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Original Paper

Design on illumination of structures for lighthouse in Korea

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Abstract: This paper presents information about the examples of the design on Illumination of Structures(LED Light Pipe for lighthouse) in Korea. We have applied illumination by flood-lighting or facade-lighting in place of the 57 lighthouses (offshore structures) and 4 beacons. The ways of illumination of structures are using direct illumination with LED, halogen lamps and metal halide lamps, and indirect illumination with LED non-neon lamps. The illumination of structures helps a observer to identify the Aids to Navigation and w aterway. The fabricated LED Light Pipe is a transparent acrylic round bar and easy to install. The Light Pipe is arranged in two rows of L ED (78ea). It can be connected in series. It has 4 colours(Red, Green, Yellow, White). We analyzed and the horizontal divergence angle of the LED light pipe is defined as the range with 50% of maximum luminous intensity. Also, we evaluated the conspicuity on the origin al lantern and LED Light pipe for lighthouse. The field experiment was conducted in 'Yeosuguhang lighthouse' in Yeosu-city (Korea). F rom the experimental results, it was confirmed that the fabricated LED Light Pipe is clearly distinguished.

Keywords: Aids to Navigation (A to N), Illumination of Structures, LED Light Pipe, Lighthouse

1. Introduction

The marine Aids to Navigation (A to N) is a device or system external to vessels that is designed andoperated to enhance the safe and efficient navigation of vessels and/or vessel traffic **[1]**.

Visual aids are purpose-built facilities that communicate information to a trained observer on a vessel for the purpose of assisting the task of navigation. The communication process is referred to as marine signaling. Common examples of visual aids include lighthouses, beacons, leading (range) lines, buoys, day marks and traffic signals **[1]-[3]**.

The ways of illumination of structures are using direct illumination with LED, halogen lamps and metal halide lamps, and indirect illumination with LED non-neon lamps. We have applied illumination by flood-lighting or facade-lighting in place of the 57 lighthouses (offshore structures) and 4 beacons.

The illumination of structures helps the observer to identify the A to N and waterway **[3]-[6]**. The exterior illumination of A to N structures improves visibility (conspicuity) for marine navigators.

We fabricated LED Light Pipes(3 types, 4 colours) and analyzed the horizontal divergence angle of them **[7]**. Also, we evaluated the conspicuity on the original lantern and LED Light pipes. From the experimental results, it was confirmed that the fabricated LED Light Pipe is clearly distinguished.

2. Example of the Illumination of Structure for Lighthouse

To improve visibility (conspicuity) for marine navigators, the light illuminates outside of the A to N structure. **Figure 1** and **Figure 2** show example of the the illumination of structures for lighthouse in Korea. The whole view of Wando Hang Lighthouse (direct illumination) on day and night is shown in **Figure 1** and **Figure 2** shows a night view of Pohang Hang Lighthouse located in breakwater (indirect illumination).

Figure 1: Wando Hang Lighthouse - Direct illumination

Using the same color of illumination lighting and the A to N lighting can enhance conspicuity of A to N. It has helped mariners on the sea

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voyage and it also provide a new sight of beautiful port.

Figure 2: Pohang Hang Lighthouse -Indirect illumination

3. Fabrication and Analysis

3.1 Fabrication of LED Light Pipes

The LED Light Pipe is designed to be easy to install, including connectors, mounting holes and transparent acrylic round bar. The Light Pipe is arranged in two rows of LED (78ea). It can be connected in series.

We designed Light Pipes with 3 types, as shown in **Figure 3** and **Figure 4**. LEDs of Type-1 and Type-2 are installed on the flat plate and V-type plate and covered with condensing lens (60°). LEDs of Type-3 is arranged on the V-type plate without condensing lens.

The photograph of fabricated LED light pipes is presented **Figure 5**. There are 4 colours (Red, Green, Yellow, White).

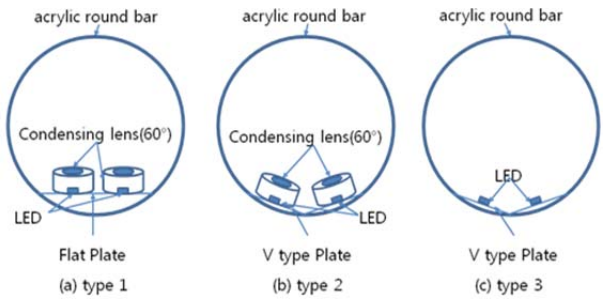


Figure 3: The internal structure of the LED light pipes

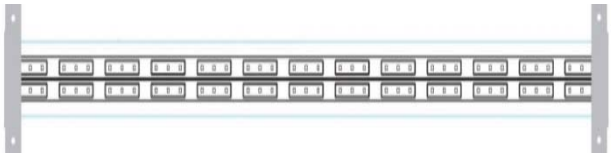


Figure 4: Schematic drawing of LED light pipes

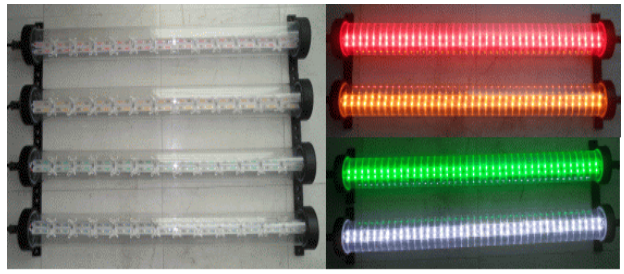


Figure 5: The photograph of LED light pipes.

3.2 Measurement and Analysis of LED Light Pipe

Figure 6 shows the photograph of the experimental apparatus to analyze the electrical and optical characteristics of LED Light Pipes.

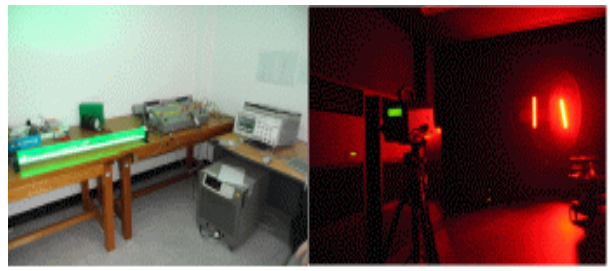


Figure 6: The photograph of the experimental apparatus.

The following **Table 1** and **Table 2** show the specifications and optical characteristics of the LED light pipes. The applied voltage of the Light Pipe is DC 12V using a battery, and the value of current flowing in Light Pipe is applied differently depending on the colour. Power of that is in the range of 14.04W (White) ~ 16.44W (Red).

The horizontal divergence angle of the LED light pipe is defined as the range with 50% of maximum luminous intensity.

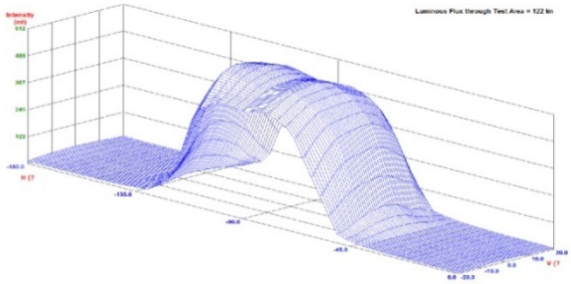
Table 1: Specifications of LED Light Pipes.

Light Pipe Type	LP-G	LP-R	LP-Y	LP-W
Colour	Green	Red	Yellow	White
Size (L)	Φ80, 1000mm	Φ80, 1000 mm	Φ80, 1000 mm	Φ80, 1000mm
LED quantity	78 (2rows)	78 (2 rows)	78 (2 rows)	78 (2 rows)
Voltage (V)	12	12	12	12
Current (A)	1.21	1.37	1.29	1.17
Power Consumption(W)	14.52	16.44	15.48	14.04

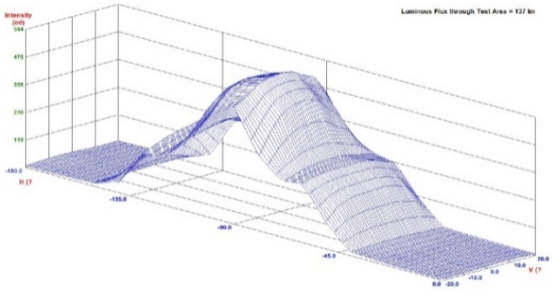
Table 2: Optical characteristics of the LED Light Pipes

Light Pipe Type	**LP-G-1**	**LP-G-2**	**LP-G-3**
Maximumluminous intensity (cd)	613	594	252
Luminance(cd/㎡)	4,785	4,634	1,920
Horizontal divergence angle(°)	60	51	100
Light Pipe Type	**LP-R-1**	**LP-R-2**	**LP-Y-1**
Maximumluminous intensity (cd)	293	297	257
Luminance(cd/㎡)	2,659	2,691	2,347
Horizontal divergence angle(°)	60	51	59
Light Pipe Type	**LP-Y-2**	**LP-W-1**	**LP-W-2**
Maximumluminous intensity (cd)	250	905	883
Luminance(cd/㎡)	2,484	7,633	7,172
Horizontal divergence angle(°)	52	61	52

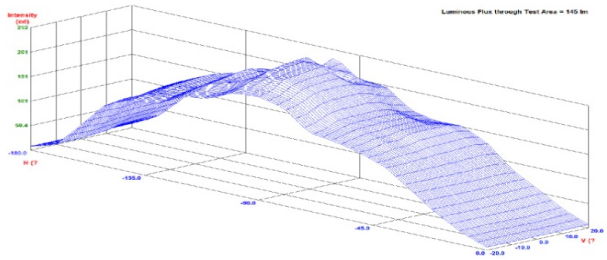
The light distribution curves of the LED light pipes with 3 types are shown in **Figure 7**.



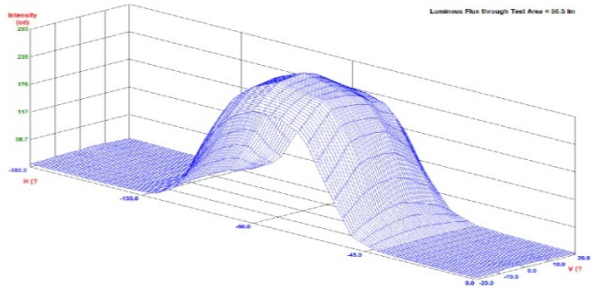
(a) Type-1, Green (LP-G-1)



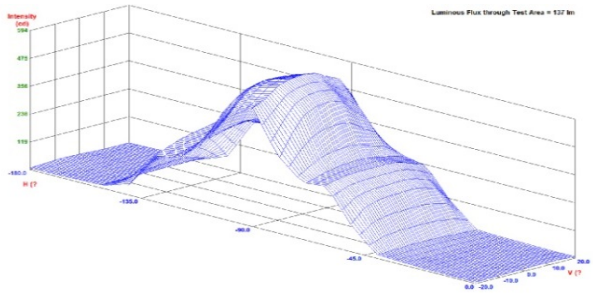
(b) Type-2, Green (LP-G-2)



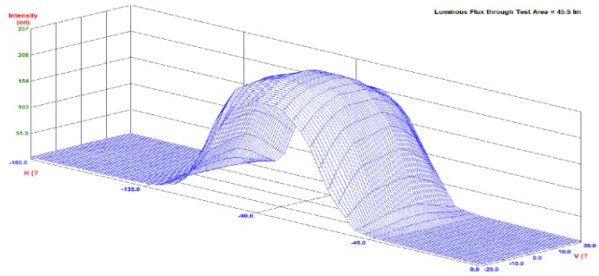
(c) Type-3, Green (LP-G-3)



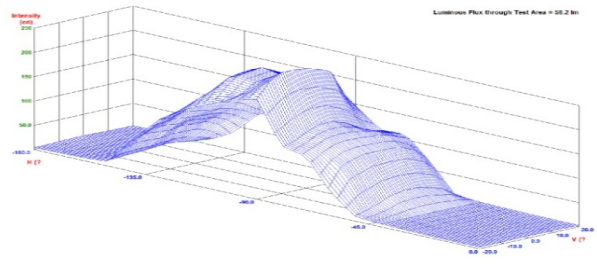
(d) Type-1, Red (LP-R-1)



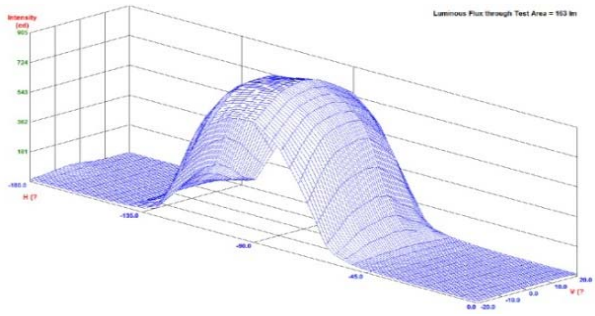
(e) Type-2, Red (LP-R-2)



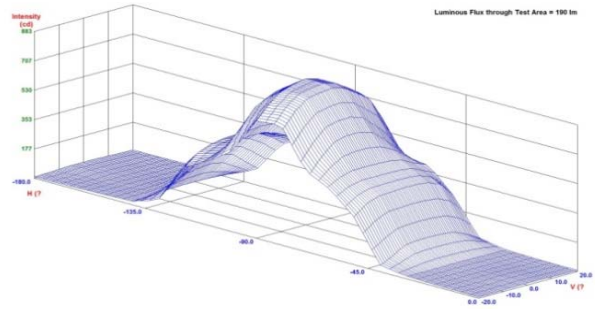
(f) Type-1, Yellow (LP-Y-1)



(g) Type-2, Yellow (LP-Y-2)



(h) Type-1, White (LP-W-1)



(i) Type-2, White (LP-W-2)

Figure 7: The light distribution curves of the LED light pipes

Figure 7 (a) ~ Figure 7 (c) : Green LED Light Pipe

The maximum luminous intensity of Type-1 (flat plate with 60° lenses) was 613cd, that of Type-2 (v-type plate with 60° lenses) was 594cd, and that of Type-3 (only v plate) was 252cd. The horizontal divergence angle of Type-1 sample was 60°, that of Type-2 was 51°, and that of Type-3 was 100°.

Figure 7 (d) ~ Figure 7 (e) : Red LED Light Pipe

The maximum luminous intensity of Type-1 (flat plate with 60° lenses) was 293cd and that of Type-2 (v-type plate with 60° lenses) was 297cd. The horizontal divergence angle of Type-1 sample was 60° and that of Type-2 was 51°.

Figure 7 (f) ~ Figure 7 (g) : Yellow LED Light Pipe

The maximum luminous intensity of Type-1 (flat plate with 60° lenses) was 257cd and that of Type-2 (v-type plate with 60° lenses) was 250cd. The horizontal divergence angle of Type-1 sample was 59° and that of Type-2 was 52°.

Figure 7 (h) ~ Figure 7 (i) : White LED Light Pipe

The maximum luminous intensity of Type-1 (flat plate with 60° lenses) was 905cd and that of Type-2 (v-type plate with 60° lenses) was 883cd. The horizontal divergence angle of Type-1 sample was 61° and that of Type-2 was 52°.

From the performance evaluation of produced Light Pipes, it was generally confirmed that Type-1 is better than Type-2 with a wider horizontal divergence angle and larger maximum luminous intensity.

4. Results of the Field Test

In the field experiments, we evaluated the conspicuity on the original lantern and LED Light pipe for lighthouse. The field test was conducted in 'Yeosuguhang lighthouse' in Yeosu-city (Korea). We observed a distance of 790m from the lighthouse.

Figure 8: The location of the field test (Yeosu-city)

Figure 9: Photograph of the original lantern and installing LED Light Pipe (Green)

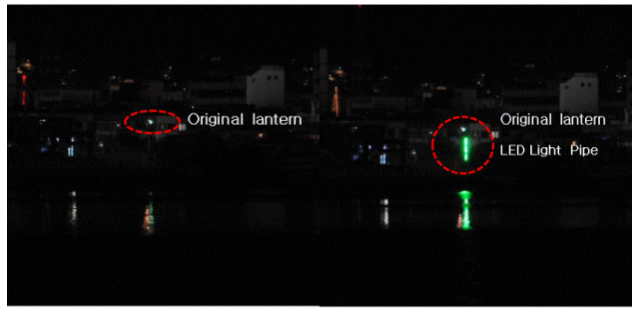


Figure 10: Comparison of conspicuity on the original lantern and LED Light Pipe (Green)

Three Light pipes fixed on the mounting plate were installed as a serial in the vertical direction (LP-G-1 (upper), LP-G-2

(middle), and LP-G-3 (lower)). In order to distinguish the original lantern and LED Light Pipe, the developed Light Pipe left a interval (1.5m) from the original lantern. The rhythm characteristic of light was set equal to F1 G 4s (original lantern) so as to compare the conspicuity on the original lantern and LED Light pipes.

From the field test, it is confirmed that the fabricated LED Light Pipe was clearly distinguished in the conditions that exist in the background lights.

The field experiment is required for the different colours of the Light Pipe. The optical characteristics (including luminous intensity, luminance, visible range, et al.) on Illumination of Structures should be continually considered.

5. Design of Illumination of Structures

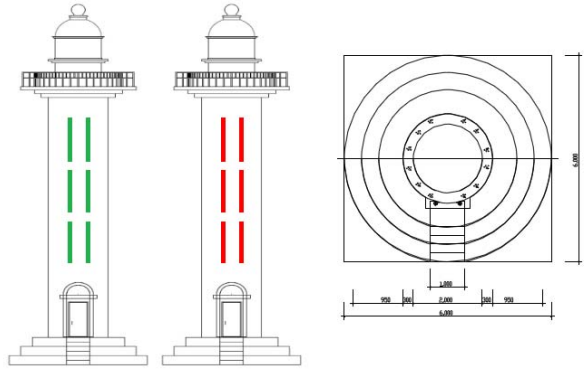
The method of installing the LED light pipe in place of the existing LED floodlight (breakwater lighthouse installed in Jeju Island) is proposed.

Figure 11 presents example of LED floodlights installing illumination of structure for Seogwipooehang lighthousein Jeju Island. The configuration diagram of the LED light pipe arranging intervals of 30° in a breakwater house is shown in **Figure 12**. It is for the ship to enter the harbour. The arrangement of LED light pipe, depending on the installation environment, can be variously changed.

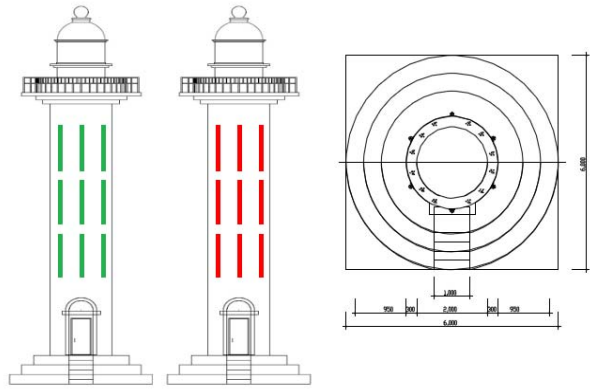
Table 3 shows the electrical characteristics to compare exiting LED floodlight with LED light pipes. It is possible to operate with only 27.5% of the power by installing the Light Pipe instead of exiting LED floodlight for illumination of structures.

Also, the study on the method of installing the LED light pipe in place of the conventional LED floodlight is needed.

Figure 11: Pictures of breakwater lighthouse installing LED floodlight (Seogwipooehang in Jeju Island).



(a) 2 lines arrangement (intervals of 30°)



(b) 6 lines arrangement (intervals of 60°)

Figure 12: Design of the LED light pipes on the breakwater lighthouse

Table 3: Comparison of the proposed method using LED light pipe and existing LED Floodlight.

Item	unit	LED Floodlight (Red)	LED light pipe (Red)	
Voltage	V	DC 15V	DC 12V	
1set Power Consumption	W	36	16.5	
Number of LED (1set)	EA	12	78	
Size	㎜	360x100x55	1,000x80x80	
Total Number of the Light	set	30	6	18
Total Power Consumption	W	**1,080**	99	**297**
Viewing angle	º	360	120	360
Installation type	-	Radial arrangement (Round)	2 lines at intervals of 30°	6 lines at intervals of 60°

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