn based on the analysis presented in this paper:

- Screen barrier height is constant for plane surface.
- Screen barrier height varies inversely with the radius of the surface for spherical surface and depends on semi-major and semi-minor axes for elliptical and hyperbolic surfaces.
- Screen barrier height is constant with a large radius of the surface.
- Screen barrier height can be modified considering the radius of surface.
- Heights obtained using other models are more or less the same using three-dimensional analysis.
- Heights of anti-glare screen barrier obtained from three-and two-dimensional analyses are compared and found more or less the same for both cases.
- Height of the glare screen barrier (1.85m) is proposed for Indian conditions.

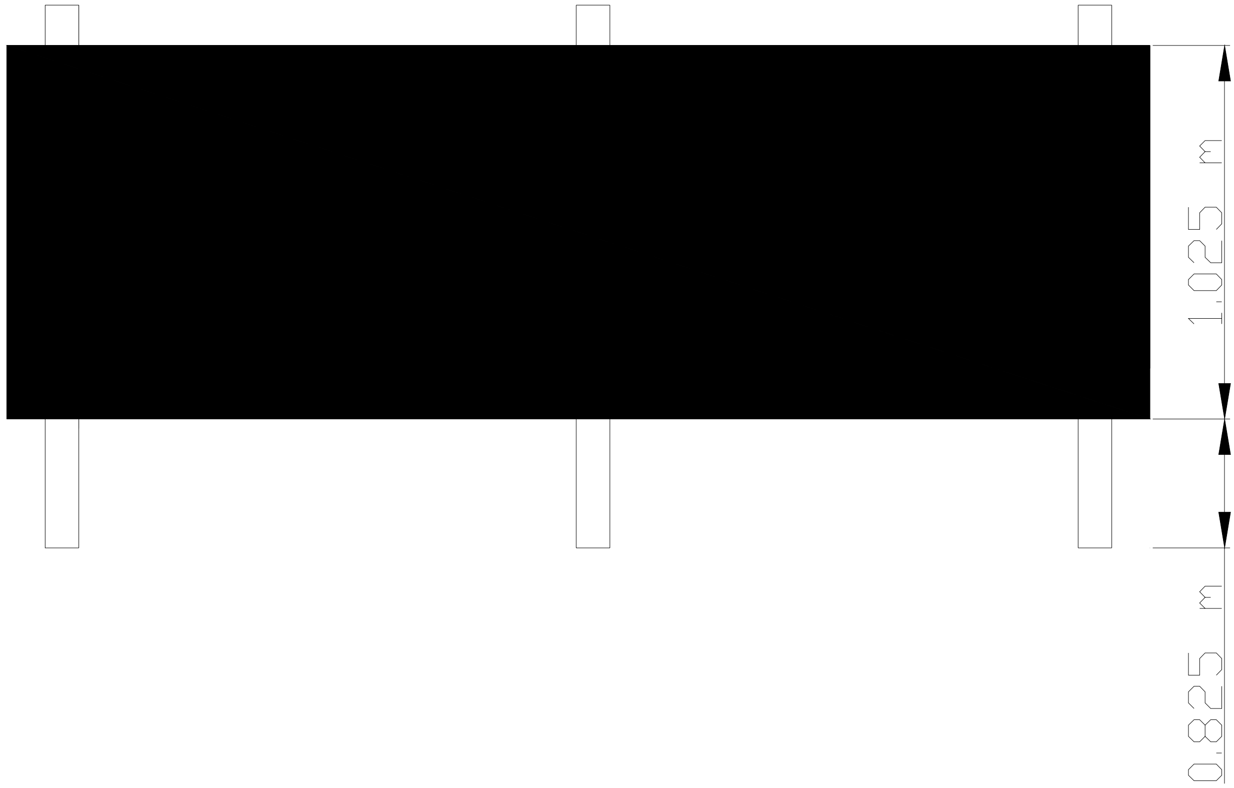

Figure 3: Typical most economical anti-glare screen barrier

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