Lighting Simulation of Flat and Slightly Arched Type Tunnel Based on Pasar Rebo Tunnel Data

by Endah Setyaningsih

PAPER • OPEN ACCESS

Lighting Simulation of Flat and Slightly Arched Type Tunnel Based on Pasar Rebo Tunnel Data

To cite this article: Endah Setyaningsih and Jeanny Pragantha 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **508** 012077

Lighting Simulation of Flat and Slightly Arched Type Tunnel Based on Pasar Rebo Tunnel Data

Endah Setyaningsih [1] and Jeanny Pragantha [2]

[1] Department of Electrical Engineering, Universitas Tarumanagara
[2] Department of Computer Science, Universitas Tarumanagara

[1] endahs@ft.untar.ac.id [2] jeannyp@fti.untar.ac.id

Abstract. In previous studies lighting levels were measured in several tunnels in DKI Jakarta, one of them was Pasar Rebo Tunnel. The measurement results indicate that the level of lighting in the tunnel does not meet the SNI standards. Then based on those lighting measurement, a tunnel model was developed to make a simulation of lighting level in the tunnel. This paper will discussed the influence of tunnel ceiling shape on the distribution of lighting levels in the tunnel. Simulation is done with the help of DIALUX software.

1. Introduction

The tunnel has now become part of the road infrastructure, due to the existence of a tunnel which capable of overcoming congestion that occurs on crowded roads. At daytime, tunnels generally have a natural lighting level that is inversely proportional to their length, ie the longer a tunnel is, the lower the level of natural lighting in the tunnel. In addition to the tunnel length, opening area, tunnel height, opening orientation, and surface reflection coefficients in the tunnel also influence the level of natural lighting in the tunnel [1]. The above shows the importance of artificial lighting systems that are used as the main lighting source at night when natural lighting is not available and also during the daytime when tunnel lighting levels do not meet the standards. According to the Indonesian National Standard (Standar Nasional Indonesia - SNI), the lighting level on the road surface inside the tunnel must be in the range of 20 lux to 25 lux, while the luminance is 2 cd/m^2 [2].

Besides the adequate of lighting level on the road surface inside the tunnel, the luminance or brightness of the road surface in the access zone and threshold zone of the tunnel must also be well designed, especially during daytime conditions when the contrast or brightness difference between outside and inside the tunnel is very large. In these conditions, when entering the tunnel, the driver must adapt to the difference in brightness outside and inside the tunnel in the shortest possible time, to minimize the risk of accidents due to glare. For this reason, the geometry and layout of the lights on the face of the tunnel must be well designed.

From previous studies, the results of the measurement of lighting levels and luminance at the entrance of several tunnels in DKI Jakarta were obtained. This result is used as input in the lighting model and simulation of the lighting tunnels is used the DIALUX 4.12 software. The results of measurements of actual conditions in a number of tunnels in DKI Jakarta will be optimized so that the optimal luminance parameters can be obtained at threshold zone and transition zone. The simulation consist of varying the geometry and layout of the tunnel entrance.

2. Tunnel Lighting

The tunnel is a road that is enclosed by a structure, generally the elevation of the road is below the soil surface [3]. Tunnels can be divided into "long tunnels" and "short tunnels" based on their clarity of view. Short tunnels are tunnels whose exit is clearly visible from a point directly in front of the tunnel entrance, when there are no vehicles passing by. Usually the length of a short tunnel is limited to 75 meters [1, 4]. During day time, the short tunnel generally do not need a lighting system. In contrast to the long tunnel, the driver cannot see the end of the tunnel and the sun light is blocked so an artificial lighting system is needed to increase the level of illumination in the tunnel.

The purpose of tunnel lighting is to enhance the v drivers visual performance and to maintain their sense of confidence so that they can safely pass through tunnels [5]. To achieve this goal, there are several things that must be considered [1,4]:

1. Lighting must provide the driver with sufficient illumination level throughout the tunnel in dry and wet conditions.
2. The angle of light coming relative to the driver's vision must give a high level of vision to the road markings in all weather conditions.
3. The bottom of the tunnel must also have an adequate level of lighting
4. Lighting cannot cause glare
5. Lighting should not contain flicker

2.1. Tunnel Lighting Zones

The ability of the human eye to adapt changes in the lighting level from light to dark is not as fast as adapting changes in the lighting level from dark to light. This is called a black out condition. For this reason, the level of lighting in the long tunnel is divided into 5 (see fig. 1 below) [1, 4]:

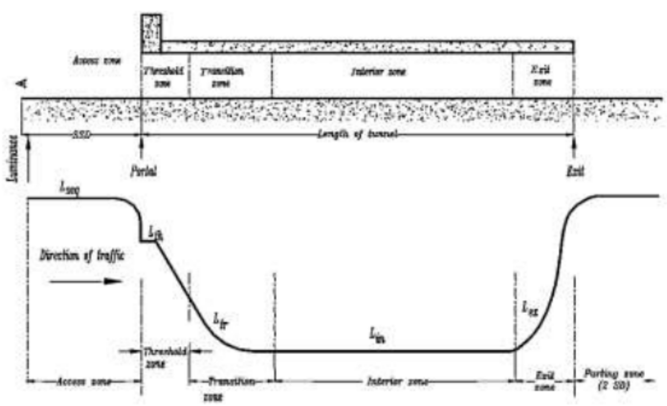

Figure 1 Tunnel Lighting Zones [1]

1. The access zone is part of the road leading to the front of the tunnel. In this zone the driver can see the tunnel. The lighting level is the same as the level of lighting outside the tunnel. Figure 2 is an example of an access zone from a flat and arched tunnel
2. The threshold zone is part of the road where the driver can look into the tunnel. The length of the threshold zone is the same as the length of the vehicle stop distance (stopping distance). Drivers in the access zone must be able to detect obstacles in the threshold zone before the driver enters the tunnel. Figure 2 shows the lighting level in the threshold zone will gradually decrease.

IOP Conf. Series: Materials Science and Engineering **508** (2019) 012077 doi:10.1088/1757-899X/508/1/012077

3. Transition zone is the zone where the light level transition occurs, which is initially relatively high in the threshold zone and then becomes much lower in the interior zone.
4. The interior zone is a part of the tunnel located on the inside of the tunnel so that it does not get significant sunlight. The driver's vision, in this zone, is only provided by artificial lighting. The interior zone has one special property, namely a constant level of lighting throughout the zone.
5. The exit zone is the last zone where the driver exits from the tunnel, the level of illumination in this zone is linearly increased to reach the level of natural light outside the tunnel.

(a) (b)

Figure 2 (a) Access Zone of Flat Tunnel – Pasar Rebo Tunnel [6]
(b) Access Zone of Arched Tunnel [7]

2.2. *Tunnel Lighting Factors*

Tunnel lighting during the day is different from tunnel lighting at night. The factors that influence tunnel lighting are: [4]:

1. Lighting control
2. Glare
3. Uniformity
4. Flicker

There are several settings for the arrangement of lights in the tunnel to achieve the appropriate level of lighting, namely [7]:

1. *Ceiling mounting*, installation of luminaires along the tunnel ceiling, can be installed on 1 line or 2 lines
2. *Wall mounting*, installation of luminaires along the tunnel wall, usually installed in 2 lines, left wall and right wall of the tunnel.

3. **Pasar Rebo Tunnel**

Pasar Rebo tunnel (or TB Simatupang tunnel) is a two-way tunnel, one way lead to Kampung Rambutan and the other way lead to Cijantung. Each tunnel is separated by a dividing wall. So this tunnel is a devided tunnel, that is, there is only one direction of traffic in each tunnel. On the left side of tunnel, there are 1 m sidewalk, 30 cm roadside gutter and 2 m roadside. The gutter is partially covered since some covered had been damaged / lost. On the right side there is only 0.5 m roadside. There three lanes vehicle in each tunnel, lane 1 is 4 m wide, lane 2 is 3.34 m wide and lane 3 is 3.34 m wide. So the total width of the Pasar Rebo tunnel is 14.38 m. The tunnel length is 270 m and 5 m high (see fig 2.a).

The number of lamps in each tunnel is 142 lamps consisting of (28 x 2) 250 watts High Pressure Sodium (HPS) lamps and (38 x 2) 400 watts HPS lamps in yellow color or CCT 2700 K and (5 x 2) LED lamps in white color or CCT 5000 K. In other words there are 71 lamps on each side of the tunnel. The distance between lamps is 5 meters away, except in the threshold zone, the distance is 0.5 meter away from the entrance portal of the tunnel, and then 2 m away until the 3rd light. Likewise the installation of lamps in the exit zone. The distance anomaly also occurs from the 47th lamp until the 57th lamp, the distance between 2 lamps is 2 m. Overall the lighting system in the Pasar Rebo tunnel

IOP Conf. Series: Materials Science and Engineering **508** (2019) 012077 doi:10.1088/1757-899X/508/1/012077

is called the wall mounting asymmetrical lighting system [7], the installation of lights can be seen in Figure 3.

4. Tunnel Lighting Simulation

In this study, Dialux software is used for modelling and simulation of lighting levels in tunnels. The data needed are the tunnel dimension, the number of lanes in the tunnel and the location and height of the lamps in the tunnel. In addition, also data about the type of lamp, lamp power, distance between lamps, type of lamp direction and some other data are also needed.

To facilitate tunnel modelling, data from the Pasar Rebo tunnel are used since it is a straight tunnel with flat ceiling. There is a slight modification, which is used 300 m tunnel length instead of 270 m length. Assuming the threshold zone 100 m length, the transition zone in 100 m length, and the rest as interior zone and exit zone. The driver's direction is from east to west. The tunnel width is 14.38 m and height is 5 m. The road reflectance is assumed to be 10% and the wall reflectance is assumed to be 20%. The tunnel is a straight tunnel, with no bends and no light holes in the ceiling of the tunnel. The type of lamp used is HPS lamp. The position of the lamp refers to the position of the installed lamp (existing condition) at the Pasar Rebo tunnel when data was collected in 2015, i.e. the position of the lamp is in the upper left and upper right corner of the tunnel, as shown in Figure 3.

Figure 3 Pasar Rebo Tunnel with flat ceiling shape

Simulations are performed to optimize the front of the tunnel by considering the intensity of sunlight. The geometric variation of the tunnel is in the form of flat ceiling tunnels and arched ceilings tunnel. Figure 2.a is an example of a flat ceiling tunnel shape and Figure 2.b is an example of an arched ceiling tunnel shape

4.1. Simulation of Flat Ceiling Tunnel

The simulation results from Dialux software for flat ceiling tunnels can be seen in figure 4 to 10. The geometry of the tunnel with a flat ceiling can be seen in Figure 4, and the tunnel dimensions can be seen in Figure 5. Tunnel lighting simulation results from the tunnel entrance can be seen in Figure 6, and on the exit zone in figure 7. On the tunnel entrance which is the threshold zone, it can be seen that the number of lamps is far more than the other zones and mounted with a very close distance. This is intended to obtain level of illumination that will decrease gradually to comfort the driver vision. The number of lamps begin to decrease in the transition zone and the least number of lamps in the interior zone. While in the exit zone, the number of lamps is more than the transition zone, so that the eyes of the driver can directly adjust to the high lighting level outside the tunnel (sunlight). The total number of lamps in the tunnel is 185 lamps, the lamps used for the simulation are HPS lamps. The simulation results of false color tunnel on a flat ceiling (see figure 8), shows the magnitude of the illuminance value (E, in Lux units) of the tunnel. It appears that E is 750 lux to 850 lux in threshold zone, in the transition zone E is 250 lux to 625 lux and in the interior zone E is125 lux. The amount of illumination for the exit zone is not visible. Illuminance at tunnel portal of the threshold zone can reach 1000 lux

Illumination of the tunnel ceiling reaches 500 lux in the near the lamp and 250 lux on the center of the ceiling. This illuminance value also appears from the isoline form as shown in Figure 9, and the isoline luminance form (in Cd/m2) as in Figure 10. Luminance at the threshold zone, L is 24 to 27 Cd/m2, at transition zone, L is 6 to 15 Cd/m2 and at interior zone L is 3 Cd/m2. Isoline is collection of points that have the same illumination or luminance value. Luminance value in this interior zone is in accordance with the standard, which is 3 Cd/m2 [1]

4.2. Simulation of Arched Tunnel

In the second simulation it is assumed that the ceiling of the tunnel is arched. The simulation results can be seen in Figure 11 to Figure 15. In all illumination tunnel and luminance zones of tunnels with arched ceilings have a greater value than the tunnel with a flat ceiling. This is caused by the reflection of the semicircular arched ceiling so that the reflection is diffuse in many directions. The spread of these light reflections increases illuminance and luminance values in all tunnel zones. The simulation results in the false color tunnel image (figure 13), illumination insulation (figure 14) and isoline luminance (figure 15), all show a greater level of illumination than the flat form of ceiling. For arched ceiling, E is 900 lux to 1000 lux and L is 28 Cd/m2 to 36 Cd/m2. Luminance value in interior zone is 4 cd/m2 which is above the standard.

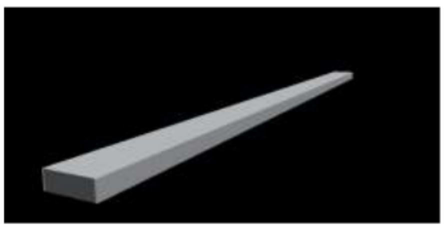

Figure 4 Simulation of tunnel geometry With flat ceiling

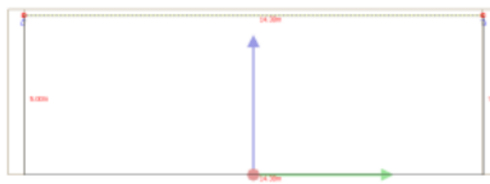

Figure 5 Dimension of flat ceiling tunnel

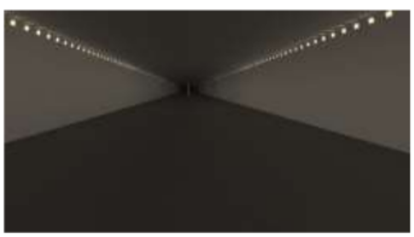

Figure 6 Simulation of tunnel lighting at entrance zone

Figure 7 Simulation of tunnel lighting at exit zone

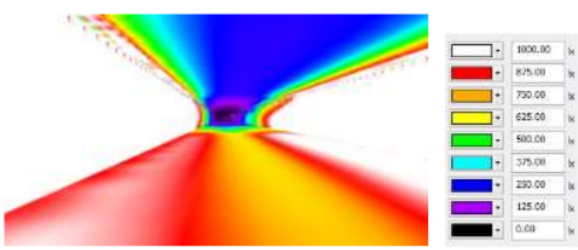

Figure 8 False color image from flat ceiling tunnel simulation

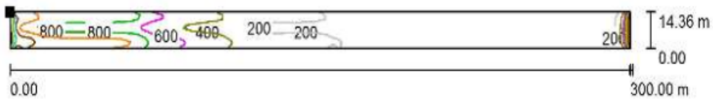

Figure 9 Isoline illuminance (in lux) for flat ceiling tunnel

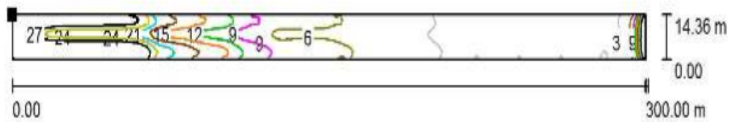

Figure 10 Isoline Luminance (in Cd/m^2) for flat ceiling tunnel

Figure 11 Geometric simulation of arched ceiling tunnel

Figure 12 Simulation of arched tunnel lighting at entrance zone

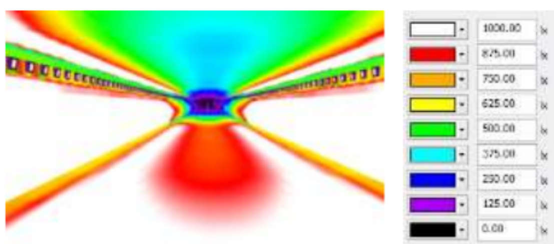

Figure 13 False color image from arched ceiling tunnel simulation

Figure 14 Isoline illuminance (in lux) for arched ceiling tunnel

Figure 15 Isoline luminance (Cd/m^2) for arched ceiling tunnel

5. Conclusion

The conclusion derives from simulation are:

1. To lighting level in the flat tunnel is according to standard

2. With the same number of lamps, lighting level in the arched tunnel is higher from the flat tunnel. Thus to achieved the same lighting level, tunnel with arched ceiling requires less lamps.
3. Lighting level at Pasar Rebo tunnel should be increase by adding more lamps

References

[1] Commision International de L'Ecclairage, 2004. "CIE Technical Report: Guide for Lighting Road Tunnels and Underpasses CIE 88-2004" 2nd Edition. Vienna: CIE Central Bureau.
[2] SNI No. 7391-2008, Penerangan Jalan Umum, Badan Standarisasi Nasional, 2008.
[3] Departemen Pekerjaan Umum, *Geometri Jalan Bebas Hambatan untuk Jalan Tol: Standar Kontstruksi dan Bangunan*, Jakarta: Departemen Pekerjaan Umum, 2009, No. 007/BM tyle.
[4] Illuminating Engineering Society of North America, 2011. "ANSI/IESNA RP-22-11: American National Standard Practice for Tunnel Lighting". New York: IESNA.
[5] Wout van Bommel, 2015. "Road Lighting: Fundamentals, Technology and Application". London: Springer
[6] Setyaningsih, Endah dan Pragantha, Jeanny, 2015, *Visual Performance Of Tunnel LightingAlongThe Jakarta Outer Ring Road*, International Conference on Engineering of Tarumanagara (ICET 2015), Faculty of Engineering, Tarumanagara University, Jakarta-Indonesia, October, 22-23, 2015
[7] Thorn, 2004. "Tunnel Lighting". Hertfordshire: Thorn Lighting Main Office

Lighting Simulation of Flat and Slightly Arched Type Tunnel Based on Pasar Rebo Tunnel Data

ORIGINALITY REPORT

9%	6%	6%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Road Lighting, 2015. Publication	2%
2	backend.orbit.dtu.dk Internet Source	2%
3	iopscience.iop.org Internet Source	1%
4	www.mdpi.com Internet Source	1%
5	Submitted to SDM Universitas Gadjah Mada Student Paper	1%
6	Salata, Ferdinando, Iacopo Golasi, Simone Bovenzi, Emanuele Vollaro, Francesca Pagliaro, Lucia Cellucci, Massimo Coppi, Franco Gugliermetti, and Andrea Vollaro. "Energy Optimization of Road Tunnel Lighting Systems", Sustainability, 2015. Publication	1%
7	repository.usu.ac.id Internet Source	<1%

8	S.Y. He, L. Tähkämö, M. Maksimainen, B. Liang, G.B. Pan, L. Halonen. "Effects of transient adaptation on drivers’ visual performance in road tunnel lighting", Tunnelling and Underground Space Technology, 2017 Publication	<1 %
9	media.neliti.com Internet Source	<1 %
10	Parise, Giuseppe, and Luigi Martirano. "Structured Distribution of Electric Power Systems: The Example of a Roadway Tunnel Architecture", IEEE Transactions on Industry Applications, 2010. Publication	<1 %
11	ebpj.e-iph.co.uk Internet Source	<1 %
12	documents.mx Internet Source	<1 %
13	sportdocbox.com Internet Source	<1 %
14	"Retraction: Detecting Faults within a Cloud Using Machine Learning Techniques (IOP Conf. Ser.: Mater. Sci. Eng. 981 022029)", IOP Conference Series: Materials Science and Engineering, 2020 Publication	<1 %