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Field evaluation of selected light sources for roadway lighting

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HIGHLIGHTS

- The illuminance values of various types of devices were measured under actual roadway lighting conditions.
- The performances of the luminaires were evaluated and compared to the conventional HPS luminaires in both roadside lighting and high mast lighting.
- LED lighting technologies were recommended for roadway lighting applications.
- It was recommended that further efforts be made by manufacturers to improve the light uniformity.

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ABSTRACT

The development of new lighting sources, such as light emitting diode (LED), induction, and plasma, presented more possible cost effective ways for roadway lighting. A study was therefore conducted for the Indiana Department of Transportation (INDOT) to evaluate the performance and effectiveness of some selected new lighting devices in roadway lighting. This paper describes the field evaluation process and presents the evaluation results. A number of LEDs, plasma and induction luminaires from various manufacturers were selected to replace the existing high pressure sodium (HPS) lamps in conventional and high mast lightings. Illuminance values were measured over a period of 12 months on the existing and new light sources. Light performance metrics, including illuminance level and uniformity ratios, were calculated to make quantitative comparisons of the HPS and new types of light devices. Based on the evaluation in terms of lighting performance and life cycle costs, it was concluded that LED luminaires should be utilized in roadway lighting in place of HPS luminaires. The results of this study will be useful to state highway and city street agencies in making decisions on their lighting policies and developing technical specifications for use of the new lighting technologies in roadway and street lightings. The study provides a basis for manufacturers to improve their luminaire design and integration to better fit the needs of roadway and street lightings.

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1. Introduction

There is an increasing interest in using new lighting technologies in roadway and street lightings. The new lighting technologies include light emitting diode (LED), induction and plasma light sources. The most commonly claimed benefits of the new light sources include increased reliability, improved efficiency, and reduced maintenance costs. Due to this growing interest and demand, an NCHRP study (Bullough et al., 2013) was conducted to evaluate the potential and proper application of LED lighting technology. They concluded that efficiency and photometric performance had evolved to the point that LED roadway lighting was a feasible choice and could often lead to reductions in energy use of around 15% or greater, or life-cycle cost reductions in the long term, depending upon the initial cost of LED luminaires. However, specific luminaires using LED sources can have a wide range of performance, and should be judged on an individual luminaire basis.

The Indiana Department of Transportation (INDOT) has been contacted by vendors requesting possible application of the new light sources for roadway lighting. Before adopting the new lighting systems, INDOT would like to determine if the new lighting systems meet required light output and if they are cost effective. Moreover, it is necessary for INDOT to establish standardized guidelines for evaluating the new lighting systems prior to the formal adoption. This study was conducted to evaluate some selected lighting devices in roadway lighting. The major effort of this study was to address engineering issues, such as light levels, life cycle cost, maintenance, traffic safety, and approval procedures for new lighting technologies based on field evaluations. The evaluations include the properties, benefits and costs, and effectiveness of selected new lighting devices in roadway lighting applications. Illuminance values were measured over a period of 12 months on the existing and new light sources to identify light distributions. Light performance metrics in terms of illuminance levels and uniformity ratios were calculated to make quantitative comparisons between the lighting performances of the existing and new lighting devices. It is believed that the information presented in this paper will be useful to state highway and city street agencies in making decisions on their lighting policies and developing technical specifications for use of the new lighting technologies in roadway and street lightings. It is also believed that such information is useful for manufacturers to improve their luminaire model design and integration to better fit the needs of roadway and street lightings.

2. Highway lighting luminaires

2.1. *HPS lamps*

There are three types of lighting sources that have been widely used for indoor and outdoor lighting applications, including incandescent, fluorescent, and high intensity discharge (HID) lights. For highway facilities, lighting is commonly provided at interchanges, rest areas, weight stations, tunnels, and parking lots. The HID light source family consists mainly of four members, including mercury vapor (MV), low-pressure sodium (LPS), high pressure sodium (HPS), and metal halide (MH) lights. HPS is the most commonly used for roadway lighting. HPS luminaires are the main lighting source for almost all state-owned highways in Indiana (INDOT, 2012).

HPS lamps were introduced in the 1960s. An HPS lamp commonly consists of four basic components, including a sealed, translucent, ceramic arc tube, main electrodes, an outer bulb, and a base (Halonen et al., 2010; USDOE, 2010). The arc tube ceramic contains a mixture of a small amount of xenon gas and sodium-mercury amalgam and is used to provide a proper environment for producing light. The xenon at a low pressure is used as a "starter gas" in the HPS lamp. Lying at the coolest part of the lamp, the sodium-mercury amalgam provides the sodium-mercury vapor that is needed to draw an arc. The main electrodes are made of tungsten and carry a high-voltage, high-frequency pulse to strike the arc and vaporize the mercury and sodium. The outer bulb, typically elliptical in shape and made of hard glass, protects the arc tube from damage and prevents oxidation of the internal parts. It also contains a vacuum that reduces convection and heat losses from the arc tube to maintain high efficacy. The lamp base is typically a screwed base made of brass or nickel and provides a socket for electrical connection. An HPS lamp requires an inductive ballast to regulate the arc current flow and deliver the proper voltage to the arc.

2.2. *MH lamps*

MH lamps are also a member of HID lamp family. MH lamps can offer an excellent combination of quality and performance. MH lamps not only present more natural blue-white light compared to HPS lamps, but also provide increased efficacy compared to MV lamps. A standard MH lamp consists of four basic components, including quartz arc tube, main electrodes, outer bulb, and base. The operation of metal halide lamps is similar to HPS lamps in that they produce light by way of an arc tube contained within a glass bulb (LSC, 2017). When an MH lamp is energized, the