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# Illumination Guidelines for Nighttime Highway Work

*An NCHRP digest of the findings from the final report on NCHRP Project 5-13, "Illumination Guidelines for Nighttime Highway Work," conducted by the University of Florida. Drs. Ralph D. Ellis, Jr. and Zohar Herbsman served as co-principal investigators.*

## INTRODUCTION

This digest presents guidance in selecting a suitable illumination system for nighttime highway construction.

An increased amount of nighttime highway work is being performed on both divided and undivided highways in urban and rural settings to minimize the congestion effects of daytime reductions in capacity and/or to accelerate the work. This often necessitates the use of illumination to facilitate work while maintaining a safe work area for the travelling public and the workers. As nighttime work continues to increase in frequency, guidelines for illumination systems need to be developed and made available to public agencies and contractors. These guidelines will identify the types of light sources and the minimum and maximum levels of illumination required for a variety of nighttime work in typical highway situations. Without such guidelines, illumination will continue to be provided on a trial and error basis, which can be costly in both time and safety. NCHRP Project 5-13 was initiated to address this need.

An initial phase of research was conducted under NCHRP Project 5-13, "Illumination Guidelines for Nighttime Highway Work," by the University of Florida. This research, completed in 1995, provided preliminary illumination guidelines for construction and maintenance activities. To assess the suitability of these guidelines based on evaluations of a variety of nighttime highway work projects, to recommend design requirements for temporary roadway lighting in work zones, and to prepare illumination guidelines that can be considered for adoption by AASHTO, a second phase of research—to be completed in early 1998—is being performed under NCHRP Project 5-13(2), also by the University of Florida.

This digest provides a summary of the work performed in the first phase of research. The material in this digest is extracted from the final report on NCHRP Project 5-13.

## FINDINGS

As part of the project, current practices for nighttime highway work and illumination were reviewed. This review revealed that nighttime construction and maintenance work is performed by at least 24 state departments of transportation. The construction activities most commonly performed at nighttime are resurfacing, barrier walls and traffic separators, milling and surface removal, marking and stripe painting, bridge deck construction, concrete pavement construction, base course construction, ditch and channel excavation, embankment filling and compaction, and highway signing.

The maintenance activities most commonly performed at nighttime are sweeping and cleanup, concrete pavement repair, bridge deck rehabilitation and maintenance, resurfacing, milling and surface removal, lighting system repair, traffic signal maintenance, marking and stripe painting, surface treatment, and barrier walls.

The preliminary guidelines prepared in this project are intended to assist in planning, designing, and operating nighttime highway work zone lighting systems. These guidelines address visibility requirements, lighting equipment, lighting configuration and arrangement, lighting system design, system operation and maintenance, and economic considerations.

## Visibility Requirements

To ensure visual acuity and provide an environment in which both workers and motorists can function effectively, comfortably, and safely, consideration must be given to visual task, lighting condition, and human factors.

The visual task is largely influenced by the luminance of the object, luminance of the background, contrast, size, and duration. Lighting condition—sometimes referred to as quantity and quality of lighting—deals with illuminance, glare, and uniformity. Issues associated with human factors include both physical and psychological factors, such as eye condition, adaption level, fatigue level, and subjective impressions.

To facilitate highway construction lighting design, three illumination categories have been proposed. These categories, designated Categories I, II, and III, require average maintained illumination levels of 54, 108, and 215 lux (5, 10, and 20 foot-candles), respectively. Category I is recommended for the general illumination in the work zone and areas where crew movement takes place. Category II is recommended for illumination on and around construction equipment. Category III is recommended for tasks that require increased attention. Table 1 lists examples of nighttime construction and maintenance activities suited for each category.

**TABLE 1 Illuminance Levels and Categories for Nighttime Highway Work**

| Category | Minimum Illuminance Level | Area of Illumination | Application | Example of Areas and Activities to be Illuminated |
|---|---|---|---|---|
| I | 54 lux (5 fc) | General illumination throughout spaces | Large size visual task<br>Low accuracy<br>General safety requirement | Excavation<br>Sweeping and cleanup<br>Movement areas in the workzone<br>Movement between two tasks |
| II | 108 lux (10 fc) | General illumination of tasks and around equipment | Medium size visual task<br>Low to medium contrast<br>Medium accuracy Safety on and around equipment | Paving<br>Milling<br>Concrete work<br>Around paver, miller, and other construction equipment |
| III | 216 lux (20 fc) | Illumination on task | Small size visual task Low contrast<br>High accuracy and fine finish | Crack filling<br>Pot filling<br>Signalization or similar work requiring extreme caution and attention |

## Lighting Equipment

The selection of lighting equipment must consider light sources, luminaries, and photometric data.

Two basic types of light sources are commonly used for construction work zone lighting: incandescent and electric discharge. Incandescent lamps include general service and tungsten halogen lamps. Electric discharge lamps include metal halide, mercury, high pressure sodium, low pressure sodium, and florescent lamps. Table 2 lists the general features of several light sources and the recommended application for each.

**TABLE 2 Lamp Characteristics and Applications**

| Light Source | Lumen Output per Lamp | Efficacy (Lumens per watt) | Life (hrs) | Color Adaptability | Degree of Light Control | Maintenance of Lumen Output | Recommended Applications |
|---|---|---|---|---|---|---|---|
| Incandescent Tungsten Halogen | Fair | Low (24) | Low (2,000) | High (Daylight White) | High | Fair | Task oriented lighting<br>Equipment mounted lights<br>Small areas<br>Low mounting heights |
| Mercury Vapor | Good | Fair (63) | High (24,000) | Fair to Good (Medium White) | Fair | Fair | Not recommended |
| Metal Halide | High | Good (110) | Good (10,000) | Good (Bright White) | Good | Good | Medium sized areas<br>Good color rendition required<br>Varied mounting heights |
| High Pressure Sodium | High | High (140) | High (24,000) | Fair (Soft, Orange) | Good | High | Large areas<br>Color rendition not important<br>Varied mounting heights |
| Fluorescent | Low | Fair to Good (85) | Fair (7,500) | Fair to High (Daylight White) | Fair | High | Not recommended |

Illuminaries are composed of one or more lamps and other parts to distribute light, control glare, position and protect lamps, and connect them to the power supply. Typical luminaries used for floodlighting include round spun and cast heavy duty with vertical and horizontal lamps. Performance of luminaries is measured in terms of light distribution by photometric data. These data generally include the level of symmetry of the light distribution for different horizontal angle ranges.

**Configuration of the Lighting System**

As part of the lighting system design, an illumination system configuration is selected with consideration to work zone size, required mobility, duration of work, required illuminance level, and cost. The basic options for configuring illumination systems are the temporary, portable, and equipment mounted.

A temporary system is a fixed lighting system consisting of luminaries mounted on poles to illuminate an entire work zone or a large portion thereof. With such a system, a high quality of illumination can be achieved although at a high cost and potential for inefficiency. A portable system, however, is designed so that it can be easily moved from one location to another, and, therefore, it may be mounted on a trailer and produced in a collapsible tripod arrangement. Because of ease of movement about the job site, portable systems provide flexibility in illuminate design. In addition, they are easy to operate and maintain and are highly reliable. However, because portable systems are often provided on a rental basis, they are often equipped with more lighting than desired, may create glare hazard, and may not be cost effective. Equipment-mounted lighting systems generally are not engineered to provide predetermined task-specific lighting levels. However, they provide the advantages of high-intensity illumination on the work plan, adjustment capability, elimination of shadows, availability of lighting where needed, and elimination of manpower otherwise needed for transporting and erecting lighting systems.

In selecting a configuration for the lighting systems, consideration should be given to the luminaire mounting systems to ensure structural integrity and to minimize glare effects. The vertical supports should be capable of supporting the mounted equipment weight (including luminaries, brackets, and crossarms) and of withstanding the effect of wind and other climatic factors. In addition, consideration should be given to the use of spread beams and to mounting height, location of luminaries, and aiming of luminaries to avoid or minimize glare hazard to work zone workers and passing motorists.

**Lighting System Design**

The lighting design procedure relies on the amount of light flux reaching work surfaces and light uniformity on that surface. The procedure includes the following seven steps:

1. Assess the work zone to be illuminated,
2. Select the type of light source,
3. Determine recommended lighting levels (in watts/$m^2$),
4. Select lighting fixture locations,
5. Determine luminaire wattage,
6. Select luminaire and aiming points, and
7. Check design for adequacy and glare.

This process, discussed in detail with an illustrative example in the project's final report, is an interactive procedure and should be repeated until the required criteria are met. The design can be performed by an individual with some engineering background and limited lighting experience.

**System Operation and Maintenance**

Proper operation and maintenance of the lighting system is essential for achieving the intended lighting quantity and quality and avoiding delays due to illumination system malfunctions.

Operation of the lighting system requires a power source such as a power line, portable generators, or alternators installed on the construction equipment. Periodic monitoring of the power supply will ensure proper lighting system operation. Maintenance of lighting system hardware is necessary to reduce light losses due to the effects of lamp lumen depreciation due to time and use, dirt accumulation on lamps and luminaries, lamp

burnouts, and misdirected lights. These factors could contribute to an illuminance reduction by as much as 50 percent. The need for backup equipment depends upon the specific job and the equipment employed; is particularly recommended for critical functions.

### Economic Considerations

A primary concern in designing a lighting system is to provide efficient amounts of quality light at a reasonable cost. An economic analysis of a lighting system should consider fixed and variable costs. Fixed costs are those associated with initial installation, and include material and installation costs for hardware such as lamps, luminaries, ballasts, wiring, mounting devices, and shielding. Costs of generators and portable light towers should also be considered as part of the fixed costs although they might have been incurred over time. Variable costs are those associated with the operation and maintenance of the system, and include energy costs, lamp replacement cost, and maintenance labor. An analysis that considers fixed and variable costs and accounts for anticipated reuse of materials provides a practical approach for comparing alternative lighting systems.

## CONCLUSIONS

The need to develop illumination guidelines for nighttime highway work has been recognized by state highway agencies and other organizations. The initial phase of research resulted in preliminary illumination guidelines for nighttime construction and maintenance activities.

To develop a set of guidelines that can be used by public agencies and contractors in determining the types of light sources and the minimum and maximum levels of illumination for a variety of nighttime work in typical highway situations as well as recommendations for design requirements for temporary roadway lighting in work zone, a second phase of research will be performed under NCHRP Project 5-13(2). To accomplish these objectives, the research will include field reviews of various nighttime construction and maintenance projects.

## FINAL REPORT

The agency final report has been prepared in two parts. One part titled "Illumination Guidelines for Nighttime Highway Work" gives a detailed account of the project, findings, and conclusions. The other part titled "Guidelines for Work Zone Illumination Design" discusses the preliminary illumination guidelines. The report, which has been distributed to the NCHRP sponsors (i.e., the state departments of transportation), is available for loan on request to the National Cooperative Research Program, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

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