DETERMINING THE NUMBER OF ROWS WITH SCREENING FOR VIEWERS IN THE CINEMA

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Abstract: The way to determine the number of rows in the cinema for which there is screening is given. The rows are situated in two segments form on the plan. Breakpoints of rows lie in the vertical plane of symmetry of the standard zone for viewers. The rise of rows was calculated in the same plane according to known equations. The rows were located on inclined planes' compartments and were divided into four groups (four inclined planes). The X axis was set at the floor level of the first row. The screening arose only for a number of the latter rows in each group. And this number of rows was different for each group. In the article, we first found the equations for determining the number of the last row in a group for no screening. And then, we found the equations for determining the number of rows in this group for which it arises.

Keywords: Anthropometrical, Area, Excess screen film screening, Focal point, Rise of rows.

1 Introduction

Cinemas appeared with startling suddenness and in profusion. They affected an evident change along many of the capital's prominent thoroughfares and drew in a vast new, mainly working-class, audience. Cinema was a powerful democratizing force in an era of significant social change, brought about by new technologies and a perception of a time for leisure [5].

Nowadays, when designing cinemas, be sure to comply with current rules regarding security, safety, accessibility, etc., when making the seating layout in your auditorium [3].

The seating row distance should cover the seats and give enough clearance for access and escape between the seating rows but should be larger to offer more legroom and more excellent sitting comfort. The row distance is measured from the back of one seat to the back of the next row seat [3].

We can often meet cinema with rows situated in two segments of our practice plan (Figure 1 and Figure 2) [1, 2, 4]. Imagine such a cinema with rows situated in two segments form on the plan and inclined planes' compartments.

First we describe the geometric principle of unobstructed visibility calculating for viewers of all rows [2, 6, 7]. Aim the beam of light from focal point F to viewers' monocular eye O_n of the last row. And this beam touches the top of the viewer of the previous (penultimate in the group) row (Figure 3). This is done within each group of rows [8].

The distance from the focal point to the first row of the k-th group x_k (Figure 4), if there are no transverse passes, can be calculated by the equation:

$$x_k = x_1 + d\left(\sum_{i=1}^{k-1} n_i - k + 1\right), k = 2,3,\ldots,m+1 \quad (1)$$

where $x1$ – distance from the cinema screen to the seatback of the first row; d – the space between the backs of adjacent rows (row depth); n – number of rows located on one inclined plane; m – number of inclined planes (groups of rows). Then z-coordinate of the viewers' monocular eye of the k-th group first row z_k can be determined by the recurrence equation:

$$z_k = \left(z_{k-1} + C_{k-1}(n_{k-1} - 1) - Z_f\right)\frac{x_k}{x_{k-1}} + Z_f, z_1 = h \quad (2)$$

where Z_f – distance from the floor level of the first row to the focal point (the focal point z-coordinate); h – the height of the eyes of the sitting viewer above the floor level; C_{k-1} – the excess of vision beam taken for the $(k-1)$-th group of rows (could be the same for all groups).

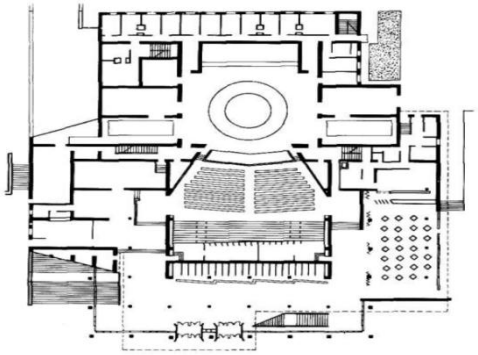

Figure 1 – The hall with two groups of rows (the first group on the plan situated in a two segments form)

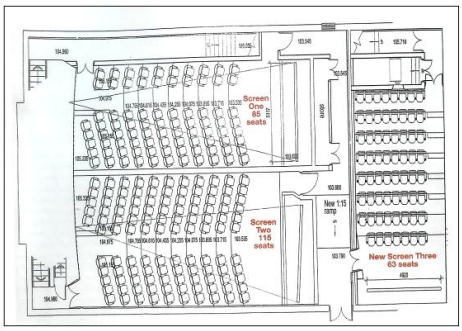

Figure 2 – The plan of project of Burnham-On-Sea Cinema

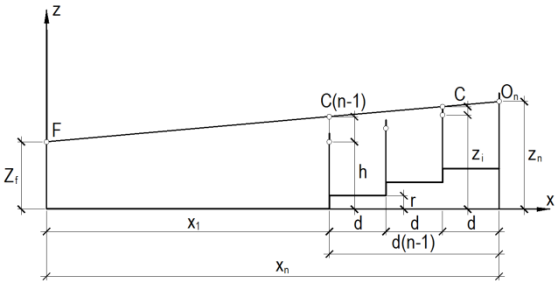

Figure 3 – The geometric principle of unobstructed visibility calculating

In design practice, the rows rise calculation is often carried out in a vertical plane along the X axis (Figure 5). Screening appears because every row has some chairs back, which belong to this vertical plane and situated further to the movie screen than other chairs' backs of this same row.

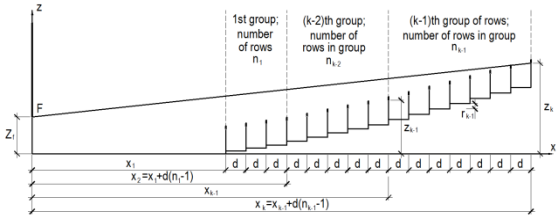

Figure 4 – An example of placement of seats for viewers on three compartments of inclined planes

A straight line of eye viewers of the next row and a straight line of heads tops of the previous row are parallel. The straight line

of head tops was created by adding anthropometric excess C_o to eye viewers *z*-coordinate. We shall also have such parallel lines because the height of the row floor is assumed to be the same for all its chairs. These lines form a plane that will give a straight line in the intersection with the movie screen (Figure 6).

If this straight line crosses the screen's side edge above its lower edge (focal line), it will appear screening. Screening can be valued by the screen area, which is between the intersection straight line, the screen lower edge, and its side edge. But screening can appear only for the last few rows in each group of rows divided by the total number of rows. However, it cannot appear. This can be checked graphically by constructing the bottom and side edges of the screen and the intersection lines of the planes formed by the pairs of the above-mentioned parallel lines with the plane of the screen.

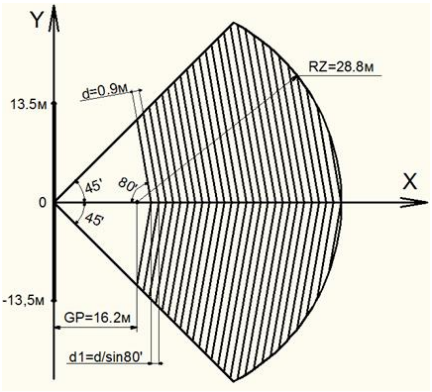

Figure 5 – The standard zone of places for viewers in the cinema, rows on the plan (lines of rows backs), movie screen and coordinate axis

Therefore, in this article, we had a goal to get a formula for determining the number of the last row for which still screening appears and determine in each group the number of rows for which this screening appears. And also, to show how to angle increase between the X axis and a row segment affects the number of rows in the group for which there is screening.

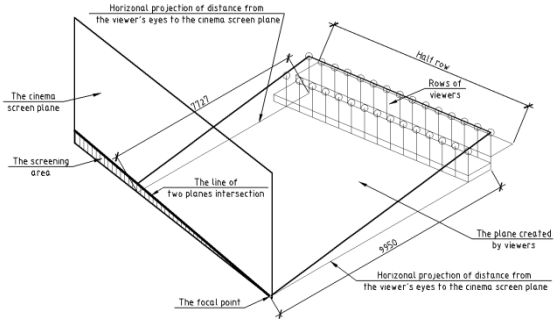

Figure 6 – To graphically determination of the cinema screen plane screening area

2 The Main Part

2.1 Output Data

We divided the total number of rows (29 rows) into four groups to achieve the goal. The first group has three rows. The second group has six rows. The third group has nine rows. The fourth group has fourteen rows. And the last row of the previous group is the first row of the next group. Calculate the rise of the rows in the hall for known recurrence formulas [6].

The height of the focal point above the floor of the first row was z_f = 1,2m; the screen width was 27 m, the distance from the focal point to the back of the first-row chair on the plan was 19,056 m, anthropometric excess was assumed to be same for all groups of rows and was C_o = 0,15 m, the row depth *d1* = 0,914 m, the eyes height of the sitting viewer over the floor was *h* =1,2 m. As a result of the calculation (Figure 7), graphs of the viewers' eyes' heights and the rows heights (*z*-coordinates) were received.

The row height is a difference between the viewer's eyes *z*-coordinate and size above the floor of the seated viewer's eyes. Also, the heights of steps were calculated.

The heights of steps were equal r_1= 0,164 m for the first group of rows, r_2= 0,197 m for the second group of rows, r_3 = 0,240 m for the third group of rows, and r_4 = 0,295 m for the fourth group of rows.

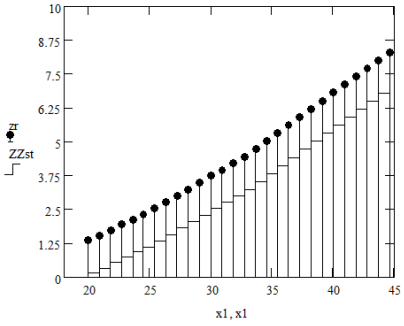

Figure 7 – Z-coordinates of the viewers' monocularеyes (zr) androws height (ZZst) depending on the distance (x1) of the row back from the focal point

2.2 Graphical Way to Determine the Number of Rows

First, we will graphically construct straight lines of intersection of the plane with the screen for viewers of each inclined plane's rows to explain calculations better. The screening will occur for spectators of every last row in the group. It follows from the method of calculation of rows rise.

Moreover, the intersection's straight line with the screen plane will pass through the middle of its lower edge (the focal point). Then we will compare the results with the results that we get analytically.

2.2.1 Results of Graphical Way

It was shown (Fig. 8) a straight line of intersection with the screen for the third (the last row of the first group) and second rows (for both links of broken rows) and the bottom edge of the screen (thick horizontal straight line).

As can be seen from the figure, already for the second row (the penultimate row of the first group), there is no screening. Screening also occurs only for the last row in the second group (the eighth row) (Figure 9). But it occurs for the last (the sixteenth) and penultimate (the fifteenth) rows in the third group (Figure 10). And it occurs over the previous three rows in the fourth group (the 29th, 28th, and 27th rows) (Figure 11).

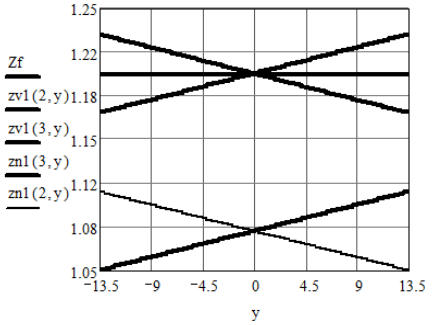

Figure 8 – The straight lines of intersection of the plane with the screen for viewers of the 3rd and 2nd rows

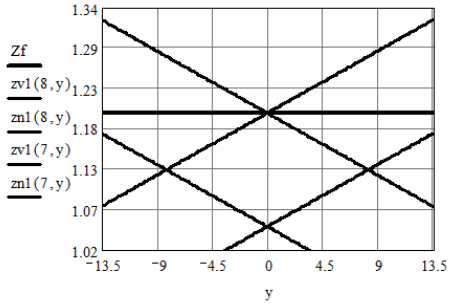

Figure 9 – The straight lines of intersection of the plane with the screen for viewers of the 8th and 7th rows

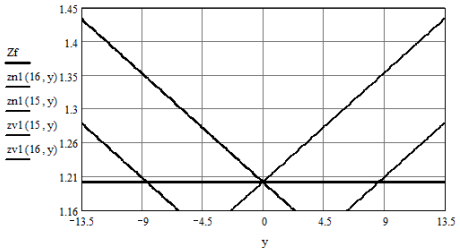

Figure 10 – The straight lines of intersection of the plane with the screen for viewers of the 16th and 15th rows

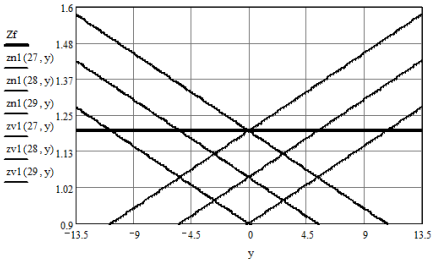

Figure 11 – The straight lines of intersection of the plane with the screen for viewers of the 29th, 28th, and 27th rows

2.3 Analytical Way to Determine the Number of Rows

Now we write the equation of a plane that passes through the viewers' monocular eyes line of the next *i*-th row and the viewers' heads tops line of the previous *i-1*-th row for the upper half of the seats (Figure 5). The plane formula can be written as a determinant.

$$\begin{vmatrix} x-x_i & y-0 & z-z_i \\ x_{i-1}-x_i & 0 & z_{i-1}+c_0-z_i \\ x_{i-1}-\cos\alpha-x_i & \sin\alpha & z_{i-1}+c_0-z_i \end{vmatrix}=0 \quad (3)$$

where x, y, z – the plane coordinates that moves; x_{i-1}, x_i, y_{i-1}, y_i, z_{i-1}, z_i, – the viewers' monocular eye coordinates of the next and the previous rows; c_0 – anthropometric excess and angle α was shown on Fig. 5.

We obtain the equation of the intersection line of the plane (3) with the screen plane x = 0 substituting in (3) zero instead of x.

$$z=\frac{(z_{i-1}+c_0-z_i)yctg\alpha+(x_{i-1}z_i-x_iz_{i-1}-x_ic_0)}{x_{i-1}-x_i} \quad (4)$$

Screening will not occur if the line intersects the side edge of the screen below its lower edge (focal line). It will happen if $y=H/2$ (H – screen width). In this case z must be less than or equal to z_f. It follows that

$$\frac{(z_{i-1}+c_0-z_i)\frac{H}{2}ctg\alpha+(x_{i-1}z_i-x_iz_{i-1}-x_ic_0)}{x_{i-1}-x_i}\le z_f \quad (5)$$

Now let's determine from (5) the last row number in the group for which there is no screening yet. For this we shall express the coordinates of the viewers' monocular eyes of the next and previous rows as a function of the row total number *i*and also the number in the group *nrg*as a function of the total number *i* of the row and the number of the group *j* in which it is located.

Let the first row of the next group be simultaneously the last row of the previous group. Then the row number in the j-th group, depending on the row total number *i* and the group number *j*, in which it is located, can be determined by the equation

$$nrg=i-\sum_{k=1}^{j-1}n_k+(j-1) \quad (6)$$

where k – the group number, j – the group number in which the row is located, i – the row total number, n_k– the rows number in the k-th group.
For example, for the fourth row, which is in the second group we shall receive

$$nrg=4-3+(2-1)=2$$

that is, the forth row is the second row in the second group of rows.

Therefore, z-coordinate of the viewers' monocular eye of the i-th row, which is in the j-th group of rows, can be determined by the equation

$$z_i=h+\sum_{k=1}^{j-1}r_k(n_k-1)+r_j(nrg-1) \quad (7)$$

Where r_k, r_j – steps height in k-th and j-th groups of rows.
In order to determine z-coordinate of i-1 row, it is necessary to subtract in the last part of equation (7), not 1, but 2. The equation will look like

$$z_{i+1}=h+\sum_{k=1}^{j-1}r_k(n_k-1)+r_j(nrg-2) \quad (8)$$

Z-coordinates of the viewers' monocular eye of the i-th and i-1 rows can be determined by the equations

$$x_i=x_1+d_1(i-1) \quad (9)$$

$$x_{i-1}=x_1+d_1(i-2) \quad (10)$$

where x_i, x_{i-1}, $x_1$are the distances from the focal point to the seats' backs of the i-th, i-1, 1-st rows and *d1*is the depth of the row along the x-axis.

Substituting (7), (8), (9), (10) into (5) and taking into account that the total number of a row can be only an integer, we obtain equation for determining the total number of the last row in the group for which there is not yet screening

$$nri=Ent\left(\frac{A+B}{D}\right) \quad (11)$$

$$A=(c_0-r_j)\frac{H}{2}ctg\alpha+(x_1-2d_1)\left(h+\sum_{k=1}^{j-1}r_k(n_k-1)-r_j\left(\sum_{k=1}^{j-1}n_k-j+2\right)\right)$$

$$B=z_fd_1-(x_1-d_1)\left(h+\sum_{k=1}^{j-1}r_k(n_k-1)-r_j\left(\sum_{k=1}^{j-1}n_k-j+3\right)+c_0\right)$$

$$D=d_1c_0$$

Where *Ent* – Antje function (the integer part of the expression given in brackets).

2.3.1 Results of Analytical Way

The equation (11) for the first group of rows gives a value of 2, for the second one – 7, for the third one – 14, for the fourth one – 26. It is clear that for the rest of the rows in groups, screening occurs.

Screening occurs in the first group only for the last third row, in the second group also only for the previous eighth row, in the third one for the previous two rows (fifteenth and sixteenth), and the fourth one for the previous three rows (27th, 28th, and 29th). The above is the total rows numbers, not the rows numbers in the groups. Therefore, the results obtained graphically and analytically are the same. Generally, the number of rows N in the *j*-th group, for which there is a screening, can be determined by the equation.

2.4 The Angle between the Screen Plane and Row Influence

The number of rows N, for which there is screening, depends on the angle α. In numerous auditoriums, the side walls are not parallel. If the walls are merely slightly angled, this will be great for acoustics and still allow for big picture size [3].

If we consider this angle to be variable, we can construct graphs of this dependence for each row. Figure 12 shows a graph for the first group of rows (the variable angle α is indicated for convenience as β, the angle is determined in radians).

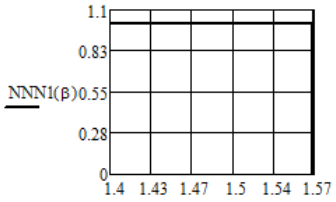

Figure 12 – The dependence of the rows number for which there is a screening zone from the angle β for the first group of rows

Figure 12 shows that the number of rows falls from one to zero for which there is screening. It happens when the angle β becomes equal $\pi/2$, that is, the broken line is straightened out.

We have a similar picture for the second group of rows. The graphs are also shown in Figure 13 and Figure 14 for the third and fourth groups of rows. We can see that for certain values of the angle β there is a jump, and the number of rows decreases.

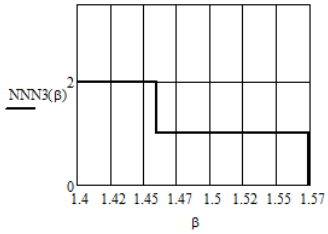

Figure 13 – The dependence of the rows number for which there is a screening zone from the angle β for the third group of rows

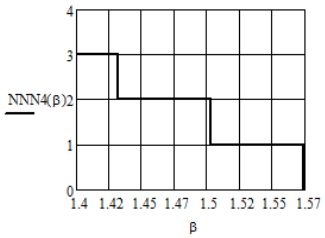

Figure 14 – The dependence of the rows number for which there is a screening zone from the angle β for the fourth group of rows

3 Conclusion

Designing a cinema is relatively possible if you follow the rules. Although, if everyone follows all the rules, all the halls will look the same. Go beyond the limitations, but always remember that a movie theater's primary goal is to give viewers the best possible movie experience. Besides, the cinema has many other rooms where you can use your creativity to create an unforgettable experience for visitors and make them come back [3].

The article described the method that allows determining the number of rows in each group for screening. The screening arises depending on the angle formed by segments of rows. The research method can be used during the design of cinemas with rows situated in two segments start on the plan. It can also be used to assess the comfort of visibility in the room and the differentiation of ticket prices.

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