TUNNEL LIGHTING FOR VEHICLES IN DKI JAKARTA

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Abstract

Tunnel, a subsidiary structure of the street, must have lighting system in accordance with the public street lighting. Many streets in DKI Jakarta don't have sufficient lighting, and so do tunnels. This research aim is to know the lighting of two tunnels, located on Tomang junction and Jl. TB Simatupang, by measuring illuminance and luminance with light meter. Night time illuminance of first tunnel is 32 - 120 lux. Illuminance of second tunnel is 53 - 163 lux. Theses values are far above SNI value which is 20 - 25 lux. Meanwhile the lighting before tunnel entrance and after exit zone are not sufficient (below 8 lux), causing driver' sight to feel uncomfortable when he enters or exits tunnel (black hole effect). HPS lamps of Tomang tunnel give yellow color impression but TB Simatupang tunnel gives white-yellow color impression because of alternate installation of HPS lamps with some LED lamps on treshold zone. These conditions show that there isn't good planning in choosing tunnel lamp.

***Key Words**: black hole effect, illuminance, luminance, tunnel lighting, tunnel zone*

Abstrak

Terowongan diklasifikasikan sebagai bangunan pelengkap jalan, yang harus mempunyai sistem penerangan sebagaimana penerangan jalan umum. Banyak jalan di DKI Jakarta pencahayaan jalannya belum memadai, hal ini juga yang terjadi di terowongan. Penelitian ini untuk mengetahui pencahayaan pada 2 (dua) terowongan, yaitu terowongan di ~~Jl.~~ Perempatan Tomang Jakarta Barat dan di Jl. TB Simatupang Jakarta Selatan, yaitu dengan melakukan pengukuran iluminansi dan luminansi menggunakan alat ukur light meter. Iluminansi malam hari pada terowongan di perempatan Tomang dan TB. Simatupang berturut-turut adalah 32 – 120 lux dan 63 – 163 lux yaitu jauh melebihi SNI sebesar 20 - 25 lux. Sementara itu pencahayaan sebelum portal terowongan dan setelah zona exit, iluminansinya lebih kecil dari 8 lux, sehingga mengakibatkan pengemudi merasakan ketidaknyamanan penglihatan pada saat masuk dan keluar terowongan (black hole effect). Lampu HPS di terowongan perempatan Tomang memberikan kesan warna kuning, dan di Jl. TB Simatupang menggunakan jenis lampu HPS juga, namun sebagian menggunakan jenis lampu LED yaitu di zona threshold, sehingga kesan warna pada terowongan kuning dan sebagian putih. Hal ini menunjukkan perencanaan dalam pemilihan lampunya kurang baik.

***Kata Kunci**: Pencahayaan terowongan, Iluminansi, Luminansi, Zona terowongan, Black Hole effect*

INTRODUCTION

The street lighting is one part that needs to be considered in street transportation planning, especially the street lighting at night time. Good lighting is needed to estimate the car' speed, to monitor a hazard coming from the side of the car, and to maintain the inter car distance (Fusheng Li, 2012), so that the main function of the public street lighting is to provide the light for the street users to recognize the things around them quickly, accurately, and comfortably. The value of illuminance and luminance for the street lighting are mentioned in Indonesia National Standard, which are published by The Committee of National Standardization/BSN (SNI 7391, 2008). There are a lot of street lightings in DKI Jakarta which do not meet the lighting standard (Setyaningsih, et al, 2013). This conclusion is based on the measurements done on many locations in DKI Jakarta, such as in major

streets (Jl. Patimura, Jl Antasari, Jl. Daan Mogot dan Jl. Satria), in collector streets (on Pasar Rebo area and on Jl. PBSI, East Jakarta), and in some alleys in Kebon Jeruk, West Jakarta. Based on these data, it can be estimated that tunnel as street subsidiary structure has insufficient lighting. Main criteria that affects good lighting and comfortable sight of the street user is the illuminance and luminance. Other criteria is color rendering index (the unit is percent) or cgi, and color temperature (the unit is Kelvin degree). The term "tunnel" can mean *underpass* or *tunnel*. Tunnels in DKI Jakarta are the ones on Jl. TB Simatupang, on Pasar Rebo area, on Tomang junction, on Jl. Casablanka, on Cawang area and on Blok M area. Introductory survey shows that some of the tunnel lamps are on for the whole 24 hours, and some of them are off, and the illuminance of some tunnels do not meet the required standard. Maintenance of lamps and luminairres are not done regularly and it causes some tunnels look dark and neglected. Because of it, this research will measure illuminance and luminance of tunnel area, both during the day and night time. The measurement has to be done in order to design the a good tunnel lighting both on day and night time. Tunnel lighting at daytime is not the same for all the zones because of the effect of sun light at the entrance and exit area of the tunnel. Significant light contrast between the outside area and inside area of tunnel can cause the driver reduce vehicle speed as he enters the tunnel. This phenomena is called "*black hole effect*". This effect can be minimized by providing enough lighting on the entrance zone or on treshold zone so that the eyes can do the adaptation (Buraczynski, et al, 2010). The tunnel lighting at nightime should be distributed equally on all zones. The important factor of tunnel lighting is luminance because of the continuous reflection effect from the street surface, tunnel wall and tunnel roof.

The aim of this research is to analyze the tunnel lighting on Jl TB Simatupang. The result of the research will be given as a recommendation to public street lighting manager (PJU) or The Department of Energy and Industry in DKI Jakarta. The expectation is PJU will plan, design, and maintain the tunnel lighting well so that society will have a guarantee of safety, security and comfortable feeling when they pass through the tunnel.

TUNNEL

The term tunnel can mean underpass. Underpass is a street which is covered all round it, and its street elevation is generally under the ground (PU, 2009). The term underpass is more accurate to be used on the transportation sector. But the term tunnel can also mean street covering, both the natural and artificial one, without paying attention to the lenght and characterisitic of the tunnel itself. According to the practical guide of safety aspect in design, made by Public Work Ministry, tunnel is a subsidiary street structure, which must have public street lighting system. The tunnel design has to consider the need of minimum space which must be provided by all good facility and architectural element. Tunnel dimension covers the width of the street body, width of street shoulder, and width of bicycle path. Width of the down traffic should be the same as the width of the up traffic. The width of the down traffic shouldn't be less than 8 meters. When there is no shoulder of the street, the path for the street side should be provided with the hardened covering on both of traffic sides and its width shouldn't be less than 0.5 meter. The pedestrian path should be provided with no less than 0.5 meter width on both sides and no less than 5.1 meter vertical height from the hardened surface of the street. This pedestrian path is intended to give access for the pedestrian in case of emergency and for the cleaning and

maintaining service. The other meaning of tunnel is a constructional part of the street that functions as traffic service structure (traffic continuous movement). Tunnel is a shortcut way under the ground, or the hill. Generally tunnel is covered on every side except on the tips of the tunnel which both of them are open to outside surroundings. Some civil engineering experts make a condition that the tunnel shouldn't be less than 0.1 mile (approximately 160 meters). If it is less than 0.1 mile, it should be called underpass (Practical Guide of Safety Aspect of Public Work Ministry, 2013).

Tunnel consists of long tunnel and short tunnel according to its visibility. Short tunnel is a tunnel whose its exit is clearly seen from a point in front of its entrance when there is no vehicle passes by. Usually the length of the short tunnel is around 150 feet. Some tunnels whose length is 400 feet can be classified as a short tunnel if the tunnel is straight, flat, and it has certain ratio between its height and length. Short tunnel generally doesn't need lighting system in order to provide good visibility for driver. Sunlight penetration at daytime from both sides of the short tunnel, and the sillhouette effect of the light from the tip of the other side of tunnel, will provide adequate visibility. All the tunnel whose exit cannot be seen clearly from a point in front of its entrance when there is no vehicle passing by, are called long tunnel. Usually the length of long tunnel, when it is straight, is more than 150 feet. The brightness of the exit of the long tunnel, as the sillhouette effect, is usually too small to support he driver visibility.

A long tunnel can be classified into several different zones for the purpose of lighting design. The five zones are:

1. Access zone
   Access zone is part of the street which is close to the entrance of the tunnel,where the driver can detect any obstructions inside the tunnel. On this zone, the adaptation level of the driver's eyes can be determined. This adaptation level will determine how much luminance is required by the tunnel entrance located on threshold zone.
2. Threshold zone
   Threshold zone is one of the four tunnel zones which have certain characteristic. A driver on access zone must be able to detect the obstructions in threshold zone before the driver enters the tunnel. The length of this zone depends on determined maximum traffic speed. It shouldn't be less than the vehicle stopping distance. Threshold zone requires a relatively high lighting level.
3. Transition zone
   Transition zone is a zone where the transition of lighting level occurs, from the relatively high one in treshold zone to the relatively low one in interior zone. The lighting level transition occurs step by step. This zone length is a function of certain maximum traffic speed and the lighting level difference between threshold zone end and interior zone beginning.
4. Interior zone
   Interior zone, is a tunnel part which gets the least effect of sun light. The driver' visibility at this zone is really determined by the artificial lighting. Interior zone has one special feature, a constant lighting level on the whole area.
5. Exit zone
   Exit zone is a tunnel part where the sight of the driver heading to exit is affected by the light brightness from outside area of tunnel. The driver should be able to predict the

movement of the car ahead when that car is covered by the bigger shadow of other car. Figure 1 below shows the five zones of tunnel.

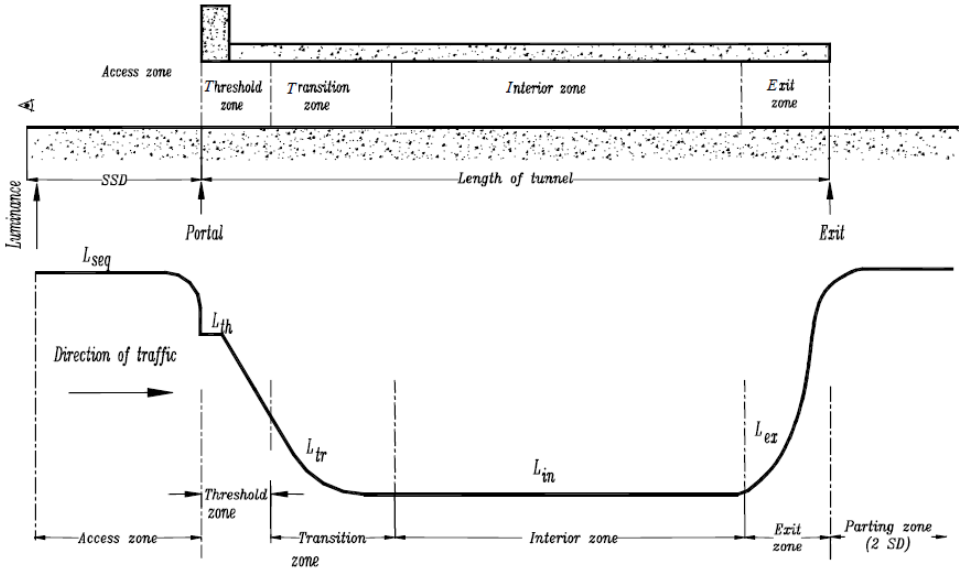


Figure 1 The Five Zones of Tunnel (CIE,2004)

Tunnel Lighting

The basic purpose of tunnel lighting is to provide adequate and comfortable visibility to tunnel user, both at day and night time (IES, 2010). Some main factors that affect the lighting design are:

1. Minimum black hole effect at tunnel entrance
   Driver eyes at daytime will adapt to high luminance on access zone, causes the tunnel entrance with a low luminance is seen as "black hole". Figure 2 is the picture of the black hole effect at tunnel.

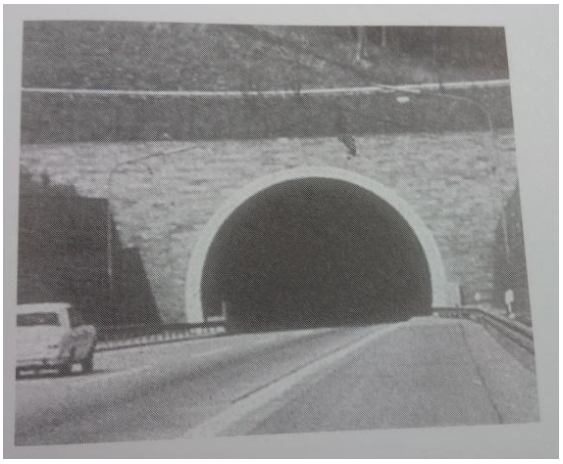


Figure 2 Black Hole Effect at Tunnel Entrance with Bad Lighting

(Phillips,1993)

2. Tunnel classification into zones with different length and different lighting level so that the eyes can adapt from the strongest sun light to the minimum tunnel lighting level.
3. Location and position of the light source
4. Minimum glare
5. Minimum flicker on dark-bright area (zebra area)
6. Adequate reflection along the tunnel
7. Comfortable color contrast along the tunnel
8. Sufficient lighting for traffic signal and signs

Tunnel lighting level is stated in average horizontal values of highway at the minimum condition. The wall reflection of 70% or more and luminaire usage which shine the street and the wall will produce horizontal lighting level according to the rule, and makes the visibility become satisfactory or good enough. At this condition, the horizontal lighting level will also produce enough vertical lighting level. The vehicle speed limit inside the tunnel is 75 miles per hour (ANSI/IES Rp-22-11, 2011), and in the crowded traffic, the maximum inter vehicle distance is 50 feet. The driver focus is paid mainly on the signs located on the pavement body and side, which shapes the vehicle path. The driver focus is also paid on the vehicle in front of him and to the vehicles of the opposite direction. Well distributed lighting level on vertical and horizontal surface is very important for a good visibility inside the tunnel. Luminance on vertical surface is very important for the tunnel path beside the wall. High wall luminance on the tunnel entrance is very useful to reduce the black hole effect.

Tunnel Lighting at Daytime

A tunnel doesn't need extra lighting at daytime when the exit is fully visible from a point in front of the tunnel, which is a stopping distance from the entrance. On the other hand, a tunnel needs extra lighting when the exit, from the same distance above, looks like a black frame and the obstructions inside the tunnel (for example: a vehicle) cannot be seen. A tunnel is classified as a long tunnel, although the length is short, when the driver cannot see the exit from stopping distance in front of tunnel. The need of daytime lighting can be seen on the diagram made by CIE (Commission Internationale de L'Eclairage), and it is shown in Figure 3.

Below are the types of lamps recommended for tunnel lighting (Buraczynski,et all, 2010 and SNI 7391, 2008):

1. Fluorescent lamp
2. Low pressure sodium lamp (LPS)
3. High pressure sodium lamp (HPS)
4. High voltage mercury lamp
5. LED (Light Emitting Diode) lamp
6. Electrodeless lamp (induction lamp)

The LED lamp is not recommended for tunnel lighting because of its complex installation, its inconsistency in light color, lamp age, and efficacy (Buraczynski,et all, 2010). Recently there is a LED lamp used for public street lighting with good performance (Fat, 2013). But LED lamp will not give good performance when the planning, design and installation are

not optimum. This thing can be found on the major street lighting in Jl. Antasari DKI Jakarta. The excessive numbers of LED lamps are causing glare and its lighting level is far above the SNI value (Setyaningsih, et al, 2013).

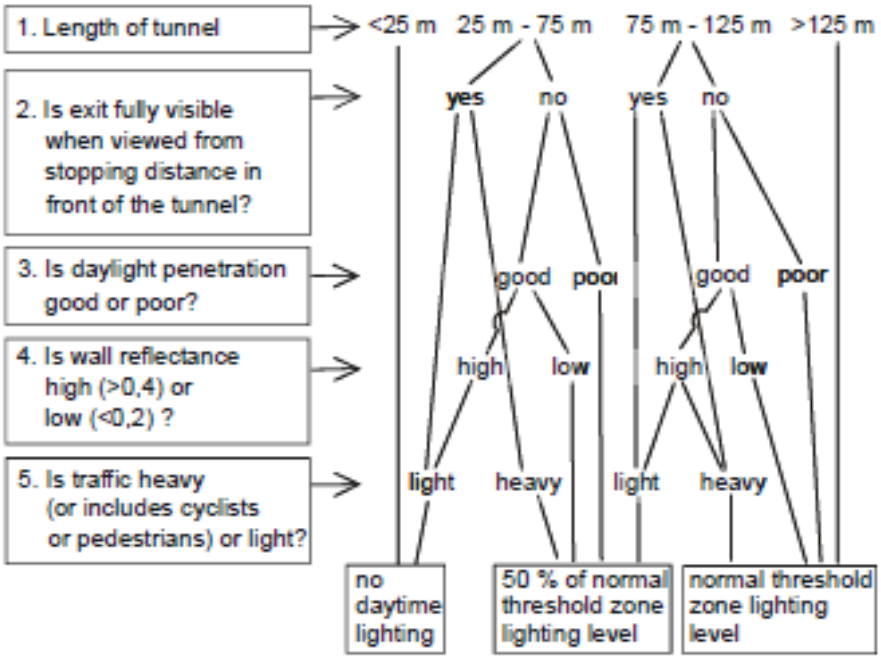


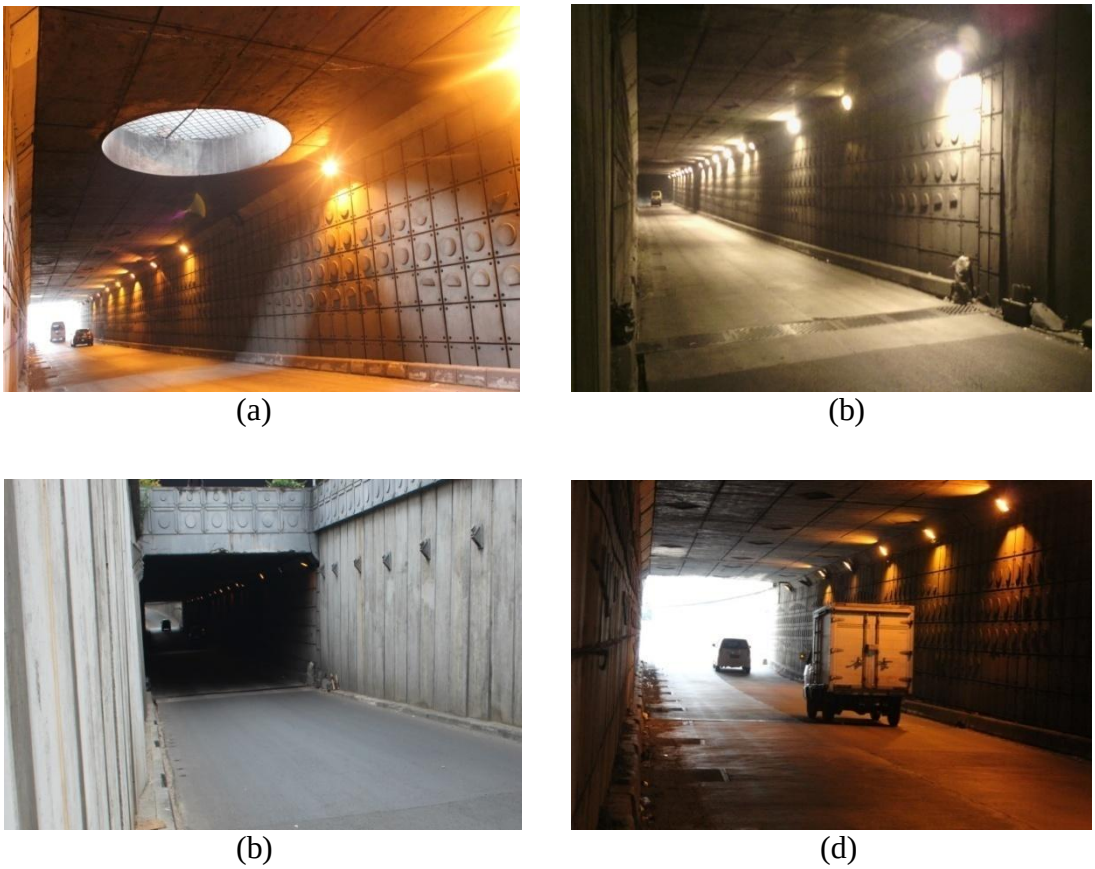
Figure 3 The Need of Lighting at Daytime for Tunnels with Various Length (CIE, 2004)

MEASUREMENT RESULT AND ANALYSIS

Tomang junction tunnel consists of tunnel to Tangerang direction and to Jakarta direction with the average speed of car passing by is around 60 km/hour. This tunnel is 120 meters in length. Each tunnel has 20 HPS lamps. The inter lamp distance is 6 meters, and the power of each lamp is 250 watt. HPS lamp has yellow color impression with *corelated color temperature* (CCT) of 2000 degree Kelvin. In the tunnel, there is one lamp housing with one broken HPS lamp and one off HPS lamp.

The device needed in this research is luxmeter or light meter to measure illuminance (the unit is lux), luminance meter tomeasure luminance (the unit is candela per square meter) and the ruler to measure the distance (the unit is meter). The measurement is done on Tomang junction tunnel at night and day time and its lighting can be seen on Figure 4. The Tomang junction illuminance at night based on the measurement done is 30 to 120 lux (the distribution is 0.26). Day illuminance is of 65 to 580 lux with the distribution of 0.11. Both day and night illuminances exceed SNI which is between 20 and 25 lux. The illuminance increase at daytime is caused by sunlight coming from the entrance and exit of the tunnel. There is also a light hole with the diameter of 3 meters on the middle of the tunnel (as shown in Figure 4) which causes the lighting not well spread along the tunnel (day distribution is smaller than night distribution). It also causes the tunnel luminance exceed SNI in the proximity of the light hole, with the value of 5.5 cd/m^2 (SNI value is 2

cd/m^2). The luminance along the tunnel is between 1.2 and 42 cd/m^2. The luminance of 42 cd/m^2 is the luminance of treshold zone due to sunlight. The much smaller value of luminance on treshold zone compared to luminance on access zone has caused the black hole effect which is very disturbing for the driver visibility and the the driver eyes cannot adapt to the lighting change quickly. Figure 4 also shows Tomang junction tunnel provide no pavement. There is only a narrow side strip with the small width which doesn't comply to the safety aspect width of 0.5 meter in minimum. The tunnel width of 7 meter also doesn't comply with the safety requirement, which is of 8 meter. The height of the tunnel is only 4 meters, although it is supposed to be 5 .1 meters in minimum. The tunnel length of 120 meters causes the tunnel being classified as underpass, and not tunnel. According to Practical Guide of Safety Aspect by Public Works Ministry, 2013, the minimal length of a tunnel is 160 meters. But according to CIE, 2004, the Tomang junction tunnel can be classified as tunnel, so that it has to comply with the tunnel lighting conditions, both at night and daytime.



(a) (b)

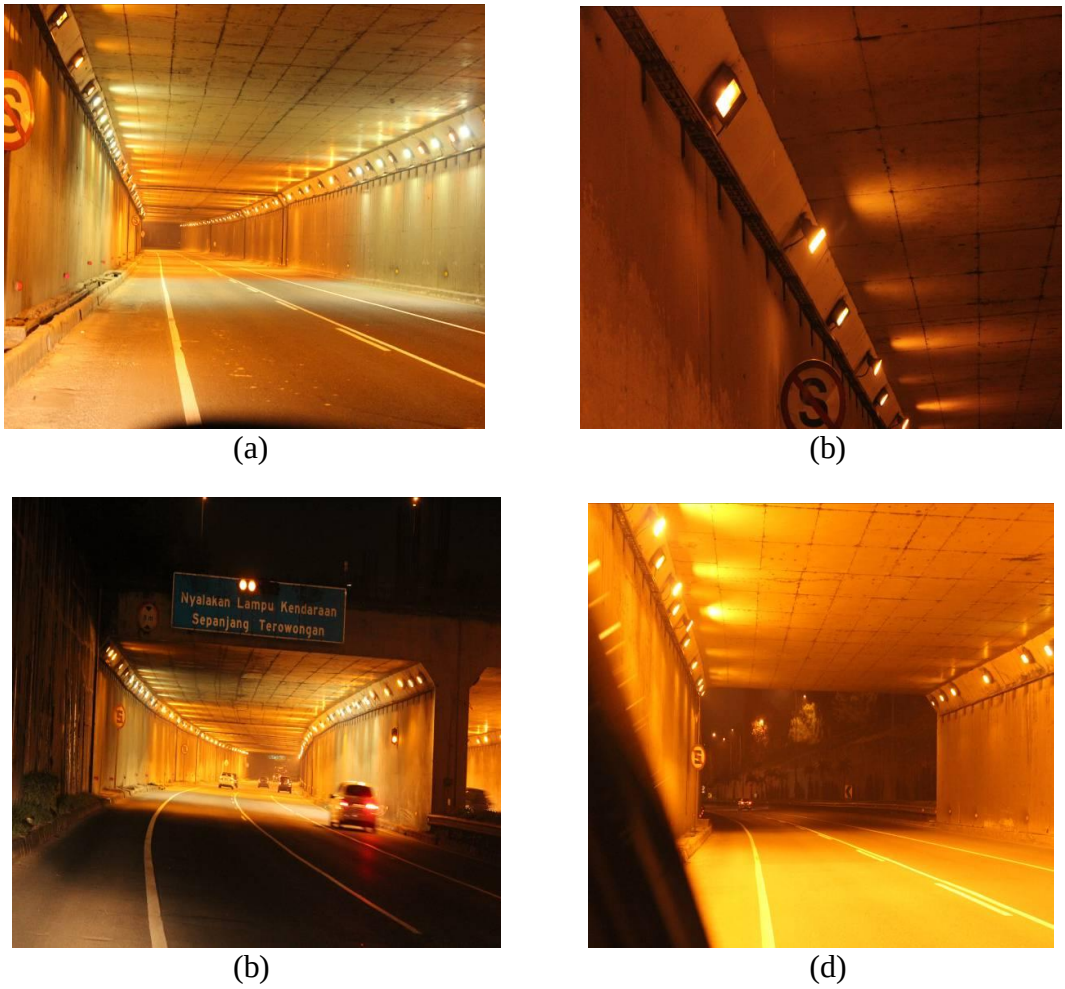
(b) (d)

Figure 4 Tomang Tunnel Lighting

(a) Daytime (b) Nighttime (c) *Black Hole effect* dan (d) Exit Zone.

The next measurement is done on TB Simatupang tunnel which also consists of two tunnels. One tunnel is to Kampung Rambutan direction and the other one is to Cijantung

direction. The illuminance data of these two tunnels vary from 53 lux to 163 lux. The numbers of lamps used on each tunnel are 66. The HPS lamps with yellow color are 61, and its CCT is 2000 degree K. The LED lamps with white color are 5, and its CCT is 5000 degree Kelvin. The tunnel are 250 meters in length, 11 meters in width, and 5 meters in height. Lamps are installed with the same distance at all zones. The distance is 4 meters. The pavement dimension is only 30 cm in width. It even cannot be called a pavement because it is actually a gutter without covering. The tunnel lighting at night time can be seen in Figure 5.



(a) (b)

(b) (d)

Figure 5 Tunnel Lighting on Jl. TB Simatupang at Night Time

(a) All Tunnel Zones (b) Lamp Installation (c) Lack of Illumination before Tunnel Entrance
(d) Lack of Illumination after Tunnel Exit

Based on measurement data of both tunnels on Tomang junction and TB Simatupang, the illuminance is bigger than SNI value (20 – 25 lux). The distributions are of 0.26 and 0.32, which are bigger than SNI, 0.2. A distribution value bigger than 0.2 shows big difference between minimum and maximum illuminance due to improper lamp installation (see Figure 5b). The alternate lamp installation towards the street body towards tunnel side are meant for better light distribution. Although the lighting is on at daytime, the black hole

efffect still appears on both directions of the tunnel. The illuminance of interior, transition and treshold zone are not well designed. Daytime tunnel lighting also doesn't consider different illuminance requirement on each zone of tunnel. Meanwhile the lighting of access zone is around 3000 lux due to sunlight (this value is a lot bigger compared to the value of lighting of other zones in the tunnel). But the big illuminance difference at night time between tunnel entrance – exit lighting (below 8 lux) and lighting inside tunnel (53 to 163 lux) is disturbing visual comfort of the driver (see Figure 5c and 5d). This can also be called as black hole effect.

The mixture alternate installation of HPS lamps and 5 LED lamps on TB Simatupang tunnel are causing mixture color impression of yellow and white (see Figure 5a). This thing shows the lack of planning in choosing type of lamp for the tunnel. It is recommended to use one type of lamp for one tunnel. The age of HPS lamp is around 20,000 hours and its efficacy is high (85-150 lumen/watt). But its color renderation is 23%, which is not good enough to identify the object color inside the tunnel. Higher color renderation will cause the color of the shone object mimic the real color of the object, and it is good for identifying the color of traffic signs and signal. This is in accordance with the safety practical guide of Public Work Ministry, which states that traffic signs and signal have to be fully visible and get the sufficient lighting from car lights and street lighting. Regardless of its low color renderation, the yellow color impression of HPS lamp is good for public street and tunnel lighting when the weather is rainy and foggy. Its light distribution is also good and well spread. Actually the LED lamp is recommended for the public street and tunnel lighting due to its very long age (100,000 hours) and its higher efficacy, compared to the age and efficacy of HPS lamp. The LED lamp is very suitable for energy conservation program. The color choice of white can be replaced by yellow color, for the LED lamps already installed inside the tunnel. The inter lamp distance and the housing of LED lamps should be reconsidered because its light distribution is not good enough.

CONCLUSION

Tunnel illuminance of Tomang junction and Jl. TB Simatupang are a lot bigger than the recommended value by Indonesia National Standard No. 7931 year 2008. It is, of course, a waste of energy. It also causes big illuminance difference among the major street lighting, both before and after the tunnel, and creates visual discomfort to the driver. On the other hand the light distribution is also not good. Lamps used for one tunnel should be of the same type. The CCT, color rendering index and lamp type should be put into consideration too. The existence of light hole in the middle of the Tomang junction tunnel makes the tunnel luminance higher than SNI. It also makes the lighting not distributed well.

Black hole effect appears at daytime both on Tomang junction and TB Simatupang Street tunnels due to big luminance and illuminance difference between acces zone and other zones (treshold, transition and interior zones). Tunnel lighting should be different at daytime and night time due to the penetration of sunlight into the tunnel during the day through threshold and exit zones.

Generally the lighting of Tomang junction and Jl. TB Simatupang are not good enough. The lighting on major street, before and after the tunnel, is supposed to follow the SNI. If condition of these two tunnels can represent the tunnels on DKI Jakarta then Department of Industry and Energy as tunnel and public street lighting manager, has to plan, design, install, and maintain tunnel lighting in a better manner so that the drivers can have a guarantee of safety, security and comfort when they pass through tunnel.

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