Research on Illumination Energy Saving Technique of Highway Tunnel

Zhi Han    Yun Tu
Jian Zhou   Xiaojun Wang
Chongqing Communications Research & Design Institute
Oct 2006

Contents
1. Energy Saving in China
2. The development of Chinese Highway Tunnel
3. Energy consumption at Road Tunnel
5. Main methods for energy-saving

Energy Saving in China

Energy saving is a mainly problem to be faced by the developing countries. "The middle and Long Period Special Planning of Energy Saving" was published by Chinese government in 2004. It states the efficiency of energy saving is 2.2% for each year from 2003 to 2010; every ten thousand Yuan GDP energy saving in 2010 requires to decline 18% than 2003, and the mainly unit energy saving is near or up to international level of the early period of 90th century. National "the 11th of five years" planning states, the aims in the nearly five years are to increase the efficiency of resource utilization and decline the unit GDP energy consumption about 20% than the end of the 10th of five years.

The development of Chinese Tunnel

Coastal Bohai sea crossing project, DaLan sea crossing project, Qing-Huang under sea tunnel object, Chong-Ming Island channel project, Hangzhou bay project, Taiwan Channel Connection project, Nanwan toy Channel project, Houpkong-Zhu-Mao sea crossing project, Qiongzhou Channel project.
Energy consumption at Road Tunnel

Energy consumption in road tunnel is tremendous. Calculating by theory, the value of electricity is about three powers of the value of ventilation. Normally, energy consumption at ventilation is about 70% to 80% of total tunnel energy consumption. Apart from a little bit less electricity is used at night and in a clouded day, full-load running is performed almost in all of other times. This also implies that half of whole energy consumption is wasted on ventilation instead of equipment. Energy consumption at Qinling Zhongnanshan Highway Tunnel (18.02km) is up to 7,880,000kwh every year. The West-lake North Section Tunnel which is in the process of building of Shanghai-Chengdu Highway is 150km (one direction). Illumination electricity has been a heavy burden in highway operation management, and even unable to make ends meet.

Current Status of Energy Saving for Highway Tunnel of China

The mostly methods
Considering the power supply and illuminator source in design.
Achieving energy saving by stage implementing and parameters optimizing

The mostly technologies
Frequency conversion timing, Fluorescence lamp, High efficiency energy saving illumination lamp, SLM street lamp electricity efficiency management system and no-harmonic high voltage frequency converter.
Database of tunnel entrance luminance design

Database explain: Open explanation window

Information input:
Query by environment:
Open environment query window
Query by sort:
Open sort query window
Custom query:
Open corresponding founded query
Close window:
Macro demand

Management:
Open tunnel entrance watch preview table
Open statistic window
Close window:
Macro demand

Applying new energy saving lamp source

The values (cd/m²) of lightness at each stage of the north hole of YanLie mountain tunnel (applying electromagnetic induction lamp)

<table>
<thead>
<tr>
<th>Illumination stage</th>
<th>Entrance Stage</th>
<th>Transition Stage 1</th>
<th>Transition Stage 2</th>
<th>Middle Stage</th>
<th>Exit Stage 1</th>
<th>Exit Stage 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requiring Value</td>
<td>140</td>
<td>42</td>
<td>14</td>
<td>4.3</td>
<td>22.5</td>
<td>22.5</td>
</tr>
<tr>
<td>Testing Value</td>
<td>60.5</td>
<td>39.9</td>
<td>25.6</td>
<td>5.0</td>
<td>24.2</td>
<td>37.7</td>
</tr>
</tbody>
</table>

The symmetrical value of ground at the north hole of YanLie mountain

<table>
<thead>
<tr>
<th>Item</th>
<th>The total symmetrical value of ground</th>
<th>The symmetrical value of ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requiring Value</td>
<td>0.4</td>
<td>0.6-0.7</td>
</tr>
<tr>
<td>Testing Value</td>
<td>0.87</td>
<td>0.95</td>
</tr>
</tbody>
</table>

P.S.: The upper data multiplied the maintain coefficient of electromagnetism telepathy lamp

The symmetry value of ground at the north hole of YanLie mountain

<table>
<thead>
<tr>
<th>Item</th>
<th>The total symmetrical value of ground</th>
<th>The symmetrical value of ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requiring Value</td>
<td>0.4</td>
<td>0.6-0.7</td>
</tr>
<tr>
<td>Testing Value</td>
<td>0.87</td>
<td>0.95</td>
</tr>
</tbody>
</table>

P.S.: The upper data multiplied the maintain coefficient of electromagnetism telepathy lamp

Investigation result of drivers' illuminating effect

<table>
<thead>
<tr>
<th>Research Items</th>
<th>Evaluation Effect</th>
<th>Person</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength Contrast of</td>
<td>Electromagnetic</td>
<td>172</td>
<td>89.12%</td>
</tr>
<tr>
<td>Beam (feeling)</td>
<td>induction lamp</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>strong</td>
<td>16</td>
<td>8.29%</td>
</tr>
<tr>
<td></td>
<td>Same</td>
<td>5</td>
<td>2.59%</td>
</tr>
<tr>
<td>Safety Contrast</td>
<td>Electromagnetic</td>
<td>171</td>
<td>88.60%</td>
</tr>
<tr>
<td>induction lamp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>strong</td>
<td>15</td>
<td>7.77%</td>
</tr>
<tr>
<td></td>
<td>Same</td>
<td>7</td>
<td>3.63%</td>
</tr>
<tr>
<td>Effect</td>
<td>Electromagnetic</td>
<td>165</td>
<td>85.49%</td>
</tr>
<tr>
<td>induction lamp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>strong</td>
<td>22</td>
<td>11.40%</td>
</tr>
<tr>
<td></td>
<td>Same</td>
<td>6</td>
<td>3.11%</td>
</tr>
</tbody>
</table>

P.S.: The upper data multiplied the maintain coefficient of electromagnetism telepathy lamp
LED lamps are applied to Guizhou highway

Application of energy-saving control equipment

The energy saving efficiency of the energy saving control equipments of HuaYing mountain tunnel in Si Chuan is up to 30%

Energy saving 30%

Dezhou was been named the sun city of China in June 2005; applying for taking the international sun city convenence in 2010; the solar energy application of tunnel illumination energy saving research on less than 500m tunnels was organized by Chinese ministry of communications.

The lowest illumination requirement research on road tunnel was developed in Hubei to discuss the contribution of LED inducement lamp in tunnel illumination and safety.
Main routes are possible for energy-saving of highway tunnel.

1. Reduced brightness of tunnel opening: Brightness value outside tunnel determines value of $l_{20}$, and value of $l_{20}$ determines lighting standard $L_{20}$ of entrance section. $L_{20}$ not only decides lighting standard of entrance section, but also determines lighting standard of transition section. And entrance section and transition section are the sections where maximum electricity is used. For design vehicle velocity above 60km/h, value is taken between $30 \sim 270 \text{cd/m}^2$, with discrepancy as high as 9 times. This shows that reduced brightness at entrance and exit may bring very remarkable effect of energy-saving.
2. Improved reflectivity of road surface: Cement concrete road surface causes big noise, and bitumen road surface allows small noise and comfortable driving, but pollution is easily caused by fire. Considering from view of lighting and based on “specifications”, conversion between average brightness and average luminosity, bitumen road surface is \((15-22) \times 10^3 \text{lx/cm}^2\), and cement concrete road surface \((10-13) \times 10^3 \text{lx/cm}^2\). Calculated by average value, use of cement concrete road surface will save energy 61% more than that in adoption of bitumen road surface.

3. Application of energy-saving control equipment: This mainly includes light regulation control equipment and voltage regulation control equipment, both being used in Xiamen Haicang Tunnel and Sichuan Mt.Huaying Tunnel with good results. According to test report by Sichuan Provincial Energy Saving Center, energy-saving of 29.8% is achievable when voltage regulation control unit is used.

4. Optimized parameters of lighting design: Using design velocity of 100km/h will consume 100% more electric energy than design velocity of using 80km/h. For big traffic volume, using design velocity of 80km/h will consume 80% more electric energy than using design velocity of 60km/h. For small traffic volume, 67% more electricity will be consumed.

5. Improved reflectivity of wall: Wall and road themselves in tunnel provide a background to an obstacle in tunnel. Better reflectivity of wall will enable reflectivity from light on wall to achieve stronger illumination of road. Reflection of wall should be 0.6-0.7 or better, and its surface should not be too glasslike to prevent glitter of come-and-go vehicles.

6. The low energy consumption lamp choosing:

Fluorescence Lamp
Sodium Lamp
Electromagnetic Induction Lamp
LED Lamp

7. Adoption of rational way of installation: For way of installing lamps in basic section of tunnel includes single row middle installation, symmetric installation on both sides and staggered installation on both sides. In different ways of installing lamps, quantity of lamps and degree of easiness in maintenance are not identical. At present, the newest way of installing lamps is single-row middle slanting installation, which is not only energy-saving, but also easy to maintain.

8. Selection of highly efficient way of lighting: Compared with frontlighting lighting, backlighting lighting may enhance light efficacy by 30%.

9. Intelligent control model: Automatic lighting control according to variety of traffic volume and vehicle velocity.