Final Report
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LIGHTING SPECIFICATIONS FOR NIGHTTIME CONSTRUCTION WORK ZONES ON ACTIVE HIGHWAYS

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INTRODUCTION

Background

Maintenance, repair, rehabilitation, and upgrading of existing facilities have replaced new construction as the dominant infrastructure activity on the highway system. This means that much of the work is done under traffic. In urban areas with large traffic volumes and associated congestion this has led to scheduling more nighttime construction so as to avoid high traffic volumes and congestion problems.

Nighttime work requires adequate lighting in work zones to insure quality construction. In addition, proper lighting for worker, inspector and motorist safety is a major consideration. In some instances work zone illumination requirements may be in conflict with safety requirements and require special lighting system design and application. Several types of lighting may be required to provide general site or background lighting, focused work area lighting and protective lighting for equipment and workers. Special shielding, directional control, and transition zones may be required to insure that motorist vision is not impaired.

Many work zones are at a fixed location, such as, a bridge deck repair, or mobile, such as, a paving operation. Mobile work zones create special problems because they constantly move and operations are often spread out over a large area that is often adjacent to an in-service traffic lane. A paving train constructing a hot mix asphalt concrete overlay may consist of a broom sweeping the surface, a distributor truck placing tack coat, trucks hauling mix, a paver receiving and spreading mix, several rollers compacting the mat, and technicians measuring smoothness and density. At each station

along the paving train, different levels of lighting may be required dependent on the particular work activity.

Problem Statement

ALDOT has limited experience with nighttime construction and the 1995 ALDOT Standard Specifications for Highway Construction provides only the following limited guidance:

> "When the contractor performs any operation after daylight hours, he shall provide and maintain, at his expense, sufficient artificial lighting to permit proper construction and inspection."

Only general information regarding lighting for nighttime work is presented in the Manual on Uniform Traffic Control Devices, Part VI, "Standards and Guides for Traffic Controls for Street and Highway Construction, Maintenance, Utility, and Incident Management Operation." The requirements of retroreflective clothing, retroreflective stop/slow paddles and illumination of flagger stations are identified in the Manual.

The Manual considers lighting devices for work area traffic control to be floodlights, hazard identification beacons, steady-burning electric lamps and warning lights. On the subject of floodlights, the MUTCD provides only general guidance:

> "On temporary traffic control projects, floodlights have limited but important application. Temporary traffic control activities on urban freeways must frequently be conducted during nighttime periods when traffic volumes are lower. Sometimes, large temporary traffic control contracts are also operated on double shift, requiring night work. When nighttime work is required for these or similar types of projects, floodlights should be used to illuminate flagger stations, equipment crossings, and other areas where existing light is not adequate for the work to be performed safely.

> In no case shall floodlighting be permitted to create a disabling glare for drivers. The adequacy of the floodlight placement and elimination for potential glare can best be determined by driving through and observing the floodlighted area from each direction on the main roadway after initial floodlight setup.
>
> Maintenance activities on urban freeways with high-volume, high-density traffic conditions are frequently conducted during nighttime periods (with low traffic volumes). Good floodlighting of the work site is needed because the workers need to see what they are doing, and because the workers and the work space be protected from, and seen by, passing drivers."

Thus there is a need for specific guidance for required illumination levels and safety considerations for nighttime construction.

Objectives

The first objective for the project is to conduct a literature review to determine recommended illumination levels for various highway construction activities, light systems for providing required illumination, and methods for directing and shielding lighting. The second objective is to review editions of the Manual on Uniform Traffic Control Devices and to cite all requirements for nighttime work zones. The third objective involves identifying and reviewing selected state departments of transportation and other agency specifications as they apply to nighttime roadway construction. The fourth objective is to conduct site investigations of nighttime work area projects. And the fifth objective is to assimilate all of the previous findings and to develop a recommended nighttime lighting specification appropriate to the Alabama DOT.

Scope

The first objective involves conducting a literature review by searching for relevant sources and summarizing principal findings. The sources are found by using the Internet and by reviewing various transportation periodicals. Chapter 2 presents the findings of the literature review. The second objective is conducted by reviewing the 1988 and later editions of the Manual on Uniform Traffic Control Devices. Chapter 3 identifies the specific nighttime lighting requirements in the most current edition of the Manual.

The third objective is achieved by contacting a selected number of departments of transportation and other agencies that have active nighttime lighting specifications. Chapter 4 presents nighttime lighting specifications of a representative sample of transportation agencies and provides a review of these. The fourth objective is attained by acquiring a light meter and conducting actual field investigations of active nighttime work zone projects. Chapter 5 summarizes the field investigations and describes the offering of several appropriate training courses. The fifth objective represents an application of the findings discovered from the previous objectives. These are presented in Chapter 6.

Lighting Terms

To assist in understanding the literature and lighting specifications, a number of lighting terms are defined as follows. A candela is a unit of luminous intensity that describes the intensity of a light source in a specified direction. Illuminance is a photometric term, which quantifies light striking a surface or plane at a point and is

expressed in foot candles or lux. The foot candle is the English unit of measurement of illuminance while lux is the metric unit of measurement of illuminance. A lumen is the metric unit that represents the luminous output of a source with a uniform emittance. A luminaire represents a complete lighting unit that consists of a lamp, the parts that distribute light, and any necessary starting components. Luminance quantifies directional brightness of a light source or of a surface that is illuminated and reflects light.

The relationship between candela, lumen and foot candle is shown in Figure 1.1. A uniform point source (luminous intensity or candlepower = 1 candela) is shown at the center of a sphere of one-foot radius. It is assumed that the sphere surface has zero reflectance. The illumination at any point on the sphere is one foot candle (one lumen per square foot). The solid angle subtended by the area A, B, C, D is one steradian, which corresponds to a luminous intensity of one candela, as originally assumed. The sphere has a total area of 12.57 or 4π square feet, and there is a luminous flux of one lumen falling on each square foot. Thus, the square provides a total of 12.57 lumens.

Since lux represents lumens/m^2 and foot candle represents lumens/ft^2, the relationship between them is found using the factor $(0.3048 m/ft)^2$. Thus, the following equivalent relationships are established:

1 lux = 0.0929 foot candles

1 foot candle = 10.7639 lux

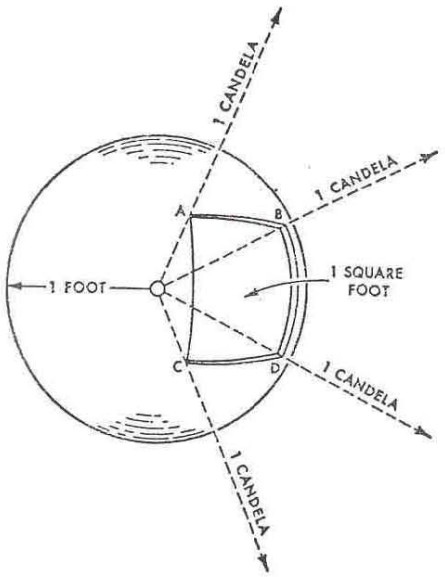


Figure 1.1 Candela, Lumen and Foot Candle Relationship
Source: Roadway Lighting Handbook (48)

CHAPTER 2

LITERATURE REVIEW

Methodology

The internet was the main tool used in the literature review in finding information related to light specifications for nighttime work zones using the Yahoo and Alta Vista search engines and by performing a Transportation Research Information System (TRIS) search. Also, the Federal Highway Administration, the Transportation Research Board and a number of departments of transportation were contacted for any light specifications for nighttime work zones.

The Yahoo search engine provided many options for possible sources related to light specifications for nighttime work zones. By using an advanced search and entering "light allocation for nighttime construction," Yahoo found one hundred eighty-eight entries related to this subject. Of these entries, thirty-two contained pertinent information related to this research project. Other advanced searches were performed using Yahoo. These searches involved rewording or transposing phrases that focused on light specifications for nighttime construction in order to insure that additional sources were not overlooked.

The second search engine used in this project was Alta Vista. An advanced word search was used and "light allocation for nighttime construction" was the only phrase entered to produce any possible sources of information. Approximately 15,125,505 entries were found, but only two entries contained pertinent information for this project.

The Transportation Research Information System (TRIS) search method was used to identify literature for this project. Two entries proved to be relevant to the subject.

The National Cooperative Highway Research Program (NCHRP) provided one of the more helpful sources to this project. Adrienne Archer, the project assistant of NCHRP was the contact for articles dealing with guidelines for planning nighttime road work and procedures.

Various departments of transportation were contacted to determine if light specifications for nighttime work zones existed. The Florida Department of Transportation, the Georgia Department of Transportation, the New Jersey Department of Transportation and the North Carolina Department of Transportation were contacted. Specifications were received from these four departments of transportation. In addition, specifications were received from the Rhode Island Department of Transportation, and the Michigan Department of Transportation. Of course, the current status of the specifications from the Alabama Department of Transportation were reviewed.

Other reference materials were collected from various transportation periodicals, and the 1988, 2000 and 2003 editions of the Manual on Uniform Traffic Control Devices.

Review of Pertinent Research

According to research performed by The Last Resource for the National Cooperative Highway Research Program in 2000, three minimum levels of lighting can be used depending on the type of nighttime project (1). Development of these levels is based on current illumination standards and regulations for construction, current State Highway Agencies' requirements for illumination, and researchers' observations of current nighttime highway construction work. An illumination level of 54 lux (5 fc) is suggested for general illumination in a work zone where tasks require low accuracy or when slow moving equipment and tasks involving large objects are present. This

illumination level is known as level I and is also appropriate for the setup of lane closures or road closures installed in conjunction with nighttime construction, and the lighting should be used at the actual points of lane closure, such as, a taper. An illumination level of 108 lux (10 fc) is known as level II illumination and is suggested for illumination on and around construction equipment and for tasks such as resurfacing. An illumination level of 216 lux (20 fc) is known as level III illumination and is suggested for projects involving higher levels of visual difficulty, such as, crack filling, critical connections, and maintenance of electrical devices or moving machinery. Research in the area of nighttime construction at the University of Kentucky also presents level I, level II, and level III illuminations for nighttime construction activities (2). The uniformity of illuminance or uniformity ratio is defined as the ratio of the average illuminance to the minimum illuminance over the work area. The uniformity ratio value should not exceed 10:1, and a 5:1 value is more desirable.

Existing street and highway lighting help to determine the types of lighting systems that are necessary for nighttime projects. Three types of lighting systems are as follows: temporary systems, portable systems, and mobile equipment-based lighting systems. Temporary lighting systems are used to light an entire work zone area and use existing or temporary poles to mount luminaires. The use of lighting from existing street poles allows light uniformity and helps to reduce costs of mounting. Portable light systems have the power supply, the luminaire and the pole in one fixture. These systems can be mounted on the ground, on trailers, or on paving machines. These systems are easy to move, but they usually provide more light than necessary and provide non-uniform light.

Glare can be described as discomfort glare, which has no effect on vision, but it can produce fatigue and may reduce acuity of vision. The other type of glare is disabling glare, which results from light scatter within the eye, which effectively reduces the visibility of objects. Disabling glare is measured in terms of veiling luminance (Lv) with units of candelas per square meter. Glare is related to the adaptation of the eye and is a subjective measurement. The Illuminating Engineering Society of North America has determined the criteria for glare in terms of the ratio of Lv to pavement luminance (3). The level of pavement illuminance is assumed to control the level of driver adaptation. The Illuminating Engineering Society of North America recommends that Lv should not exceed one third of the average pavement luminance. Minimizing glare is best achieved by diverting the axis of maximum candlepower away from the line of sight of motorists. Important lines of sight would include looking at the road ahead, reading road signs, or observing directions from flaggers. To avoid glare, three minimum requirements are necessary. Tower-mounted luminaires should be aimed either generally parallel or perpendicular to the roadway. All luminaires should be aimed as seen in Figure 2.1 such that the center of the beam axis is no greater than 60° above the vertical. And none of the luminaires should provide a luminous intensity greater that 20,000 candela at an angle of 72° above the vertical. Many agencies have used a tethered balloon with a 4000-watt halogen light source to attain portability and the luminaire height needed to control glare. Research concerning nighttime work issues conducted by Donn Hancher at the University of Kentucky also suggests using the Airstar Balloon Light as seen in Figure 2.2 to greatly reduce glare (2, 4). By using this technology, level II illumination is achieved within a 65 ft (20 m) radius.

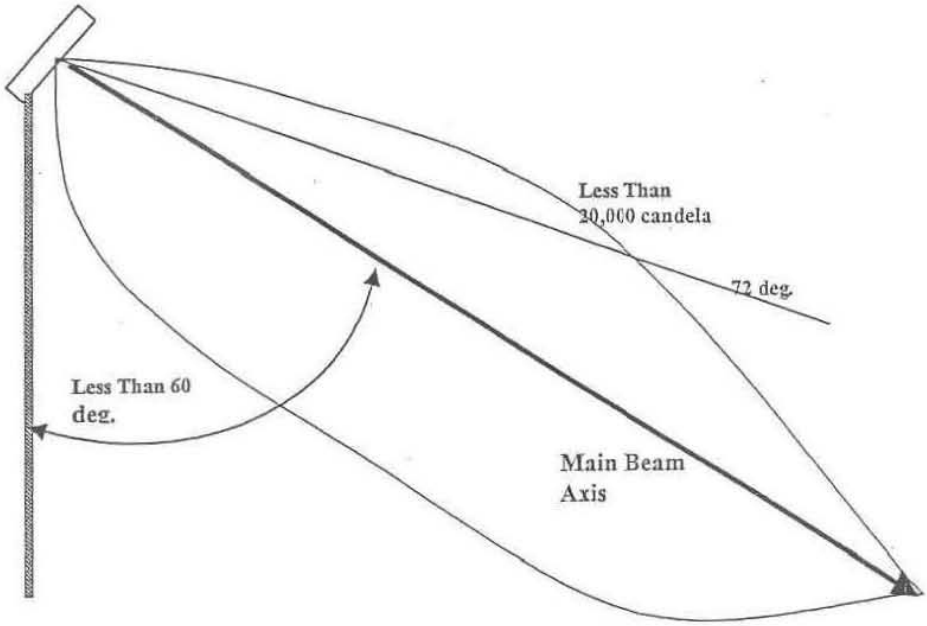


Figure 2.1 Luminaire Orientation
Source: The Last Resource (1)

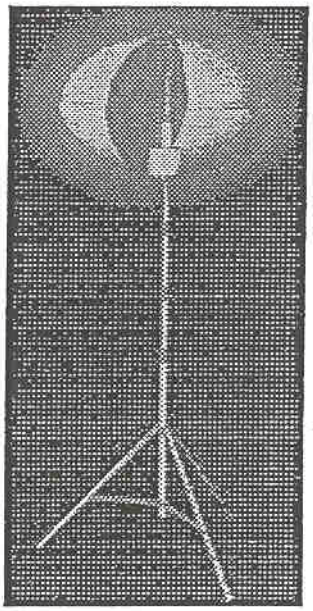


Figure 2.2 Airstar Balloon
Source: Airstar Balloon Website

Ralph D. Ellis of the University of Florida presents his research findings on nighttime highway work in a Transportation Research Board Record article titled "Development of Work Zone Lighting Standards for Nighttime Highway Work" (5) and in the National Cooperative Highway Research Program Digest titled "Illumination Guidelines for Nighttime Highway Work" (6). Both articles suggest using level I, level II, or level III illumination according to the particular nighttime project. Ellis recommends using incandescent lamps, which include general service and tungsten halogen lamps or using electric discharge lamps, which include metal halide, mercury, high pressure sodium, low pressure sodium, and fluorescent lamps. To control glare, luminaires should be placed out of the line of sight of motorists or workers, and the beam of light should not exceed an angle greater than 72° from the vertical. Barrier walls and glare avoidance screens can also be used to protect workers and drivers.

A paper concerning work zone traffic accidents involving traffic control devices and safety features by James E. Bryden of the New York Department of Transportation presents the findings of a study on 495 accidents in the 3-year period from 1994-1996 (7). During that period, 1654 contracts were awarded in New York State for $4.3 billion of work. The study examines the frequency and severity of accidents with regard to traffic control devices involved in an accident. Construction vehicles and equipment were involved in 99 of the accidents and construction and pavement features were involved in 65 of the accidents. Bryden concluded that the traffic control devices performed well in most accidents, but when out of position, they contributed to secondary collisions and other undesirable conditions. He further concluded that other than pedestrian accidents, collisions with pedestrians were rare, but construction vehicles, equipment and workers

were involved in nearly 15% of all work zone traffic accidents. His research also concluded that workspace intrusions need further study. No mention was made of any variation of frequency or severity due to daytime or nighttime occurrences nor the absence or presence of illumination. Also, no mention was made of the adequacy of the reflectivity of signs and channelizing devices.

State Specifications

According to the New Jersey Department of Transportation specification T0278, a light plan should be prepared that shows the layout of the lighting systems, the construction area needing lighting, and the illumination density of the lighting systems with calculations to show minimum lumens per square meter (lux) (8). All moving equipment used for nighttime operations should have a mounted lighting system that consists of a minimum of two lights pointed in each direction of travel of the equipment. The equipment should also have a minimum of 0.05 square meter of high intensity retroreflective sheeting toward the extremities of each side of the equipment.

A minimum of 0.1 square meter of the sheeting should be visible from each direction. Mobile light systems should be used for nighttime operations, and floodlight lamps should provide a minimum illumination of 54 lux. These light systems are to be battery-powered or powered by a generator. Both sources of power should provide lighting for a minimum of twelve hours. Battery-powered sources are used in residential areas to reduce noise pollution. General Electric has developed an hydraulically-operated lighting system for the New Jersey Department of Transportation to use for night work (9). The lighting system is used on the paver, and the system provides four 1650-watt “stadium

lights" which can be moved up and down to alter lighting angles according to the particular task. The paver is also equipped with 300-watt auger and side lights.

The New Jersey Department of Transportation specification 617.05 states that for nighttime operations, portable light towers and equipment-mounted lighting fixtures are to be used (10). A minimum illuminance level of 50 lux should be provided throughout the entire area of operation, which encompasses a minimum of 20 meters ahead and behind an employee when that employee is on or near the roadway. Figure 2.3 shows various work zone operations and the necessary illuminance levels ahead and behind equipment. Fifty lux should also be provided during the setup and removal of lane or roadway closures installed in conjunction with nighttime construction operations. Two light meters that are capable of measuring the level of illuminance in lux are to be provided to the engineer by the contractor. The engineer will take readings horizontally to the roadway surface facing the light source to ensure that minimum levels of illuminance are provided during nighttime operations.

The Florida Department of Transportation specification 8-4.1 is similar to the New Jersey Department of Transportation specification 617.05 (11). The Florida specification states that during nighttime construction, a minimum intensity of 54 lux (5 fc) should be used. Work zone lighting may be provided by portable floodlights, standard equipment lights, existing street lights, temporary street lights, or other lighting methods approved by the engineer. A lighting plan must be submitted by the contractor and approved by the engineer prior to nighttime construction projects. All pickups and automobiles must have either amber flashing lights or flashing white lights, and all other equipment should have a minimum of 4 ft^2 [0.37 m^2] of reflective sheeting or should have flashing lights.

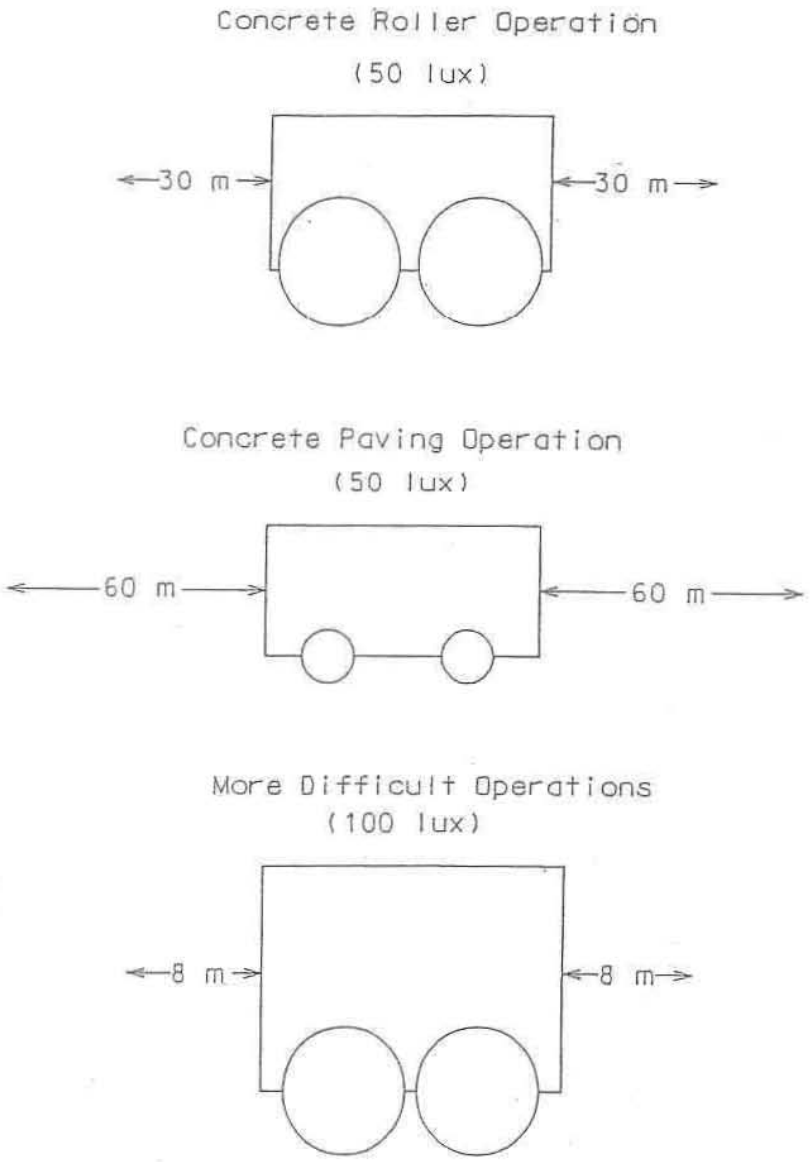


Figure 2.3 Illumination Requirements for Work Zone Operations
Source: New Jersey DOT (10)

The Georgia Department of Transportation specification for night work indicates time restrictions for nighttime construction (12). On weekdays during the hours of 5:00 a.m. to 10:00 a.m., no lane closures for northbound and southbound traffic are allowed. No lane closures are permitted for southbound traffic from 3:00 p.m. to 7:00 p.m., and no lane closures are permitted for northbound traffic from 3:00 p.m. to 9:00 p.m. Single lane closures are allowed for northbound traffic on weekdays from 9:00 p.m. to 5:00 a.m. and from 10:00 a.m. to 3:00 p.m., and single lane closures are allowed for southbound traffic on weekdays from 7:00 p.m. to 5:00 a.m. and from 10:00 a.m. to 3:00 p.m. Single lane closure is permitted for northbound traffic from 9:00 p.m. on Friday until 11:00 a.m. on Saturday and from 8:00 p.m. on Saturday until 5:00 a.m. on Monday. Single lane closure is allowed for southbound traffic from 7:00 p.m. on Friday until 3:00 p.m. on Sunday and from 7:00 p.m. on Sunday until 5:00 a.m. on Monday.

The North Carolina Department of Transportation standard specification section 1412 concerns portable construction lighting for night work (13). A lighting plan must be submitted by the contractor and approved by the engineer prior to any nighttime construction. Tower lights may be used during nighttime construction where the project is stationary and confined to a small area. Tower lights should consist of mercury vapor, metal halide, high pressure sodium or low pressure sodium fixtures that are mounted to a 30 ft tower. The fixtures should provide a minimum of 50,000 lumens but not exceed 460,000 lumens for the work area. The average illuminance should be greater than 20 fc over the work area, and the main beam of the light should not be aimed higher than 60° above the vertical. Machine lights may be used if the nighttime construction operation is continuous, and the project area is not confined to a small area. Machine lights should consist of the same fixtures that are used in tower lights, but machine lights are mounted

on supports attached to the construction machine at a height of approximately 13 feet. Each fixture used for machine lights should provide a minimum output of 22,000 lumens and a maximum output of 50,000 lumens. Machine lights should provide an illuminance greater than 10 fc on the machine and the surrounding work area and are used in addition to conventional automotive headlights.

The 2001 Alabama Department of Transportation specification 740.03 (b) states that area lighting should be used at crossovers and intersections that is not easily distinguishable at night (14). The area light should consist of a 250 watt mercury vapor light or an equivalent light and should be mounted to a 3.6 m mast arm attached to a Class 7 wood pole. The wood pole should be of the proper length in order to provide a 9 m luminaire mounting height above the elevation of the outside edge of paving. More detailed information about updated Alabama DOT Specifications is presented in Chapter 4.

The Rhode Island Department of Transportation specification T.02.0010 has requirements for lighting used in lane drop areas and on work zone equipment (15). Lane drop areas need 250 watt, 400 watt, or 1000 watt metal halide floodlights, while rollers and trucks require 250 watt metal halide fixtures that are mounted on the roller or truck. Single width and double width pavers use twin lamp fluorescent lights and 250 watt metal halide fixtures. At least 10 fc is required in the screed area and is also required a minimum of 15 ft behind the screed.

The Michigan Department of Transportation specification for construction zone operations makes the contractor responsible for making decisions concerning work zone lighting (16). The contractor has to provide an optimum and uniform lighting distribution.

Lighting Types

In a 1999 article, Ian Lewin states that nighttime visibility is an important factor to consider in street lighting design because highway accident levels increase during night hours (17). When light levels are extremely low, they are referred to as scotopic. Under scotopic light levels, a person's eyes respond much better to blue light and do not respond as well to yellow or red light. Therefore, blue lights should be used during nighttime hours. Conversely, during daylight or photopic conditions, a person's eyes are highly sensitive to yellow light and are moderately sensitive to red light. Sodium lamps mainly produce yellow light, and they are effective during the daytime. Most metal halide lamps produce light in the blue, green, and yellow regions. The blue/green light of metal halide lamps produces a high level of eye sensitivity during low light conditions. This high level of sensitivity makes metal halide lamps desirable for nighttime conditions. Energy savings are greatly increased during low levels of light when metal halide lamps are used instead of high or low-pressure sodium lamp systems.
Edward J. Kramer addresses the issue of better light uniformity in a 1999 article entitled "Technology Means Better Road Lighting" (18). He suggests that by implementing better light uniformity, direct disabling glare is reduced for drivers, and safer driving conditions are present. Light uniformity also prevents a driver's eye from having to adjust to alternating light levels. When choosing a roadway lighting system, it is important to avoid light trespass or light pollution. Light pollution from roadway or street lighting accounts for as much as 50% of the sky glow in major urban areas. Light trespass also adversely affects nearby homes and businesses and should be addressed when designing light systems.

Worker Vest Specifications

The American National Standard 107-1999 referenced from the "T^2 Bulletin" of the Washington State Local Technical Assistance Program specifies minimum background fabric amounts and retroreflectivity materials for worker garments (19). Colors for background fabrics must be fluorescent orange-red, fluorescent red, or fluorescent yellow-green. Three classes of garments are set by the American National Standard. Class one is comprised of garments with the least amount of fluorescent and retroreflective material. Class one garments are usually worn by parking lot attendants, shopping cart retrievers, or by persons working in zones with speeds under 25 miles per hour. Class two garments, which are more conspicuous than the first class are worn by workers in zones that have higher risk levels. Roadway construction workers, utility workers, survey crews, and school crossing guards use class two apparel. Complex work backgrounds, inclement weather, and areas with speed limits of 25 miles per hour or greater also require the use of class two garments. Class three apparel is necessary in heavy traffic areas, inclement weather, or when a complex background decreases visibility, and it comprises the most conspicuous class of apparel. Reflective trim allows workers to be seen in hazardous situations during nighttime or low light conditions, while fluorescent lime-yellow trim helps visibility in daylight conditions. Emergency response personnel, utility workers, and survey crews use class three apparel. Workers wearing this class of garments can be seen through the full range of body motions at a minimum of 390 meters. Class three apparel is also used in areas where traffic speeds are greater than 50 miles per hour.

Lighting Fixtures

Typical lighting fixtures are shown in Figure 2.4 (20, 21 22). In the roadways from downtown Auburn to Interstate 85, fixtures of the acorn, cobrahead, cobrahead cutoff, shoebox deep and streetlight types are all present.

The cobrahead fixture was referred to in the article by Kramer, where it was mentioned that this fixture resulted in a hot spot directly under the luminaire support. The flat glass cobrahead, also known as the cobrahead cutoff, was noted as having a similar hotspot. The other typical fixtures are common in roadway and parking area illumination but have not been evaluated for the hot spot phenomenon.

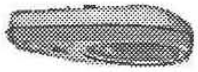
Typical portable lighting fixtures are shown in Figure 2.5 (23, 24, 25). The fixtures range from hand-held to tripod-mounted to vehicle-mounted styles. The intensity of these fixtures depends on the mounting location and the stability of the mounting hardware.

Acorn

Colonial

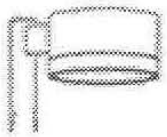
Cobrahead

Cobrahead Cutoff



Floodlight

Hatbox



Shoebox

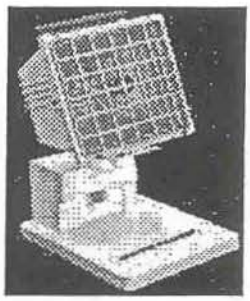
Shoebox Deep

Streetlight

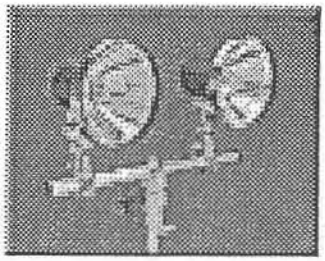
Shielded Streetlight

Figure 2.4 Typical Lighting Fixtures
Sources: IDSA, NSPC & Williams Observatory Websites (20,21,22)

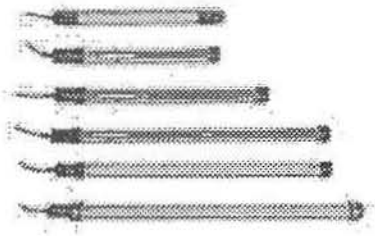
Folding Light



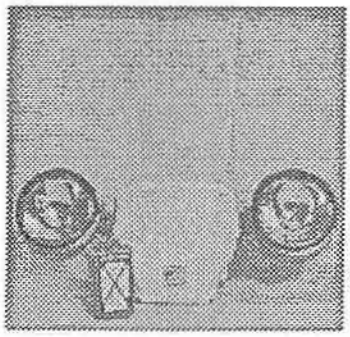
Pole Mounted



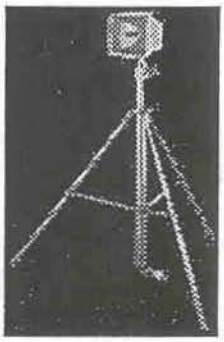
Portable Fluorescent



Spotlight



Tripod Light



Vector

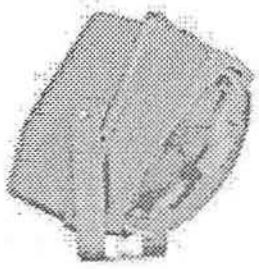


Figure 2.5 Typical Portable Lighting Fixtures
Sources: Safe-T-Lite, Jameson Corporation, Star Beam Websites (23,24,25)

Lighting Effects on Accidents

Fred Walker and Stephen Roberts discuss in their article the effect of installing lighting at rural at-grade intersections (26). Night accidents are reduced by 49 percent with the use of lighting. A paper by Paul Box presents the effect of reducing lighting spacing at intersections and using an average illumination level of 15 lux (27). Accidents at night are reduced from 31 percent to 23 percent after spacing is reduced and the illumination level is increased. In an article about public lighting, Rune Elvik uses a statistical analysis to evaluate the effect of using public lighting (28). The results show that public lighting reduces nighttime fatal accidents by 65 percent, nighttime injury accidents by 30 percent, and nighttime property-damage-only accidents by 15 percent. Richard Schwab, Ned Walton, John Mounce, and Merton Rosenbaum also cite in their article the importance of roadway lighting to decrease nighttime accidents (29). Continuous lighting is shown in an article by Jean-Francois Bruneau, Denis Morin, and Marcel Pouliot to reduce the risk of nighttime accidents (30). Property-damage-only accidents are reduced by 43 percent in comparison to total darkness and by 35 percent in comparison to simply interchange lighting after the continuous lighting method is used. The use of continuous lighting is suggested on roadways with average daily traffic volumes of more than 40,000 vehicles per day.

Procedures for Nighttime Operations

Research at Oregon State University entitled “Factors of Importance for Determining Daytime Versus Nighttime Operations in Oregon” concluded that there were nineteen factors that would influence one to determine if nighttime work was more feasible than daytime work (31). The 19 factors were safety, traffic control, congestion,

lighting, quality, public relations, worker condition, productivity, scheduling, driver condition, construction cost, accident cost, availability of material/equipment repair, communication supervision, noise, user cost, maintenance cost, air quality, and fuel consumption. These factors were implemented into a survey that was used to establish rankings that could be used as weights in a decision model. Surveys were sent to a number of personnel within the construction industry in Oregon as well as other states. This survey was used to determine which of the factors were of most importance and to identify any differences in the rankings of the factors between different positions. There were two parts of the survey. One part consisted of rating the factors from 1 to 7, with 7 being the most important. The second part consisted of the factors being ranked as a whole from 1 to 19, with 1 being the most important. By using the two parts, it allowed researchers to investigate whether each factor had consistent importance between the indicating and ranking methods. The survey also included a section that presented the question of whether they preferred nighttime work or daytime work.

The survey showed that safety, traffic control, and congestion were the most important factors affecting nighttime work. The second important group of factors included lighting, quality, public relations, worker condition, productivity, and driver condition. The third group of factors included scheduling, accident cost, construction cost, and noise. The fourth set of factors included communication supervision and user cost while availability of material/equipment repair, maintenance cost, air quality, and fuel consumption ranked as the least important factors affecting nighttime work.

The results obtained from project managers appear to be consistent with that when all the responses are pooled together. The lower rankings of construction issues by the project managers are not surprising because this does not come within the domain of the

project manager. District managers rank communication, user cost, and noise low because the life of most projects is relatively short. District managers also tend to rank availability of material and equipment repair higher than project managers because projects can be finished in a shorter period of time if the material is there and the equipment does not break down.

The results for contractors do show a difference from what project managers and district managers believe are the most important. Contractors rate factors such as productivity and construction cost higher because they are directly tied to profits. Along the same line, contractors rate other factors not related to profits much lower. The results from other state DOT's show that public relations and user cost were given higher rankings than the results in Oregon.

When presented with the question of whether they preferred nighttime work or daytime work, 83% said they prefer daytime work while only 7% preferred nighttime work. The remaining 10% did not have a preference. The main factors influencing daytime work included safety and personnel schedules. The main factor influencing nighttime work was the reduction in traffic that allows for a safer environment.

A 2002 NCHRP study on "A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance" was conducted by Bryden and Mace (32). The research project presents a decision process to assist highway agencies in evaluating night work alternatives against other work schedules. It provides a comprehensive, quantitative basis for selecting the most cost-effective plan for ensuring the safety of the public and workers, maintaining capacity, minimizing the impact on the community, and getting the work completed on schedule.

The researchers identified the factors affecting nighttime work into six groups: traffic, construction, social, economic, environmental, and other. The traffic factors are of congestion, safety, and traffic control. Productivity and quality are the two factors that are included in the construction group. Social factors include those that affect workers and drivers. Construction cost, user cost, and accident cost are the factors that make up the economic group. The two principal environmental factors are air quality and fuel consumption. The other factors include public relations, scheduling, lighting, availability of material, and labor.

The research report states that night work can only appear to be feasible when traffic volumes are lower and when setup and removal of the traffic control devices can be accomplished on a nightly basis. The report presents a method that can be used to determine if night work is the right choice if the two previous factors are met. The method includes four steps: gather information, develop traffic control options, evaluate volume/capacity, and conduct a cost-effectiveness analysis.

The first task in the assessment procedure is to gather information. This information is based primarily on the nature and duration of the work. There are several main characteristics that are to be examined in this process. One must determine the kind of work to be employed, such as, pavement overlay or bridge deck repair, and to determine the encroachment required by the construction crews. One must also determine the required time to complete the work as well as the times of the day that the roadway is under the highest traffic volumes. A main concern for the work schedule is the season in which the work will be completed. This is primarily for northern states in which temperatures fall below freezing during nighttime hours during the winter season. This could affect the curing time of concrete as well as working conditions that the

employees will face. One should also consider the impact of work on traffic flow, such as, where the work will occur. Examples include work on the shoulder of a road, work on a multilane road, or work within an intersection. Other types of information that need to be gathered are the possible constraints on traffic flow, such as, speed limits, truck volumes, schools and businesses located within the work zone, and emergency vehicle access.

The second task identified for developing a procedure to assess nighttime work capabilities is to develop the traffic control and construction options. Examples of traffic control options include closing the shoulder or one lane of traffic, moving traffic onto the shoulder or into temporary lanes, diverting traffic across a median, permitting only local traffic, or closing the entire roadway throughout a project. There are times when combinations of these options are needed to provide a safe work zone for the contractors. Traffic control options should be developed based on information gathered in the previous step and based on the number of lanes needed to adequately handle the traffic demands.

The third task takes a more in-depth look into the traffic control plans that appear to be feasible. This task examines volumes and capacities. Congestion that results from a project work zone is the main concern when evaluating volumes and capacities. Contractors will try to avoid unacceptable congestion such as queue lengths that could block intersections upstream of the work zone. Unacceptable congestion is a unique characteristic of each work zone. Some congestion cannot be avoided in some urban areas, which would conclude that nighttime work might be acceptable. If no traffic control plan satisfies the congestion criteria, then additional options should be investigated.

The last task in this process is to conduct a cost-effectiveness analysis. The cost-effectiveness analysis is chosen over a cost/benefit analysis because the benefit is the new or improved road rather than the nighttime work itself. It should be noted, however, that cost-effectiveness analysis should not replace "experiment, experience, intuition, and judgment." The first step in a cost-effectiveness analysis is to determine the total construction cost of each option, which includes traffic control, lighting, constructability, and user cost. The costs of these elements should be based on local costs whenever possible.

The second step in this analysis is to determine the effectiveness of each construction option. One begins this analysis by looking at the subgroups within community/traffic impacts, safety, and constructability. Each subgroup should be assigned a rating between 1 and 3, with 1 being unacceptable, 2 being borderline, and 3 being acceptable. After all subgroups are examined, an overall rating needs to be computed by simply calculating the numerical average or by assigning the lowest number if that subgroup is superior to all others. Table 2.1 is an example of an effectiveness rating worksheet.

Table 2.1 Effectiveness Rating Worksheet

Objective	**Factor**	**Cost**		
		Option 1	Option 2	Option 3
Community/Traffic Impact	Business impact			
	Pedestrian/Bicycle impact			
	Emissions and other environmental concerns			
	Public transit			
	Emergency services			
	Noise effect on residences or hospital			
	Effects of lighting and glare			
	Reaction to off-site traffic in local neighborhood			
	Impact on off-site traffic			
	OVERALL RATING			
Safety	Traffic accidents			
	Construction accidents			
	Maintenance			
	OVERALL RATING			
Constructability	Experience of contractor with night work			
	Suitability of temperatures for operations			
	Supervision			
	Worker efficiency at night			
	Quality of lighting plan			
	Materials/equipment availability			
	OVERALL RATING			

The third step is to assign weights to each objective. The weights should be between 1 and 3, with 3 being the most important. If all objectives are equal, then, the weight of 1 should be given to all objectives. Once the weights are determined, the weights and ratings are multiplied together to get a weighted rating, and all weighted ratings are added together to get the effectiveness rating. The effectiveness rating is then divided by the total cost to achieve the effectiveness/cost ratio. The higher number will then present the best viable option. An example of a cost-effectiveness analysis worksheet can be seen in the following table.

		Option 1		**Option 2**		**Option 3**	
		$4.4 M		**$6.0 M**		**$5.5 M**	
OBJECTIVE	**Weight**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**
Community/Traffic Impact	2	3	6	2	4	4	8
Safety	1	2	2	3	3	3	3
Constructability	1	3	3	2	2	3	3
Effectiveness Rating			11		9		14
Effectiveness/Cost			2.5		1.5		2.55

After the best viable option is determined, the option needs to be subjected to the project requirements once again so that the option will not be disapproved in the future. Once this is complete, the option is ready for detailed design.

Another NCHRP study was conducted by the same authors, Bryden and Mace, and published in 2002. This study was entitled “Guidelines for Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction” (33). This project presents guidelines to assist highway agencies in developing and implementing a plan for night work that will provide for public and worker safety and satisfy the community while minimizing waste and other problems associated with the supply of materials and capable workers. The guidelines also contain a number of innovative procedures

suggested by state DOTs to respond to special nighttime problems, such as control of glare, visibility of workers, and the need to improve conspicuity of traffic control devices.

In this research, lighting was found to be one of the most important factors in nighttime construction. A good lighting scheme for the work zone can boost the morale of workers while providing a safe work zone and increasing the quality of work. A lighting plan consists of selecting the lighting fixtures, their correct location, arrangement, and spacing needed to provide the required illuminance levels. The required levels are separated into three groups, Levels I, II, and III, described earlier.

As an example, New York State requires Level II illuminance 15 m (50 ft) ahead and 30 m (100 ft) behind the paving and milling machine for nighttime operations. Also, New York State requires Level I illuminance 120 m (400 ft) ahead and 245 m (800 ft) behind the paving or milling machine in addition to the Level II illuminance. The exception to this requirement is with finish rollers. Because the rollers often lag further than 245 m (800 ft) behind the operation, they are required to use floodlights to maintain the Level I illuminance. However, the ratio of average illuminance to the minimum illuminance over the work area, or uniformity ratio, should not exceed 10:1. The three types of lighting systems to achieve these levels and ways to minimize glare were discussed earlier.

Temporary lighting should be used to illuminate areas around a work zone. The lights should be used to help pedestrians identify potential hazards when walking or biking near the work zone. It is also recommended that nightly inspections be made to ensure that the lighting scheme is performing as required. The inspection should use a photometer taking readings every 3 m (10 ft).

The final research report also gives lighting specifications for other warning devices. Flashing warning lights are recommended on barricades for closure points. The flashing lights help to attract the attention of the driver. Two flashing lights at each end of a barricade are sufficient. Type A flashing lights are adequate for nighttime use, but Type B lights should be used if visibility is required for the daytime. Type A and B flashing lights, however, should not be used for delineation. Type C or steady burn lights should not be used for barricades, but can be used for the delineation of pedestrian pathways. Steady-burn and flashing warning lights can be used for channelizing devices. Warning lights should be visible for a minimum of 300 m (1,000 ft) in all directions with the use of amber lights. Strobe lights should be avoided since they cannot be seen at great distances and they do not allow an approaching driver the ability to recognize distances. It is recommended that the batteries used for warning lights be positioned on the ground to prevent the possibility of intruding the passenger compartment of a car upon impact.

Type C arrow panels are recommended on high-speed, high-volume roads where they can be seen at 1,600 m (5,280 ft) on axis and 460 m (1,500 ft) when viewed on a curve. Type B or larger arrow panels should be used on intermediate speed roads where they can be recognized at 1,200 m (3,960 ft) on axis or 300 m (1,000 ft) when viewed on a curve. For low-speed urban streets, Type A arrow panels should be used where they can be viewed at 800 m (2,640 ft). Lamps should measure a minimum of 150 candela on axis and 30 candela at 13 degrees horizontal and 3 degrees vertical viewing angles on high-speed roads. The minimum values on low speed roads are 90 candela on axis and 18 candela off axis. The maximum brightness for panels used at night are 5,500 candela

per panel or 550 candela per lamp for arrow displays, and 370 candela for chevron displays. Dimmers should also be used on panels to adjust daytime use to nighttime use. The research report also gives recommendations on the traffic control devices that should be used for nighttime work.

CHAPTER 3

LIGHTING GUIDELINES AND REQUIREMENTS

Part 6 of the 2003 Edition of the Manual on Uniform Traffic Control Devices was searched for several words and phrases that would make reference to night work or illumination requirements (34). The findings of these searches are as listed as the nighttime requirements for temporary traffic control in Table 3.1. Since Section 6G-20 of Part 6 is "Temporary Traffic Control During Nighttime Hours", it is reproduced in its entirety as Table 3.2. The found words or "hits" were italicized in the tables to add emphasis. They are not shown in italics in the MUTCD.

Search terms were used for the many phrases to describe night work and illumination. The searches were done in a systematic order expected to produce a reducing number of results. These phrases were also expected to produce some of the same results as earlier searches. The sequence of search was as follows:

- The word "night" produced 120 hits, of these 53 were found to deal with lighting or increased traffic control requirements.
- The spelling variation of "nite" was also searched and produced no additional results.
- The word "dark" produced 16 hits, none of which dealt with requirements for the hours of darkness in temporary traffic control.
- The word "illuminate" produced 73 hits, of these four were found in addition to the hits previously found.
- The word "glare" produced six hits, of these two were found in addition to the hits previously found.

- The phrase “street light” was chosen rather than the word “light” by itself, to reduce the number of irrelevant hits due to traffic signal references. This phrase was also chosen since it is used in Typical Application 28 for sidewalk closures. This phrase produced three hits, of these two were found in addition to the hits previously found.
- The phrase “roadway lighting” was also searched after it was noticed to be used in Section 6G-04. No additional hits were found other than this one reference in the modifications to typical applications.
- The phrase “temporary lighting” was also searched since it was found three times in Section 6G-20. The search produced only the three occurrences found in that section.

Table 3.1 Nighttime Requirements and Guidelines for Temporary Traffic Control

Page	Text
6B-1	Section 6B.01 Fundamental Principles of Temporary Traffic Control Guidance: General plans or guidelines should be developed to provide safety for motorists, bicyclists, pedestrians, workers, enforcement/emergency officials, and equipment, with the following factors being considered: F. Roadway occupancy should be scheduled during off-peak hours and, if necessary, *night* work should be considered.
6B-2	Section 6B.01 Fundamental Principles of Temporary Traffic Control Guidance: To provide acceptable levels of operations, routine day and *night* inspections of TTC elements should be performed as follows:
6D-2	Section 6D.01 Pedestrian Considerations Guidance: Covered walkways should be sturdily constructed and adequately *lighted* for *nighttime* use.
6D-5	Section 6D.03 Worker Safety Considerations Option: The following are additional elements of TTC management that may be considered to improve worker safety: D. Lighting—for *nighttime* work, the TTC zone and approaches may be *lighted*.
6E-1	Section 6E.02 High-Visibility Safety Apparel Standard: For daytime and *nighttime* activity, flaggers shall wear safety apparel meeting the requirements of ISEA "American National Standard for High-Visibility Apparel" (see Section 1A.11) and labeled as meeting the ANSI 107-1999 standard performance for Class 2 risk exposure. The apparel background (outer) material color shall be either fluorescent orange-red or fluorescent yellow-green as defined in the standard. The retroreflective material shall be either orange, yellow, white, silver, yellow-green, or a fluorescent version of these colors, and shall be visible at a minimum distance of 300 m (1,000 ft). The retroreflective safety apparel shall be designed to clearly identify the wearer as a person.
6E-1	Section 6E.02 High-Visibility Safety Apparel Guidance: For *nighttime* activity, safety apparel meeting the requirements of ISEA "American National Standard for High-Visibility Apparel" (see Section 1A.11) and labeled as meeting the ANSI 107-1999 standard performance for Class 3 risk exposure should be considered for flagger wear (instead of the Class 2 safety apparel in the Standard above).
6E-1	Section 6E.03 Hand-Signaling Devices Standard When used at *night*, the STOP/SLOW paddle shall be retroreflectorized.

6E-2	Section 6E.03 Hand-Signaling Devices Standard: When used at *nighttime*, flags shall be retroreflectorized red.
6E-4	Section 6E.05 Flagger Stations Standard: Except in emergency situations, flagger stations shall be *illuminated* at *night*.
6F-2	Section 6F.02 General Characteristics of Signs Standard: All signs used at *night* shall be either retroreflective with a material that has a smooth, sealed outer surface or *illuminated* to show the same shape and similar color both day and *night.*
6F-2	Section 6F.02 General Characteristics of Signs Standard: The requirement for sign *illumination* shall not be considered to be satisfied by street, highway, or strobe lighting.
6F-25	Section 6F.55 Portable Changeable Message Signs Guidance: Portable Changeable Message signs should be visible from 800 m (0.5 mi) under both day and *night* conditions.
6F-28	Section 6F.56 Arrow Panels Standard: Arrow panel elements shall be capable of at least a 50 percent dimming from full brilliance. The dimmed mode shall be used for *nighttime* operation of arrow panels.
6F-30	Section 6F.58 Channelizing Devices Standard: The retroreflective material used on channelizing devices shall have a smooth, sealed outer surface that will display a similar color day or *night*.
6F-30	Section 6F.59 Cones Standard: When cones are used on freeways and other high-speed highways or at *night* on all highways, or when more conspicuous guidance is needed, cones shall be a minimum of 700 mm (28 in) in height.
6F-30	Section 6F.59 Cones Standard: For *nighttime* use, cones shall be retroreflectorized or equipped with *lighting devices* for maximum visibility.
6F-31	Section 6F.60 Tubular Markers Standard: Tubular markers shall be a minimum of 700 mm (28 in) in height when they are used on freeways and other high-speed highways, on all highways during *nighttime*, or whenever more conspicuous guidance is needed.

6F-31	Section 6F.60 Tubular Markers Standard: For *nighttime* use, tubular markers shall be retroreflectorized. Retroreflectorization of 700 mm (28 in) or larger tubular markers shall be provided by two 75 mm (3 in) wide white bands placed a maximum of 50 mm (2 in) from the top with a maximum of 150 mm (6 in) between the bands.
6F-35	Section 6F.65 Temporary Traffic Barriers as Channelizing Devices Support: Temporary traffic barriers are not TTC devices in themselves; however, when placed in a position identical to a line of channelizing devices and marked and/or equipped with appropriate channelization features to provide guidance and warning both day and *night*, they serve as TTC devices.
6F-35	Section 6F.65 Temporary Traffic Barriers as Channelizing Devices Standard: If used to channelize vehicular traffic, the temporary traffic barrier shall be supplemented with delineation, pavement markings, or channelizing devices for improved daytime and *nighttime* visibility.
6F-37	Section 6F.71 Pavement Markings Standard: All pavement markings and devices used to delineate road user paths shall be carefully reviewed during daytime and *nighttime* periods.
6F-38	Section 6F.71 Pavement Markings Guidance: The intended vehicle path should be defined in day, *night*, and twilight periods under both wet and dry pavement conditions.
6F-38	Section 6F.73 Raised Pavement Markers Option: Retroreflective or internally *illuminated* raised pavement markers, or nonretroreflective raised pavement markers supplemented by retroreflective or internally *illuminated* markers, may replace or supplement markings prescribed in Chapters 3A and 3B.
6F-39	Section 6F.76 Floodlights Support: Utility, maintenance, or construction activities on highways are frequently conducted during *nighttime* periods when vehicular traffic volumes are lower.
6F-39	Section 6F.76 Floodlights Support: Large construction projects are sometimes operated on a double-shift basis requiring *night* work
6F-39	Section 6F.76 Floodlights Guidance: When *nighttime* work is being performed, floodlights should be used to *illuminate* the work area, equipment crossings, and other areas.
6F-39	Section 6F.76 Floodlights Standard: Except in emergency situations, flagger stations shall be *illuminated* at *night.*

6F-39	Section 6F.76 Floodlights Standard: Floodlighting shall not produce a disabling *glare* condition for approaching road users, flaggers, or workers.
6F-39	Section 6F.76 Floodlights Guidance: The adequacy of the floodlight placement and elimination of potential *glare* should be determined by driving through and observing the floodlighted area from each direction on all approaching roadways after the initial floodlight setup, at *night*, and periodically.
6F-39	Section 6F.76 Floodlights Support: Desired *illumination* levels vary depending upon the nature of the task involved. An average horizontal luminance of 50 lux (5 foot candles) can be adequate for general activities. Tasks requiring high levels of precision and extreme care can require an average horizontal luminance of 216 lux (20 foot candles).
6F-40	Section 6F.78 Warning Lights Standard: Type A Low-Intensity Flashing warning lights, Type C Steady-Burn warning lights, and Type D 360- degree Steady-Burn warning lights shall be maintained so as to be capable of being visible on a clear *night* from a distance of 900 m (3,000 ft).
6F-40	Section 6F.78 Warning Lights Support: Type A Low-Intensity Flashing warning lights are used to warn road users during *nighttime* hours that they are approaching or proceeding in a potentially hazardous area.
6F-40	Section 6F.78 Warning Lights Support: Type B High-Intensity Flashing warning lights are used to warn road users during both daylight and *nighttime* hours that they are approaching a potentially hazardous area.
6F-41	Section 6F.78 Warning Lights Option: Type C Steady-Burn warning lights and Type D 360-degree Steady-Burn warning lights may be used during *nighttime* hours to delineate the edge of the traveled way.
6F-42	Section 6F.81 Temporary Traffic Barriers Standard: Temporary traffic barriers shall be supplemented with standard delineation, pavement markings, or channelizing devices for improved daytime and *nighttime* visibility if they are used to channelize vehicular traffic.
6F-44	Sections 6F.85 Screens Support: Screens might improve safety and motor vehicle traffic flow where volumes approach the roadway capacity because they discourage gawking and reduce headlight *glare* from oncoming motor vehicle traffic.

6G-1	Section 6G.02 Work Duration Standard: The five categories of work duration and their time at a location shall be: B. Intermediate-term stationary is work that occupies a location more than one daylight period up to 3 days, or *nighttime* work lasting more than 1 hour.
6G-1	Section 6G.02 Work Duration Standard: Since long-term operations extend into *nighttime*, retroreflective and/or *illuminated* devices shall be used in long-term stationary TTC zones.
6G-2	Section 6G.02 Work Duration Standard: Since intermediate-term operations extend into *nighttime*, retroreflective and/or *illuminated* devices shall be used in intermediate-term stationary TTC zones.
6G-3	Section 6G.04 Modifications To Fulfill Special Needs Guidance: When conditions are more complex, typical applications should be modified by giving particular attention to the provisions set forth in Chapter 6B and by incorporating appropriate devices and practices from the following list: E. Lighting: 1. Temporary *roadway lighting* 2. Steady-burn lights used with channelizing devices 3. Flashing lights for isolated hazards 4. *Illuminated* signs 5. Floodlights
6G-7	Section 6G.11 Work Within the Traveled Way of Urban Streets Standard: All TTC devices shall be retroreflective or *illuminated* if utility work is performed during *nighttime* hours.
6G-10	Section 6G.14 Work Within the Traveled Way of Freeways and Expressways Support: Other conditions exist where work must be limited to *night* hours, thereby necessitating increased use of warning lights, *illumination* of work spaces, and advance warning systems.
6G-11 and 6G-12	Section 6G.20 Temporary Traffic Control During *Nighttime* Hours Entire section – see Table 3.2
6H-24	Typical Application 10 Standard: 5. At *night*, flagger stations shall be *illuminated*, except in emergencies**.**
6H-26	Typical Application 11 Option 2. The Type B flashing warning lights may be placed on the ROAD WORK AHEAD and the ONE LANE ROAD AHEAD signs whenever a *night* lane closure is necessary.

6H-28	Typical Application 12 Support: 10. TTC signals are preferable to flaggers for long-term projects and other activities that would require flagging at *night.*
6H-32	Typical Application 14 Guidance: 1. Floodlights should be used to *illuminate* haul road crossings where existing light is inadequate.
6H-32	Typical Application 14 Standard: Flagging Method 6. At *night*, flagger stations shall be *illuminated*, except in emergencies.
6H-34	Typical Application 15 Option: 4. If the closure continues *overnight*, warning lights may be used on the channelizing devices.
6H-58	Typical Application 27 Standard: 3. At *night*, flagger stations shall be *illuminated*, except in emergencies.
6H-60	Typical Application 28 Option: 4. *Street lighting* may be considered..
6H-60	Typical Application 28 Option: 6. For *nighttime* closures, Type A Flashing warning lights may be used on barricades that support signs and close sidewalks
6H-62	Typical Application 29 Option: 5. *Street lighting* may be considered.
6H-62	Typical Application 29 Option: 7. For *nighttime* closures, Type A Flashing warning lights may be used on barricades supporting signs and closing sidewalks.
6H-68	Typical Application 32 Option: 5. Warning lights may be used to supplement channelizing devices at *night*.
6H-72	Typical Application 34 Option: 7. Type C Steady-Burn warning lights may be placed on channelizing devices and the barrier parallel to the edge of pavement for *nighttime* lane closures.
6H-76	Typical Application 36 Option: 15. Type C Steady-Burn warning lights may be placed on channelizing devices and the barrier parallel to the edge of pavement for *nighttime* lane closures.

6H-96	Typical Application 46 Standard: 9. At *night*, flagger stations shall be *illuminated*, except in emergencies.
6I-4	Section 6I.05 Use of Emergency-Vehicle Lighting Support: The use of emergency-vehicle lighting (such as high-intensity rotating, flashing, oscillating, or strobe lights) is essential, especially in the initial stages of a traffic incident, for the safety of emergency responders and persons involved in the traffic incident, as well as road users approaching the traffic incident. Emergency-vehicle lighting, however, provides warning only and provides no effective traffic control. It is often confusing to road users, especially at *night*.
6I-4	Section 6I.05 Use of Emergency-Vehicle Lighting Guidance: Vehicle headlights not needed for illumination, or to provide notice to other road response vehicle being in an unexpected location, should be turned off at *night*.

Table 3.2 MUTCD Section G.20 on Temporary Traffic Control During Nighttime Hours

6G-11 and 6G-12	Section 6G.20 Temporary Traffic Control During *Nighttime* Hours Support: Chapter 6D and Sections 6F.68 and 6G.05 contain additional information regarding the steps to follow when pedestrian or bicycle facilities are affected by the worksite. Conducting highway construction and maintenance activities during *night* hours could provide an advantage when traditional daytime traffic control strategies cannot achieve an acceptable balance between worker and public safety, traffic and community impact, and constructability. The two basic advantages of working at *night* are reduced traffic congestion and less involvement with business activities. However, the two basic conditions that must normally be met for *night* work to offer any advantage are reduced traffic volumes and easy set up and removal of the traffic control patterns on a *nightly* basis. Shifting work activities to *night* hours, when traffic volumes are lower and normal business is less active, might offer an advantage in some cases, as long as the necessary work can be completed and the work site restored to essentially normal operating conditions to carry the higher traffic volume during non-construction hours. Although working at *nigh*t might offer advantages, it also includes safety issues. Reduced visibility inherent in *night* work impacts the performance of both drivers and workers. Because traffic volumes are lower and congestion is minimized, speeds are often higher at *night* necessitating greater visibility at a time when visibility is reduced. Finally, the incidence of impaired (alcohol or drugs), fatigued, or drowsy drivers might be higher at *night*. Working at night also involves other factors, including construction productivity and quality, social impacts, economics, and environmental issues. A decision to perform construction or maintenance activities at *night* normally involves some consideration of the advantages to be gained compared to the safety and other issues that might be impacted. Guidance: Considering the safety issues inherent to *night* work, consideration should be given to enhancing traffic controls (see Section 6G.04) to provide added visibility and driver guidance, and increased protection for workers. In addition to the enhancements listed in Section 6G.04, consideration should be given to providing additional lights and retroreflective markings to workers, work vehicles, and equipment.

	Option: Where reduced traffic volumes at *night* make it feasible, the entire roadway may be closed by detouring traffic to alternate facilities, thus removing the traffic risk from the activity area. Guidance: Because typical *street and highway lighting* is rarely adequate to provide sufficient levels of *illumination* for work tasks, temporary lighting should be provided where workers are active to supply sufficient *illumination* to reasonably safely perform the work tasks. *Temporary lighting* for *night* work should be designed such that *glare* does not interfere with driver visibility, or create visibility problems for truck drivers, equipment operators, flaggers, or other workers. Consideration should also be given to stationing uniformed law enforcement officers and lighted patrol cars at *night* work locations where there is a concern that high speeds or impaired drivers might result in undue risks for workers or other drivers. Standard: Except in emergencies, *temporary lighting* shall be provided at all flagger stations. Support: Desired *illumination* levels vary depending upon the nature of the task involved. An average horizontal luminance of 50 lux (5 foot candles) can be adequate for general activities. An average horizontal luminance of 108 lux (10 foot candles) can be adequate for activities around equipment. Tasks requiring high levels of precision and extreme care can require an average horizontal luminance of 216 lux (20 foot candles).

Table 3.1 reveals the following breakdown of the requirements and guidelines:

Standard	26	(44%)
Guidance	11	(19%)
Option	12	(20%)
Support	10	(17%)

It is noted that the standards are dominant reflecting the importance of nighttime temporary traffic control operations. This summary does not include the information from Table 3.2. Some standard, guidance, option and support statements are repeated in more than one section. Table 3.2 reveals the dominance of Guidance and Support provisions in Section 6G.20, Temporary Traffic Control During Nighttime Hours. Nearly 90 percent of the information provided in this section is categorized as Guidance or Support.

Specific illumination levels are found in only two places in the entire MUTCD Part 6. In Section 6F.76, Floodlights, reference is made to 50 lux (5 foot candles) illumination for general activities and 216 lux (20 foot candles) illumination for high levels of precision and extreme care. In Section 6G.20, Temporary Traffic Control During Nighttime Hours, reference is made to 50 lux (5 foot candles) illumination for general activities, 108 lux (10 foot candles) illumination for activities around equipment, and 216 lux (20 foot candles) illumination for high levels of precision and extreme care. Both of these statements in the MUTCD are identified as Support conditions.

ALDOT TCP Notes

The Alabama Department of Transportation website was used to review the Traffic Control Plan project notes related to nighttime work (35). The 39 notes reviewed are in the 700 series for Traffic Control Plans. Searches were done for references to darkness, illuminated, illumination, light and nighttime. As shown in Table 3.3, the results were three notes that dealt with warning light requirements and one which dealt with pavement markings. There were no references to either illuminated or illumination.

Table 3.3 Nighttime Requirements from ALDOT TCP Notes

Note	Contents
702	During non-working hours no equipment or material shall be parked or stored closer than 30 feet to the edge of any roadway carrying traffic. When this is not practical, it shall be placed in an area designated by the Engineer and delineated by reflectorized drums and warning lights. This includes storage of traffic control devices such as trailer mounted or other temporary signs, barricades, drums, etc., which are not in use during non-working hours. To be furnished by the contractor without cost to the ALDOT.
705	During all phases of work, non-applicable pavement striping or markings shall be removed and appropriate pavement striping or markings shall be placed as expeditiously as practical, but in all cases, shall be in place by nightfall on any roadway carrying traffic, except on short term operations where it is determined by the Engineer, that such removal and replacement is more hazardous than leaving existing markings in place. Cost of any removal shall be paid for under Item 701-D.
740	Lightweight Type B warning lights (weighing 3.3 pounds or less) with detachable heads may be used on drums in special situations as shown on the plans. Type B warning lights with detachable heads used on barricades shall be lightweight (weighing 3.3 pounds or less). Any heavyweight warning lights on barricades must be certified by the vendor as to crashworthiness of the barricade and warning light combination.
749	During replacement of guardrail and/or guardrail end anchors, a reflectorized drum with a lightweight Type B warning light (weighing 3.3 pounds or less) with a detachable head shall be placed before the end of any exposed guardrail at night where the guardrail end anchor cannot be replaced in one day's time.

ALDOT Standard Drawings

The Alabama Department of Transportation standard drawings for Traffic Control Plans were reviewed as they related to nighttime work. The two plan sheets reviewed were "Details for Traffic Channelization Devices" and "Barricades Type I, Type II, Type III and Vertical Panels" (36, 37).

With regard to channelizing devices, several nighttime provisions were found. For traffic cones and STOP/SLOW paddles, the sheeting was noted as "reflectorized" regardless of its being used in daytime or nighttime. For drums it was noted "drums shall be reflectorized for use at night and should never be placed in the roadway without advance warning signs. Flashing warning light should be added when drums are used singly, and steady warning lights when used in series."

With regard to barricades, the notes are similar to those for channelizing devices. All devices were noted as needing reflectorized sheeting, with the exception being the back of a Type III barricade when it does not face traffic. The use of warning lights on the vertical panel was noted as to be "when required or directed by the Engineer." Another note details "When used singly as an object marker, the warning light shall be type 'A' for nighttime use and type 'B' for 24 hour operation. When used for delineation or channelization, warning light shall be Type 'C'." The use of a "flasher" was shown on the Type I barricade, but it was not noted as an option. A note above the Type I barricade adds "If used for channelization, warning light shall be Type 'C'." The use of warning lights on both the Type II and Type III barricades were not in a note form, but shown by a dimensioning arrow "as required". This sheet also refers to MUTCD Part VI, 1988 Edition, Revision 3.

On both of these standard documents, several items need to be updated. The sheeting references should be for retroreflectivity. The barricade sheet should also consider the use of Type “D” warning lights. All lighting should be noted as for nighttime use or as directed by the Engineer. The traffic channelizing devices sheet should also mention that for nighttime use, the STOP/SLOW paddle and the red flag shall be retroreflectorized. Also when used at nighttime, the traffic cones shall have retroreflectorized white bands. The MUTCD referenced should be the latest approved version.

CHAPTER 4

NIGHTTIME LIGHTING SPECIFICATIONS OF TRANSPORTATION AGENCIES

Specifications for work zone lighting requirements were obtained from the departments of transportation in each of five states in addition to Alabama. The specifications in use in Nova Scotia, Canada, were also obtained as a result of a presentation at a Transportation Research Board Committee meeting. Using websites on the Internet, the current name of the state construction or specifications engineer was found in Florida, Georgia, New Jersey, North Carolina, Nova Scotia and Rhode Island. E-mail was used to request the current specification and any other information the engineer might offer. Standard specifications or special supplemental specifications were received from each agency and are included in this Chapter. The current standard specifications for Alabama DOT were also obtained. Each specification was reviewed to determine if it is a descriptive or performance specification, or a combination of these two common styles of specifications.

Specifications Styles and Types

Specifications for a project fall into two basic styles of writing (38). The general styles of specifying materials and workmanship are descriptive or performance. The descriptive style is one which specifies the method, while the performance style is one which specifies the results. Many types of specifications are variations of these styles.

Seven differing types of specification provisions have also been distinguished (38, 39, 40). Each type has distinguishing differences in its definition that lead to the advantages and disadvantages of each as described below.

Descriptive specifications use details of the materials and methods to be used in construction. These may be described in such detail as to be considered a cookbook fashion. Laboratory tests may be required for the materials and inspections may be required for the methods. The descriptive or design specification has the advantages of being based on a wealth of information, experience and knowledge of the specifier, using a set of known materials and describing the method of construction. The disadvantages of the descriptive specification are that the experience may not cover the current conditions and that new materials or methods may not be entertained nor permitted.

Implicit specifications use a reference to unnamed documents that will be complied with during construction even though they are not included in the project documents. The implicit specification has the advantage of involving the knowledge of persons not on the project that may have local information. The disadvantage of the implicit type is that since specific provisions are not addressed, they leave considerable room for differences of materials, methods and results.

Or Equal specifications use an acceptable standard product as an example of the desired result and allow other products that meet or exceed this standard. The advantage of simplicity leads to the disadvantage of not specifying the measurable quantities. Not specifying these quantities allows the owner to determine if an alternative method or material may be considered acceptable.

Performance specifications use the results of the materials and equipment selected to measure the service to be provided. These specifications place the responsibility of selecting material and methods on the contractor along with the responsibility for attaining the desired result. The advantages of performance specifications are in their use when one or more method or type of material may provide the desired result. The performance specification is also of value when the specifier may not be aware of which method or material will be the least expensive and produce the best result. The disadvantage of the performance specification becomes apparent when the work will be divided between two or more contractors or when the forces of the contractor and the owner share portions of the work.

Previous specifications use the results of previously prepared project specifications for the current project. These specifications were usually prepared by the specifier or by someone familiar to the specifier or on a project similar to the current one. The advantage of previous specifications is that prior successful experiences are used. This testing in practice may lull the specifier into a false sense of security that may lead to the disadvantages of this type. The previous specification may not be appropriate in all ways to the current project. It may also contain errors that have not been found or may not cover all the conditions of the current project.

Proprietary specifications use the actual make, model, catalog number or part number of a product or the installation instructions of a particular manufacturer as the only one that will meet the specification. The specifier has the option to allow certain alternatives if desired. The advantages of simplicity and clarity are offset by the limitation that other materials or methods that could produce equal results may not be

allowed, as the intended product is the only one to meet this specification. This type of specification is not allowed in most circumstances for government specifications.

Standard specifications use an established material, documented test method or installation procedure that is generally accepted in the field by experts considered as authoritative. The advantages of standard specifications are that they set procedures for the method of testing and quality of workmanship. Other advantages are that they may be considered as minimum requirements and the standard may become a part of the specification by reference. The disadvantages of standards are that they may apply only for certain general conditions of climate or geographic area, they require the specifier to be familiar with the standards, and that they may not cover all the items required by the project. In the last case, if the item is not in the standard, the selection of material or method has been left to the contractor rather than the specifier. Such standards are often referred to by their abbreviations such as MUTCD for Manual on Uniform Traffic Control Devices, NEC for National Electrical Code, NEMA for National Electrical Manufacturers Association, and OSHA for Occupational Safety and Health Administration.

Agency Specifications

Specifications from seven agencies were reviewed. Each specification was analyzed to determine if it is a descriptive or performance specification, or a combination of these two common types of specification provisions. Also noted are the other provision types found in each specification. The agency specifications are presented at the end of this section.

The Alabama specifications contain four types of provisions (41). Descriptive provisions are used for the light wattage, the length of a mast arm, the type of support and the height of the support. The performance nature of the provision is that it will adequately light the area and will not present a hazard to the traveling public, however no measurable quantities are included for this performance. A standards type of provision is present with reference to the National Electrical Code and National Safety Code. An implicit provision is present with a reference to "all local codes." The provisions of the metric units 1995 specifications are identical to the 2001 specifications that contain dual units.

The Florida specifications contain two types of provisions (42). Descriptive provisions are used for the types of devices that may be used and the conditions of a lighting plan to be submitted for approval. Performance provisions are included with reference to a 5 foot candle minimum intensity and the arrangement to prevent interference with traffic or producing undue glare to property owners. No mention is made as to the method to be used to measure glare.

The Georgia specifications contain two types of provisions, but do not address illumination of the work area (43). Standard provisions are used for references to lights on signs by mentioning the MUTCD Types A and B. Performance provisions are also used for these lights with a flash rate being specified. These performance rates are as specified in the MUTCD standards.

The New Jersey specifications contain two types of provisions (44). Performance provisions are used for the lighting levels in a table with descriptions of tasks and the areas of illumination to be provided. Performance provisions are also used for the aiming

of lights to be done is so as to maintain “the uniformity of illuminance, defined as the ratio of the average illuminance to the minimum over the work area shall not exceed 5:1.” A standards type of provision is present with reference to the NEC, NEMA and OSHA.

The North Carolina specifications contain three types of provisions (45). Descriptive provisions are used for tower and machine lights where the type of lights, the mounting and output ranges are specified. Performance provisions are included in the tower lights where an average maintained horizontal illuminance of greater that 20 foot candles over the work area is required. Standard provisions are also used for the machine lights where the mounting shall be done in accordance with the National Electrical Code.

The Nova Scotia specifications contain three types of provisions (46). Descriptive provisions are used for the laboratory tests for materials and inspection procedures to be followed for sign sheeting, channelizing devices and worker apparel. Performance provisions are included in the three levels of illuminance for the four types of operations with minimum average illuminance and minimum point illuminance specified, as well as, in the level of illuminance of the traffic control person. Performance provisions are also used for describing the results of the crash tests for sign supports and the minimization of glare. No mention is made as to the method to be used to measure the glare. The standards type of provision is present with the references to the Nova Scotia Traffic Control Manual and the “Quality Standards for Work Zone Traffic Control Devices” of the American Traffic Safety Services Association.

The Rhode Island specifications contain four types of provisions (47). Descriptive provisions are used for devices in lane drops, on rollers and as used for floodlighting. Performance provisions are used in the lane drops where the illuminations shall be at “a

minimum average of 2 foot candles" measured both horizontally and vertically at a height of "6 inches above the surface in question." Another performance provision is present for pavers where "a minimum of 10 foot candles must be provided at the screed area" and in the area 15 feet behind the screed when manual raking operations are taking place. A standards type of provision is present in a requirement to comply with OSHA and an implicit provision is present in stating that all generators and wiring "shall conform to all applicable electrical codes".

Illumination Levels in Specifications

Of the non-Alabama specifications reviewed, five of six contained specific illumination levels. Florida specifies 5 foot candles minimum intensity to permit proper workmanship and inspection. Georgia specifies an average maintained horizontal illuminance greater than 20 foot candles over the work area for tower lights. They also specify an average of 10 foot candles for machine lights. Georgia specifies a minimum 50,000 lumens for a tower light and 460,000 lumens combined outputs of all fixtures on each tower light. Machine lights shall have light outputs between 22,000 and 50,000 lumens.

New Jersey DOT's metric specifications require a minimum of 50 lux throughout the entire area of operation, including the setup of lane or roadway closures. New Jersey specifies 100 lux for general illumination of tasks on and around equipment. And they specify 200 lux for specific nighttime tasks, such as, crack filling, sawcutting and joint sealing. New Jersey also specifies that lights shall be aimed and adjusted to provide uniform illumination with a uniformity ratio of 5:1.

Rhode Island DOT specifies a minimum of 10 foot candles at the screed area and where manual raking operations are taking place in a paving operation. The specifications refer to 250 watt lights on rollers, pavers and pick-up trucks.

Night work specifications of the province of Nova Scotia in Canada describe three levels of illuminance. Level 1 means minimum 60 lux average illuminance and 30 lux point luminance. Level 1 pertains to paving, milling, shoulder and guardrail operations. Level 2 means minimum 110 lux average illuminance and 80 lux point luminance. Level 2 pertains to closer distances around pavers, material transfer vehicles and milling machines. Level 3 is defined as minimum 220 lux average illuminance. Level 3 pertains to the illumination of a traffic control person.

Alabama DOT

Specifications for Traffic Control Devices

For Construction Work Zones

SECTION 740
TRAFFIC CONTROL DEVICES FOR CONSTRUCTION WORK ZONES

740.01 Description.

This Section shall cover the work of furnishing, erecting, lighting as directed, handling and maintaining all construction signs (warning, regulatory and guide), barricades and other traffic control devices installed at locations specified by plan details, directed or approved by the Engineer for the purpose of handling traffic safely through construction work zones.

The traffic control devices covered by this Section shall meet the requirements specified in the MUTCD and as detailed on the plans. In case of conflict or discrepancy, the plans shall govern over the MUTCD.

This Section shall also cover the work of furnishing and operating pilot cars and furnishing flaggers to control traffic at such locations and for such periods as are necessary to handle traffic safely through construction work zones.

740.02 Materials.

(a) APPROVAL OF DEVICES.

All signs, barricades, markers, lights and other devices shall be approved for use in highway construction under the provisions of Section 32-5A-36 of the Alabama Code prior to their installation.

The Department has established List IV-3, Work Zone Traffic Control Devices. Devices shown on this list and devices shown on the plans will be the only devices accepted for use. The list is in the Department's manual, "MATERIAL, SOURCES AND DEVICES WITH SPECIAL ACCEPTANCE REQUIREMENTS." Information concerning this list is given in Subarticle 106.01(f) and ALDOT-355.

(b) CRASHWORTHINESS OF DEVICES.

The Contractor shall be responsible for insuring that all devices that are used for work zone traffic control meet "crashworthy" requirements given in the National Cooperative Highway research Program (NCHRP) Report 350 for the appropriate category of device.

(c) CATEGORIES OF DEVICES.

1. CATEGORY 1 DEVICES.

Category 1 Work Zone Devices are small, lightweight devices (including cones, plastic drums, flexible delineators, etc.) that are known to be crashworthy either by crash testing or by years of demonstrable safe performance.

2. CATEGORY 2 DEVICES.

Category 2 Work Zone Devices are small, lightweight devices (including barricades, sign supports, etc.) that will not produce significant velocity change when struck but may otherwise be potentially hazardous. All Category 2 devices manufactured or purchased on or after October 1, 2000 shall be crashworthy. All Category 2 devices manufactured or purchased before October 1, 2000 shall not be used after October 1, 2004.

3. CATEGORY 3 DEVICES.

Category 3 Work Zone Devices are truck mounted impact attenuators, work zone impact attenuators, and portable concrete barriers. All impact attenuators shall be crashworthy.

Portable concrete barriers that were fabricated in accordance with the details shown on Sheet 1 of ALDOT Special Drawing PNJB-629 and have "ALDOT 350-TL" cast into the top of the rails are crashworthy and are acceptable for installation.

Portable concrete barriers that were fabricated in accordance with the details shown on Sheet 2 (sheet titled "PREVIOUSLY CAST CONCRETE BARRIER") of ALDOT Special Drawing PNJB-629 do not have "ALDOT 350-TL" cast into the top of the rail. These barriers are acceptable for use until October 1, 2010.

Other types of portable concrete barrier rails may be used with the written approval of the State Construction Engineer.

4. CATEGORY 4 DEVICES.

Category 4 Work Zone Devices are large trailer mounted devices such as sequential arrow boards and changeable message signs. Standards for rating Category 4 devices as "crashworthy" have not been developed.

(d) MATERIALS FOR FABRICATION, CONSTRUCTION, AND INSTALLATION.

Materials used in the fabrication, construction and installation of the construction signs, barricades and other devices shall conform to the requirements of Article 104.04, plan details, the MUTCD and the details noted in this Section:

Sign panels may be fabricated from one of the types of material shown below:

Material	Min. Panel Thickness	* Sign Face Area
Aluminum Flat Sheets	0.080 inches {2.00 mm}	All sizes
Steel Flat Sheets	0.075 inches {1.90 mm}	All sizes
Plastic Flat Sheets	0.250 inches {6.35 mm}	All sizes
Exterior Plywood Sheets, Grade A-C	0.50 inches {13 mm} 0.75 inches {19 mm}	Up to 16 square feet {1.5 m^2} Over 16 square feet {1.5 m^2}

*NOTE: Any sign panel installation using Standard Mounting procedures, which in the opinion of the Engineer does not provide a reasonably rigid sign installation, shall be strengthened by the use of additional supports and/or backing stringers.

Sign background and messages shall be formed using materials noted for such in Articles 880.02 and 880.03. To permit visual verification of proper use, each type sheeting shall display an identifiable symbol, on the face of the sheeting, in a repeat pattern.

When no pre-requirements are specified for units, they shall comply with the manufacturer's specifications as approved by the Department under the provisions of Section 32-5-36 of the Alabama Code.

Items are not required to be new. Used items may be acceptable provided the following conditions are met:

- Units are in good repair, clean and structurally sound.
- Reflective sheeting on any unit is clean and in good repair.
- All legends and messages are sharp, clean and legible.
- Reflectivity of said units during the hours of darkness shall provide acceptable, clear and uniform delineation without dead spots.

No test reports are required, but the Engineer shall visually inspect all units and accessories for compliance with the various dimensional and material stipulations noted before approving their use in the work. The approval of any unit for use is subject to satisfactory field performance and does not preclude the Engineer ordering replacements of units; said replacements for these previously approved units shall be without additional compensation.

(e) PILOT CAR, FLAGGERS, AND FLAGGING EQUIPMENT.

The pilot car, flaggers, and all flagging equipment shall meet the requirements of the MUTCD. The pilot car shall be a registered motor vehicle designed for use upon a highway. "Off-road" type vehicles will not be allowed.

740.03 Construction Requirements.

(a) GENERAL.

The Contractor shall designate or otherwise provide personnel to furnish continuous surveillance over his traffic control operations. This designee will also be available at night to respond to calls involving damage to barricades, lights, signs, etc., either through vandalism or traffic accident. The Contractor shall make known the name of the person providing the surveillance both at the preconstruction conference and to local police establishments.

All traffic control devices necessary for the first stage of construction shall be properly placed and in operation before any construction is allowed to start. When work of a progressive nature is involved, such as resurfacing a road under traffic, the necessary signs shall be moved concurrently with advancing operation.

All construction signs shall be erected in a workmanlike manner such that all supports are vertical, sign panels generally perpendicular to the travelway and legends horizontal so that they effectively convey the intended message. These signs shall be mounted on stationary or temporary supports as directed by the Engineer and dependent on the type work being performed. In general work being performed at spot locations and of short duration will necessitate the use of temporary supports properly ballasted for stability. If the construction signs are not to be lighted, the supports shall not extend above the top edge of the sign panel.

The location, legends, sheeting, dimensions, spacing of supports, and horizontal and vertical placement with respect to the pavement of warning signs, barricades and other traffic control devices shall be as required by plan details, MUTCD and as directed or approved by the Engineer. The Contractor must advise and have the approval of the Engineer prior to installing or removing traffic control devices from the project.

During periods of non-use, construction signs and other devices shall be removed from the work area, covered with specified material or otherwise positioned so they do not convey their message to the traveling public. If covered, the covering material shall be 1/2 inch {13 mm} (nominal size) exterior plywood cut to fit the shape of the sign panel. The covering material shall be installed in accordance with the plan details and in such manner that no damage will occur to the sign panel during installation. Covering material shall be maintained in a neat and workmanlike manner during its use,

All construction signs, barricades and other devices which require lighting, as designated by plan details or directed by the Engineer, shall be provided with warning lights or electric incandescent or fluorescent lighting. It will be the Contractor's responsibility to install electric lighting in a safe workmanlike manner and in accordance with the latest edition of the National Electrical Code, National Electrical Safety Code and/or all local codes. The Contractor will be responsible for investigating, procuring and bearing the expense of a continuous power source whether by battery, generator or commercial A.C. supply.

Flagmen with proper attire and flags shall be provided when ordered by the Engineer or when the Contractor deems flagmen necessary to safely handle traffic through the construction zone. Flagmen are considered a general requirement of all traffic control schemes and no direct payment will be made for such.

If at any time the Engineer determines that proper provisions for safe traffic control are not being provided or maintained, he may order suspension of the work until the proper level is achieved. In cases of serious or willful disregard for safety of the public or his employees by the Contractor, the Engineer may proceed forthwith to replace the traffic control measures in proper condition and deduct the cost thereof from monies due or becoming due the Contractor.

(b) SUPPLEMENTARY ITEMS.

1. AREA LIGHTING.

Area lighting is designated for use at locations where standard delineation devices are not considered sufficient to properly guide the traveling public through the construction work nor advise them of the hazardous conditions which exist. The primary use will be in the areas of crossovers and intersections which are not clearly distinguishable during hours of darkness. Area lighting may consist of one or more area lights.

An area light shall consist of a 250 watt mercury vapor light or equivalent, mounted on a 12 foot {3.6 m} mast arm attached to a Class 7 wood pole of sufficient length to provide a 30 foot {9 m} luminaire mounting height above the elevation of the outside edge of paving, unless otherwise shown by plan details. These lights will be placed at locations designated by the Engineer. If possible, the locations should be such that the lights will adequately light the area, but not present a hazard to the traveling public. Bracing or guying of poles which is unsightly or presents a hazard will not be allowed. It will be the Contractor's responsibility to investigate, procure and bear the expense of the power source for these lights whether by commercial A.C. current or generator and to insure that these light sources are installed in a safe workmanlike manner and in accordance with the latest editions of the National Electrical Code, National Electrical Safety Code and/or all local codes.

2. SPECIAL CONSTRUCTION SIGNS.

Special construction signs shall consist of signs which require special fabricated sign panels or special mounting requirements; such signs will be designated as "Special" on the construction plans.

3. PILOT CAR OPERATION.

Pilot car operation and associated flagging shall be performed as described in the MUTCD. Flagmen and flagging devices are considered a necessary requirement of the pilot car operation and no direct payment will be made for such.

(c) MAINTENANCE.

The Contractor shall assume full responsibility for the continuous and expeditious maintenance of all construction warning signs, barricades and other traffic control devices. Maintenance shall include but shall not be limited to replacement of sign panels, barricades and other devices which in the opinion of the Engineer are damaged or deteriorated beyond effective use, replacement of broken supports, plumbing of leaning signs, cleaning of dirty signs, barricades and other devices, repair of defaced signs, replacement of stolen items, etc.

All items used for traffic control shall be generally maintained in its original placement condition and such maintenance will be considered a part of the original installation cost. Failure to maintain all traffic control devices in such manner as to provide adequate continuous safety to the public will be cause for action by the Engineer as noted in the last paragraph of Subarticle 740.03(a).

(d) LIABILITY.

Reference is made to Section 107 of the Specifications which covers the legal responsibilities of the Contractor to the traveling public. Although the Department will be designating and directing the placement of certain traffic control devices, the Contractor is not relieved of his responsibility to continuously review and maintain all traffic handling measures and insure himself that adequate provisions have been made for the safety of the public and workmen.

Construction signs and other traffic control devices specified by plan details are considered the necessary requirements for satisfactory traffic control. This does not preclude the Engineer from ordering, or the Contractor from requesting for approval, additional signs or traffic control devices to safely handle unforeseen traffic situations, in which case they would be paid for. The Contractor may, with the approval of the Engineer, furnish additional traffic control devices, at no cost to the Department, to protect his work and/or workmen.

740.04 Method of Measurement.

The various items used in the handling of traffic through construction zones will be measured for payment as follows:

Construction Signs and Special Construction Signs which are specified by plan details or ordered by the Engineer and approved for use will be measured in square feet {square meters} computed from measurements of the actual sign panel installed (no deductions will be made for corner radii). The sign supports and mounting hardware are considered incidental to the use of these sign units; hence no separate measurement or payment will be made for the supports and hardware. Measurement for payment under the Item of Special Construction Signs will only be made on signs designated as "Special" by plan details or ordered as "Special" by the Engineer.

Drums will be measured individually for the number ordered and furnished.

Cones will be measured per each and shall be 36 inches {900 mm} high with a ballasted base. Cones of smaller height may be used for operations such as pavement striping and marking, but no direct payment will be made.

Ballasts for cones will be measured per each for each weight {mass} ordered, accepted, and used.

Barricades will be measured individually for the type designated and furnished.

Delineators will be measured per each which includes a 3 inches {75 mm} in diameter reflector of designated color, mounted on a #2 {3 kg/m} steel post or equivalent aluminum post as specified by Part VI of the MUTCD.

Warning lights will be measured per each for the type furnished.

Electrical incandescent or fluorescent lights will be measured individually for each light installed.

Area lights will be measured individually for each light assembly installed.

Vertical panels will be measured per each installation for the number of installations ordered and furnished, which shall include the panel, or panels, post, and hardware. A single-sided installation shall be an installation requiring a panel on only one side of the post. A double-sided installation shall be an installation requiring a panel on each side of the post.

The construction plans may contain traffic handling schemes detailing the signs, barricades and other traffic control devices to be installed at certain locations or in some cases for the entire project. If specified on these traffic handling schemes, and a lump sum pay item is provided, payment shall be made on a Lump Sum basis for all signs and devices detailed on these schemes. Signs, barricades, and other traffic control devices included in this Lump Sum measurement shall meet all requirements as outlined in this Section.

Other traffic control items such as traffic control stripes, legends and markings, portable concrete barriers, sequential chevron and arrow boards and pavement markers when so required will be measured and paid for under the appropriate Section for such provided in the Specifications.

Measurement of Item 740-O, Pilot Car, will be the actual number of units (per Each) ordered and accepted. No direct measurement or payment will be made for a pilot car unless it is listed in the pay items of the contract.

740.05 Basis of Payment.

(a) GENERAL.

Payment for Construction Signs and Special Construction Signs measured as noted above will be paid for at the contract unit price bid which shall be full compensation for fabrication of sign panel with proper sheeting and legend, furnishing and erecting on proper supports, furnishing all mounting hardware, covering when not in use, handling and maintaining until project completion.

Payment for drums, barricades, cones, delineators, warning lights, vertical panels, and ballasts for cones, measured as noted above, will be paid for at the contract unit price bid which shall be full compensation for fabrication, erection at designated locations whenever required, furnishing continuous power source for lights, handling and maintenance until project completion.

Electric incandescent or fluorescent lights measured as noted above will be paid for at the contract unit price bid which shall be full compensation for furnishing all materials and mounting hardware, wiring, erecting, maintaining and investigating, procuring and bearing the expense of continuous power supply.

Area Lights measured as noted above will be paid for at the contract unit price bid which shall be full compensation for furnishing all materials and mounting hardware including 250 watt mercury vapor lamp or equivalent luminaire and luminaire mounting arm and Class 7 wood pole, wiring, erecting, maintaining and investigating, procuring and bearing the expense of continuous power supply.

Item 740-O, Pilot Car, measured as noted above will be paid for at the contract unit price bid which shall be full compensation for furnishing and operating the pilot car, for furnishing the pilot car driver and flaggers, for all equipment and materials necessary to complete the work.

Payment for Items 740-B - M will further include all costs in relocating, removing and returning these Items to the project when required to provide a complete traffic control system throughout the life of the project. No payment will be made beyond the maximum quantity of signs, barricades or other traffic control devices provided at any one time except when alternate sign panels are required for proper handling of the traffic, in such case both alternate panels will be measured for payment.

The Lump Sum payment for traffic control devices specified by plan details shall be full compensation for furnishing all materials, power sources and mounting hardware, erecting, handling, relocating signs and devices within the indicated "Traffic Handling Scheme" and maintaining all traffic

control devices until project completion. If traffic control devices are deleted from the traffic handling scheme that is to be paid on a lump sum basis, deductions for the items deleted will be made from the lump sum cost in the amount of the contract unit prices bid for the quantity of individual traffic control items so deleted. Traffic control items which are added to the lump sum traffic handling scheme will be paid for at the contract unit price for the item added. A lump sum payment will be considered as full compensation for "traffic handling scheme". Once construction signs or other warning devices are no longer needed within the designated limits of the lump sum "traffic handling scheme", they may be used in other areas of traffic control and payment will be made under the appropriate pay item.

Unless otherwise designated on the construction plans, all signs, barricades, and other traffic control devices covered by this Section shall become the property of the Contractor at the completion of the project. The salvage value for these items shall be reflected in the contract unit prices bid.

No payment will be made for stored materials under this Section unless the material in storage was either manufactured or purchased new for specific use on the project.

No payment will be made for devices installed solely for the protection of the Contractor's work and which serve no useful purpose in protecting the safety of the public or workmen such as traffic cones for paint protection, devices installed to protect fresh concrete presenting no hazard, etc.

The Contractor will be expected to submit a balanced bid for all traffic control items. The submission of unbalanced bid prices may result in loss of contract award.

(b) PAYMENT WILL BE MADE UNDER ITEM NO.:

740-A Traffic Control Scheme - per lump sum
740-B Construction Signs - per square foot {square meter}
740-C Special Construction Signs - per square foot {square meter}
740-D Channelizing Drums - per each
740-E Cones (36 inches {900 mm} high) - per each
740-F Barricades, Type ____ - per each
740-G Barricades, Type I, (Portable, 24 inches {600 mm} wide) - per each
740-H Delineators - per each
740-I Warning Lights, Type ____ - per each
740-J Electric Incandescent or Fluorescent Light - per each
740-K Area Light - per each
740-L Vertical Panel Type __* , __** Sided - per Each
740-M Ballast for Cone - per each
740-O Pilot Car - per each

* Specify either I or II
** Specify either Single or Double

Florida DOT

Night Work Specifications

8-4.1 Night Work: During active nighttime operations, furnish, place and maintain lighting sufficient to permit proper workmanship and inspection. Use lighting with 5 ft@cd [54 lx] minimum intensity. Arrange the lighting to prevent interference with traffic or produce undue glare to property owners. Oprate such lighting only during active nighttime construction activities. Provide a light meter to demonstrate that the minimum light intensity is being maintained. Lighting may be accomplished by the use of portable floodlights, standard equipment lights, existing street lights, temporary street lights, or other lighting methods approved by the Engineer. Submit a lighting plan at the Preconstruction Conference for review and approval by the Engineer. Submit the plan on standard size plan sheets (not larger than 24 by 36 inch [610 by 915 mm]), and on a scale of either 100 or 50 foot to 1 inch [30 or 15 m to 25 mm]. Do not start night work prior to the Engineer's approval of the lighting plan. During active nighttime operations, furnish, place and maintain variable message signs to alert approaching motorists of lighted construction zones ahead. Operate the variable message signs only during active construction activities. Equip all pickups and automobiles used on the project with either amber flashing lights or flashing white lights. Equip all other equipment with a minimum of 4 ft2 [0.37 m2] of reflective sheeting, or flashing lights. To avoid distraction to motorists, do not operate the lights on the vehicles or equipment when the vehicles are outside the clear zone or behind traffic control devices. Ensure that all personnel shall wear reflective vests at all times while in the work area. Comply with all applicable regulations governing noise abatement. Have an ATSSA Certified Worksite Supervisor on site during all nighttime operations to ensure proper Maintenance of Traffic. Include compensation for lighting for night work in the Contract prices for the various items of the Contract. Take ownership of all lighting equipment for night work.

Georgia DOT

Special Conditions Specifications

V. SPECIAL CONDITIONS

A. The special conditions contained herein are Project Specific. When there is a conflict between the General Provisions of Sections I through IV of this Specification and the Special Conditions, the Special Conditions will govern the Work.

B.

1. The Contractor shall sequence milling and inlay operations to begin on the outside lane/shoulder and work towards the median lane/shoulder. All milled sections of the road way shall be inlaid before opening the road way to traffic. Traffic shall not be permitted to travel on the milled surface. Solid pavement marking lines will be required in all irregular or transition areas. The minimum and maximum width for temporary lanes shall be eleven feet (11'-0") and sixteen feet (16'-0") respectively. When milling and inlaying or placement of PEM mix would create a lane width of sixteen feet or greater, the Contractor shall eradicate all existing lane lines remaining to the left and re-stripe to create lanes between eleven and sixteen feet. The proposed HOV lane shall be separated from the remaining lanes using Type II delineation and remain closed to traffic. The northbound and southbound HOV lanes shall be opened simultaneously. Temporary striping and eradication of pavement markings will not be measured or paid for separately.

2. There are lanes in the project that shall be milled and inlaid to maintain surface rideability. These areas of milling, depths, limits, and asphalt pavement requirements are shown on plan sheet 17, and the associated quantities are shown on plan sheet 16. The contractor shall perform the mill and inlay as the first order of paving work starting at the beginning of the 1999 asphalt paving season. This work has an intermediate completion date of September 30, 1999.

C. Lane closures, detours, pacing of traffic, and other activities that visibly slows traffic will be allowed in accordance with this section.

1. **Permissible Number of Lane Closures**

The following lane closures shall be permitted:

In a 3 lane section – up to 2 lanes may be closed
In a 4 lane section – up to 2 lanes may be closed
In a 5 lane section – up to 3 lanes may be closed
In a 6 lane section – up to 3 lanes may be closed

2. Weekday Lane Closure Restrictions

5:00	A.M.	-	10:00 A.M.	No Lane Closures for Northbound and Southbound Traffic.
3:00	P.M.	-	7:00 P.M.	No Lane Closures for Southbound Traffic
3:00	P.M.	-	9:00 P.M.	No Lane Closures for Northbound Traffic

3. Lane Closure Schedule

a. Single Lane Closure

Northbound

9:00 P.M. - 5:00 A.M.,
10:00 A.M. - 3:00 P.M.
Weekdays

9:00 P.M., Friday -
11:00 A.M., Saturday

8:00 P.M., Saturday -
5:00 A.M., Monday

Southbound

7:00 P.M. - 5:00 A.M.,
10:00A.M. - 3:00 P.M.
Weekdays

7:00 P.M., Friday -
3:00 P.M., Sunday

7:00 P.M., Sunday -
5:00 A.M., Monday

b. Double Lane Closure

Northbound

10:00 P.M. - 5:00 A.M.,
Weekdays

10:00 P.M., Friday -
10:00 A.M., Saturday

9:00 P.M., Saturday -
11:00 A.M., Sunday

9:00 P.M., Sunday -
5:00 A.M., Monday

Southbound

9:00 P.M. - 5:00 A.M.,
Weekdays

9:00 P.M., Friday -
10:00 A.M., Saturday

8:00 P.M., Saturday -
11:00 A.M., Sunday

8:00 P.M., Sunday -
5:00 A.M., Monday

c. Triple Lane Closure

Northbound	*Southbound*
10:00 P.M. - 5:00 A.M., Monday though Thursday	10:00 P.M. - 5:00 A.M., Monday though Thursday
Midnight, Friday - 10:00 A.M., Saturday	11:00 P.M., Friday - 10:00 A.M., Saturday
10:00 P.M., Saturday - 10:00 A.M., Sunday	10:00 P.M., Saturday - 10:00 A.M., Sunday
10:00 P.M., Sunday - 5:00 A.M., Monday	10:00 P.M., Sunday - 5:00 A.M., Monday

d. Shoulder Closures

Shoulder closures will be allowed in accordance with the schedule shown for single lane closures. Shoulders may be closed for longer periods of time for specific items of work as approved by the Engineer. Shoulder closures in excess of 2000 feet shall provide openings at intervals not to exceed 2000 feet for the purpose of clearing disabled vehicles.

4. Specific Calendar Date Restrictions

No lane closures will be allowed between the hours of 7:00 A.M. and 10:00 P.M. from November 24, 1999 to January 3, 2000, inclusive. Also, no lane closures will be allowed between the hours of 7:00 A.M. and 10:00 P.M. from November 22, 2000 to January 2, 2001, inclusive.

New Jersey DOT

Nighttime Operations Specifications

617.05 Nighttime Operations

All operations that are performed during the non-daylight hours shall be properly illuminated to allow for the complete performance and inspection of the work. This work shall consist of furnishing, installing, operating, maintaining, moving, and removing portable light towers and equipment-mounted lighting fixtures for nighttime construction operations, for the duration of nighttime work on the Contract. Nighttime operations consist of work specifically scheduled to occur after sunset and before sunrise. Should the Contractor elect on its own to operate during these hours, the requirements of this Subsection shall apply and no additional compensation will be made. Before nighttime operations may begin the Contractor shall demonstrate to the Engineer that its nighttime operation meets the light level requirements.

1. **Light Levels and Illumination Requirements.** A minimum of 50 lux shall be maintained throughout the entire area of operation. Area of operation is a work area that is a minimum of 20 meters ahead and behind the employee, where an employee is on or near the roadway.

   A minimum illuminance level of 50 lux shall be provided during the setup and removal of lane or roadway closures installed in conjunction with nighttime construction operations.

   Specific tasks should meet the minimum illumination levels shown in the following table:

Minimum Illumination Level	Description of Tasks	Areas of Illumination
50 lux	Embankment, fill and compaction Excavation-regular, lateral ditch, and channel Landscape, grassing, and sodding Maintenance of earthwork embankment Mechanical sweeping and cleaning Reworking shoulders Subgrade stabilization and construction	General illumination throughout area of operation
50 lux	Bituminous concrete milling * Bituminous concrete paving operation *	General illumination throughout area of operation Minimum of 60 meters ahead and 60 meters behind equipment
50 lux	Bituminous concrete roller operation *	General illumination throughout area of operation Minimum of 30 meters ahead and 30 meters behind equipment

100 lux	Barrier walls and traffic separators Base course construction Bituminous concrete milling * Bituminous concrete paving operation * Bituminous concrete roller operation * Bridge decks Bridge painting Concrete pavement Drainage structures, culverts, and storm sewers Guide rail and fencing Highway signs and permanent installation Removal of pavement Other concrete structures Painting stripes and pavement markers Pot hole filling Repair of concrete pavement Resetting guide rail and fencing Sidewalks Surface treatment Waterproofing and sealing Any other operation not listed in this table	General illumination of tasks on and around equipment Minimum of 8 meters ahead and 8 meters behind equipment Illumination shall be provided on the sides of the equipment
200 lux	Crack filling, sawcutting, and sealing joints Electrical work Highway street lighting Traffic signals Intelligent transportation systems	Illumination on task

* Both requirements of 50 lux and 100 lux for these operations must be met.

Light meter readings shall be taken horizontally to the roadway surface facing the light source.

If the Contractor fails to meet minimum illuminance levels at any time, the Contractor shall cease its nighttime operations until such time that required light levels are attained.

The uniformity of illuminance, defined as the ratio of the average illuminance to the minimum illuminance over the work areas shall not exceed 5:1.

2. **Equipment.** Materials and/or equipment shall be in good operating condition and in compliance with applicable OSHA, NEC, AND NEMA codes.

   The Contractor shall furnish, for use be the Engineer, two light meters capable of measuring the level of illuminance in lux. These light meters shall be supplied to the Engineer for use as necessary to check the adequacy of illumination throughout the nighttime operations. The light meters will become the property of the Contractor after acceptance.

   The Contractor shall provide suitable brackets and hardware to mount lighting fixtures and generators on machines and equipment. Mountings shall be designed so that lights can be aimed and positioned as necessary to reduce glare and to provide the required illuminance. Mounting brackets and fixtures shall not interfere with the equipment operator or any overhead structures and shall provide for secure connection of the fixtures with minimum vibration.

Portable and trailer-mounted light towers shall be sturdy and free-standing without the aid of guy wires or bracings. Towers shall be capable of being moved as necessary to keep pace with the construction operation. Portable towers and trailers shall be positioned to minimize the risk of being impacted by traffic on the roadway or by construction traffic or equipment.

Light towers mounted on paving and milling machines, rollers, and other paving equipment shall not exceed the height of vertical underclearances, such as trees, aerial utilities, or bridge underclearances. Lights shall be aimed and adjusted to provide uniform illumination with a uniformity ratio of 5:1. The hopper, auger, and screed areas of pavers shall be uniformly illuminated. The operator's controls on all machines shall be uniformly illuminated.

Conventional vehicle headlights shall not be permitted as the means of illumination while working. All moving equipment used for nighttime operations shall have a lighting system consisting of a minimum of two lights directed in each direction of travel of the equipment. The equipment shall also have a minimum of 0.05 square meter high intensity retroreflective sheeting toward the extremities of each side of the equipment. A minimum of 0.1 square meter of the sheeting shall be visible from each direction. All workers shall, during the hours of darkness, wear reflectorized garments as specified for traffic directors.

Existing street and highway lighting shall not eliminate the need for the Contractor to provide lighting. Consideration may be given to the amount of illumination provided by existing lights in determining the wattage and/or quantity of lights to be provided.

The Contractor shall provide sufficient fuel, spare lamps, generators, and qualified personnel to ensure that all required lights operate continuously during nighttime operations. Each generator shall have a fuel tank of sufficient capacity to permit operation of the lighting system for a minimum of 12 hours. In the event of any failure of the lighting system, the operation shall be discontinued until the required level of illumination is restored. Hydraulic generator systems shall be used in residential areas and areas designated to minimize noise pollution. If hydraulic generator systems are unavailable, other generator-powered systems may be used with the approval of the Engineer.

A supply of emergency flares shall be maintained by the Contractor for use in the event of emergency or unanticipated situations.

3. **Glare Control.** All lighting provided under this item shall be designed, installed, and operated to avoid glare that interferes with traffic on the roadway or that causes annoyance or discomfort for residences adjoining the roadway. The Contractor shall locate, aim, and adjust the lights to provide the required level of illuminance and uniformity in the work area without the creation of objectionable glare. The Engineer shall be the sole judge of when glare is unacceptable, either for traffic or for adjoining residences. The Contractor shall provide screening such as shields, visors, or louvers on lights as necessary to reduce objectionable levels of glare.

North Carolina DOT

Portable Construction Lighting Specifications

SECTION 1412
PORTABLE CONSTRUCTION LIGHTING

1412-1 DESCRIPTION.

This section describes portable lighting which shall be used for compliance with the Standard Specification Section 105-14 Night Work requirement for artificial lighting.

1412-2 MATERIALS.

All lighting equipment will be furnished as required and retained by the Contractor after the work is completed. Material and/or equipment is not required to be new but shall be in good operating condition and in compliance with applicable safety and design codes.

The Contractor shall submit, for the Engineer's review and approval, a lighting plan showing the type and location of lights he proposes to use for night work. The plan shall be presented on standard size roadway plan sheets (22" x 36") and on a scale of either 100' or 50' to the inch. It shall clearly show the location of all lights necessary for every aspect of work to be done at night. In addition to the plan sheets, the Contractor shall submit catalog cuts giving the specific brand names, model numbers and ratings of the lighting equipment. The submittals shall include power ratings and photometric data. The Contractor shall allow 40 days for the Engineer to review the submittals. Night work shall not begin without the Engineer's approval of a lighting plan and the indicated lighting equipment and/or materials being in operation.

1412-3 TOWER LIGHT.

A tower light shall consist of mercury vapor, metal halide, high pressure sodium or low pressure sodium fixtures mounted on a tower approximately 30' in height. The tower light fixtures shall be heavy duty flood, area, or roadway style with wide beam spread. Fixtures used for a tower light shall have an output of 50,000 lumens minimum, and the combined outputs of all fixtures on each tower light shall not exceed 460,000 lumens. The fixtures shall be weatherproof and supplied with attached waterproof power cord and plug. The tower shall be sturdy and free-standing without the aid of guy wires or bracing. The power supply shall be of sufficient capacity to operate the light(s) and shall be located for the shortest safe routing of cables to the fixtures. A tower light consisting of the combined fixture(s), tower and power supply is preferred.

Tower lights shall be of sufficient wattage and/or quantity to provide an average maintained horizontal illuminance greater than 20 footcandles over the work area.

The lights shall be aimed and positioned to not only illuminate the area for construction work, but to assist the motorist. There shall not be any disabling glare to the motorist. In no case should the main beam of the light be aimed higher than 60° above straight down. The lights should be set as far from traffic as practical and aimed in the direction of, or normal to, the traffic flow.

1412-4 MACHINE LIGHTS.

Machine lights shall be mercury vapor, metal halide, high pressure sodium or low pressure sodium conventional roadway enclosed fixtures mounted on supports attached to the construction machine at a height of approximately thirteen feet (13'). Each fixture used for machine lights shall have light output between 22,000 and 50,000 lumens. The power supply shall be of sufficient capacity to operate the light(s) and shall

be securely mounted on the machine. Electrical grounding of generators to frames of machines on which they are mounted shall be done in conformance with the National Electrical Code (NEC).

The machine light fixtures shall be of sufficient wattage and/or quantity to provide an average maintained horizontal illuminance greater than 10 footcandles on the machine and the surrounding work area. Machine lights are in addition to conventional automotive type head lights which are necessary for maneuverability.

1412-5 CONSTRUCTION METHODS.

Tower lights may be used when the night work is confined to a fairly small area and is essentially a stationary operation.

Machine lights may be used when the night work is not confined to a small area and is essentially a continuous moving construction operation.

Tower lights may be provided in lieu of machine lights upon approval by the Engineer. Use of tower lights in lieu of machine lights will be considered when the number of machines, type of work, or need for inspection justify their use as decided by the Engineer.

The work area where traffic control devices are being set up or repositioned at night shall be illuminated.

The work areas to be illuminated are the areas where construction equipment and labor are in operation and may be different from the work areas shown in the plans.

The illuminated work area shall be large enough so that the movements of all personnel and equipment engaged in the work will be contained in the area.

The Contractor shall provide sufficient fuel, spare lamps, generators, and personnel qualified to operate the lights to assure that they will be maintained in operation during night work.

Existing street lights shall not eliminate the requirement for the Contractor to provide lighting. Consideration may be given to the amount of illumination provided by existing lights in determining the wattage and/or quantity of lights to be provided, if noted in the Contractor's submitted lighting plan.

1412-6 BASIS OF PAYMENT.

Payment for lighting provided by Tower and Machine Lights will be made only when a significant amount of night-time work is explicitly required and a pay item for portable lighting has been included in the contract. Otherwise, portable construction lighting will be considered incidental to other contract items and no direct payment will be made.

Payment for the lighting provided by tower and machine lights will be made at the contract lump sum price for "Portable Lighting". Partial payments for this pay item will be made as follows:

1. 50% of the lump sum price on the first partial payment estimate.
2. 25% of the lump sum price on the first partial payment estimate made after the project is 50% complete.
3. 25% of the lump sum price on the first partial payment estimate made after the project is 100% complete.

Such price and payment will be full compensation for all work of furnishing, operating and maintaining everything necessary to provide lighting.

1412-7 COMPENSATION.

Payment will be made under:

Portable Lighting ..... Lump Sum

Nova Scotia DOT and Public Works

Night Work Specifications

Night Work Specification

1.0 Hours of Work

The contractor is advised that most work for this contract will be carried out during night time hours. For the purposes of this contract "night" is defined as the period beginning one half hour after sunset and ending one half hour before sunrise as posted by Environment Canada.

Full or partial lane closures (including ramps) will **not** be permitted during the following hours :

Monday to Friday	6:00 AM to 7:00 PM
Saturday	10:00 AM to 7:00 PM
Sunday	11:00 AM to 7:00 PM

Lane closures not in compliance with these limits will be subject to a lane rental fee of $750.00 for every 15 minute increment or any part thereof.

2.0 Traffic Control Plan

At least 30 days prior to the start of work the contractor must submit 4 bound copies of a detailed "Night-Time Work Plan" for review and approval by the Department. The plan must be updated by the contractor as operations require.

The plan must include, but may not be limited to :

Traffic Control

Detailed written description of all traffic control procedures (referenced to drawings).
Detailed drawings of all traffic control procedures and signing including controls for ramp traffic - all drawings to be on either letter or tabloid size sheets with title blocks.
Detailed description of set-up/tear down and lane shift times, sequences & procedures.
Detailed description of all channelization and guiding devices to be used.
Detailed plan for handling emergency vehicles passing through the site.
Frequency of inspection and detailed procedure of patrolling the traffic control set-up.
Details for placing temporary traffic markings & erection of shoulder hazard signing.
Details of Traffic Control Person personal protective equipment.
Detailed sketch of proposed temporary sign stand design.
Detailed drawings of all work area internal traffic control procedures - all drawings to be on either letter or tabloid size sheets with title blocks.

Gerard Kennedy, P. Eng - Project Engineer - February 23, 2004
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Lighting Plan

The lighting plan must be prepared by a Professional Engineer knowledgeable in the science of photometrics and vision.

Descriptions and sketches of the layout of light towers including spacing, luminary height, lateral placement and anticipated illuminance provided.
Photometric & physical specifications of all lighting equipment.
Detailed description of all lighting to be used on construction equipment.
Methods to be employed to reduce glare.
Contractor's frequency and procedure for checking illumination levels.

Special Safety Elements

Details of personal protective equipment which will be required for workers.
Detailed lesson plans for training which will be given to workers and an example of the card which will be issued to personnel who have received the training.
Details of equipment warning devices which will be employed.
Detailed Hazard Assessment for night work.
Emergency response plans.

Other Elements

Noise and vibration abatement methods which will be employed where necessary

3.0 Minimum Requirements

The provisions of the Nova Scotia Temporary Traffic Control Manual apply to this project. A pilot vehicle shall be used to guide traffic during all lane closures on this project.

Additional minimum requirements for work at night on this project are as follows.

3.1 Signing

3.1.1 Materials : All signs shall have retroreflective sheeting which meets the requirements of ASTM Type III sheeting.

3.1.2 Placement : Signs shall be erected at a minimum height of 1.5 m to the bottom of the sign. They must be essentially perpendicular to the direction of traffic and vertical. The sign shall be adequately supported to ensure minimal movement from this position.

The supports for these signs shall be constructed so that they break away or collapse on impact.

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3.1.3 Flashing Light Units : Units shall have lights which can be dimmed. Non-functioning lamps and bulbs shall be replaced immediately. Red and white reflective tape shall be applied to all sides of the unit such that it defines the outline of the unit.

3.2 Channelization Devices

3.2.1 Materials : Retroreflective sheeting for all channelization devices (cones and drums) shall meet the requirements of ASTM Type III sheeting.

Drums shall be used for all channelization on "100 Series" highways.

Cones may be used for channelization on "non-100 Series" highways. Cones for night work shall be a minimum of 700mm in height with two reflective bands as described in Figure 1 of this specification.

Ballast for all channelization devices shall be placed at ground level.

3.2.2 Placement : The maximum distance permitted between channelization devices shall be based on work zone operating speeds as follows :

Estimated Operating Speed (km/h)	Maximum Spacing (m)
Less than 50	2.5
50 to 70	5
Greater than 70	10

3.2.3 Ramps and Intersections : Devices used at ramps and intersections shall be spaced at intervals equal to one-half of the values show in Section 3.2.2. In these areas it is permissible to alternately space with drums and cones.

When exit ramp gores are relocated with channelization devices, a temporary exit sign shall be erected at the relocated gore. The signs shall be a minimum 100 cm x 75 cm with white 15 cm letters on a green reflective background. The sign shall have the exit number and a directional arrow.

3.2.4 Transverse Drum Barriers : Two drums shall be placed transversely across the closed lane at a spacing of 250 meters to alert errant drivers.

3.3 Traffic Control Persons

3.3.1 Training : All traffic control persons shall receive training in addition to the general worker training which deals specifically with nighttime traffic control procedures. Traffic control persons on-site must carry a card certifying they have received this training.

3.3.2 Illumination : The traffic control person shall be illuminated from above at minimum of Level 3 illuminance as defined in Section 3.6 of this specification.

In the event of failure of any portion of the lighting system at a traffic control person station, all operations must be discontinued until the required illumination is restored.

3.3.3 Visibility : In addition to their standard protective equipment, Traffic Control Persons shall wear a CSA Z96-02 Class 2 fluorescent orange-red vest or jacket over white coveralls. They shall also have a minimum of 80 sq. cm of reflective material added to their hard hats which is visible from all sides. They must also be equipped with a flashlight complete with semi -transparent red cone.

3.3.4 Communications : All traffic control persons shall be equipped with radios so that they have communication with each other and the pilot vehicle operator.

3.4 Workers

3.4.1 Training : All workers shall receive specific training on night work operations. Personnel on-site must carry a card certifying they have received this training.

3.4.2 Visibility : In addition to their standard protective equipment, All workers shall wear a high-visibility vest or jacket which meets the requirements for CSA Z96-02 Class 2 apparel. They shall also have a minimum of 80 sq. cm of reflective material added to their hard hats which is visible from all sides.

3.5 Work Vehicles

3.4.1 Training : All vehicle operators shall receive specific training on night work operations. Personnel on-site must carry a card certifying they have received this training.

3.4.2 Visibility : In addition to their standard protective equipment, all equipment operators who leave their vehicles shall wear a high-visibility vest or jacket which meets the requirements for CSA Z96-02 Class 2 apparel. They shall also have a minimum of 80 sq. cm of reflective material added to their hard hats which is visible from all sides.

3.4.3 Flashing Lights : All vehicles in the work area must operate rotating or flashing incandescent amber lights visible in 360 degrees around the vehicle. Strobe lights are not permitted.

3.4.4 Reflectorized Markings : All work vehicles including trucks must have red and white reflective tape applied to all sides such that it defines the outline of the vehicle.

3.4.5 Truck Message Signs : All trucks which are required to enter and exit the lane closure will display a sign on their rear which reads "WORK VEHICLE - DO NOT FOLLOW". The sign shall be reflectorized and at least 120 cm x 60 cm with 15 cm black letters on an orange background.

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3.4.5 Truck Turning : To avoid confusing motorists and to improve site safety, trucks will not be permitted to turn around on the site. After delivery of their load all trucks must proceed to the next interchange to turn.

3.4.6 Internal Traffic Control Plan : A detailed traffic control plan for the movement of construction vehicles on the site shall be developed and included in the training of all personnel.

3.6 Lighting

3.6.1 Illuminance : The level of illuminance required for various tasks will be defined in three "levels". Luminaries must be of sufficient wattage and quantity to provide a minimum horizontal illuminance as follows.

Level	Minimum Average Illuminance	Minimum Point Illuminance
Level 1	60 Lux	30 Lux
Level 2	110 Lux	80 Lux
Level 3	220 Lux	

3.6.2 Work Area : Level 1 illumination shall be provided in all areas which workers and inspection staff regularly carry out their duties. In addition to this basic requirement the following illuminance levels shall be provided :

3.6.2.1 For paving operations :
Level 2 - a minimum of 15 m ahead of the paver and material transfer vehicle. A minimum of 30 m behind the paver.
Level 1 - a minimum of 120m ahead to 250 m behind the paver.

3.6.2.2 For milling operations :
Level 2 - a minimum of 15 m ahead and 15 m behind the milling machine.
Level 1 - a minimum of 120m ahead to 250 m behind the milling machine.

3.6.2. For shouldering operations :
Level 1 - a minimum of 120m ahead to 250 m behind the shouldering machine.

3.6.2.4 For guardrail operations :
Level 1 - a minimum of 100 m ahead to 100 m behind the section under construction.

3.6.3 Glare : All luminaries shall be located and directed in such a way to minimize glare to both motorists and work vehicles. If severe glare is noted from any travel path, the contractor must adjust the lighting to reduce the glare to an acceptable level.

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3.6.4 Measurement of Illuminance :Measurements shall be taken at the road surface, in a uniform pattern spaced at 5m throughout a representative test area. Illumination measurements are to be made by a person familiar with using a photometer and the operator shall not wear reflective materials while taking the measurements.

The contractor shall check the illumination levels on the site each time a change in lighting configuration is made and at least once every 5 working days. A copy of the measurements shall be given to the Engineer within 24 hours.

The contractor shall also provide on-site, for use by the Engineer, a photometer capable of measuring the level of illuminance.

3.6.5 Lighting Maintenance: The contractor shall replace non-functioning lamps immediately. The luminary aiming shall be checked daily. The luminaries shall be cleaned regularly.

3.7 Accommodation of Traffic

3.7.1 Delays :On this Contract the Work Zone, consisting of the Work Area and Buffer Area, shall not exceed 1.5 km in length, unless authorized by the Engineer.

The Contractor shall carry out their work activities in such a manner to minimize traffic delays. The following maximum time delays to traffic shall be adhered to:

a) an accumulative 20 minutes through the Contract limits, and
b) 10 minutes through any one Work Zone.

The Contractor will be required to adjust work activities, minimize the length and/or number of Work Zone(s), to adhere to these limits.

During times of high traffic volumes, should the limits not be met, the Contractor may be required to stop work activities and pull off the road until volumes permit restarting.

3.8 Traffic Control Maintenance

The contractor must employ a full time traffic control supervisor with enough staff to ensure constant patrol and maintenance of all traffic control devices.

3.8.1 Traffic Control Devices :

All signs, channelization devices and other traffic control devices shall be kept clean and in acceptable condition. The minimum standard for acceptability shall be the latest edition of "Quality Standards for Work Zone Traffic Control Devices" by the American traffic Safety Services Association.

3.8.2 Lane Openings : Prior to opening any lane to traffic all the temporary pavement markings, hazard markers and hazard signing must be in place.

Temporary markings must be spaced at a maximum of 10m. Markings may be made with an approved temporary marking tape or with a combination of painted marks and temporary overlay markers. Where painted marks are used they must be coated with glass beads and temporary overlay markers (TOMs) must be placed at a maximum spacing of 20m over the painted marks.

4.0 Traffic Control Trial

Prior to the start of work a traffic control trial shall be carried out for inspection by the Contractor and a Department representative. The trial shall involve setup and operation of the full traffic control system and work area lighting system. No work shall commence until approval is given by the Department to proceed.

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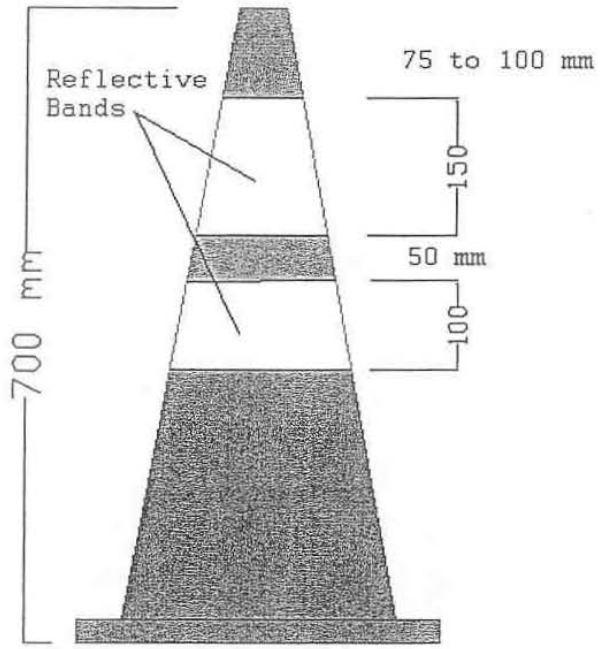
Night Work Specification
Figure 1- Cone for Night Work



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Rhode Island DOT

Equipment Lighting Specifications

Equipment Lighting

Rollers: Each roller shall be equipped with a two (2) unit light cluster on both the front and back. A single cluster with two (2) units (one (1) wide beam and one (1) narrow beam) aimed towards the front is to be used. All floodlights shall be securely mounted to minimize vibrations during roller operations. Floodlights should be mounted on steel bullhorn style brackets with two (2") inch tenons and a 36 inch spread. Mounting height shall be a minimum of eight (8") above the top platform surface of the roller (provided the overall height from ground level does not exceed 15 feet). Mounting height and placement shall be designed to allow the operator to run the roller from a standing position without blocking the lighting beams onto the roadway. Floodlights for the roller shall be 250 watt metal halide fixtures as described below.

Truck: A minimum of two (2) pickup trucks equipped with floodlights shall be provided by the contractor. Each truck shall have a minimum of three (3) (one (1) wide beam and two (2) narrow beams) 250 watt metal halide floodlights mounted on supports on the pickup truck bed. The floodlights shall be aimed in a forward direction over the truck cab but shall also have the capability of being adjusted and aimed in any direction, if required. Floodlights for truck mounting shall be as described below.

Pavers: Single width (12 foot nominal) and double width (24 foot nominal) pavers shall be equipped with a continuous twin lamp fluorescent bar consisting of enclosed four (4) foot fluorescent fixtures mounted end to end across the full width of the screed area. Fixtures shall be adjustable so that they may be tilted toward the work area. A minimum of 10 footcandles must be provided at the screed area and in the area (minimum 15 feet) immediately behind the screed where manual raking operations are taking place. Two (2) auxiliary floodlights (narrow beam) shall be provided, one (1) to illuminate guide line and one (1) to illuminate the auger area. Care shall be taken in the placement of these floodlights to avoid aiming of the lights into the line of sight or into the mirrors of trucks which are backing into the auger/hopper area to unload bituminous concrete.

Lighting Equipment Schedule

LOCATION	# OF FIXTURES	SIZE	TYPE	REMARKS
Lane Drop Area	Varies	Varies	Metal Halide	Min. 10 fc.
Rollers	4	250 w	Metal Halide	aim 2 forward & 2 back
Pick-up Trucks	3	250 w	Metal Halide	Variable Aiming
Pavers (Single Width)	3	48"	Twin Lamp Fluorescent	Screed Area
	2	250 w	Metal Halide	Auger & Guide Line
Pavers (Double Width)	6	48"	Twin Lamp Fluorescent	Screed Area
	2	250 w	Metal Halide	Auger & Guide Line

CHAPTER 5

FIELD INVESTIGATIONS AND TRAINING

During the course of the project, seven field visits were made to DOT projects in Alabama and a nearby section of Columbus, Georgia. The purposes of these visits were to observe how the agencies made measurements of roadway illumination, to observe nighttime construction practices, to learn how nighttime traffic control pans were implemented, and to become experienced at note taking at night in a manner similar to what will be needed for project engineers and inspectors. During these visits it became apparent that there is a significant difference between the visual needs of routine roadway illumination and the needs of workers or inspectors on a nighttime project. Both construction and maintenance projects occurring at night were visited during this process,

Field Visits with ALDOT

Six field visits were made with ALDOT employees to review the existing procedures used for evaluating roadway lighting installations and illumination on nighttime construction projects. Two of the visits were made at an off-roadway location to compare equipment under a relatively protected environment. The other four visits were made at locations under traffic. One field visit under traffic was made at a work zone on U. S. Highway 431, one at a complete lighting project I-65, one at a completed lighting project on I-20 and another at a work zone on I-85.

I-85 Field Visits Away From Traffic

On July 20, 2001, John McCarthy met with Jim Eatman, Electrical Engineer Technician of Alabama DOT, at the rest area on the northbound lanes of I-85 in Macon County. The luminaires installed at the rest area were discussed along with the equipment ALDOT used to measure the illumination. Based on these discussions a light meter was obtained for use on the project and a method of testing the readings from two devices was developed. The effect of vehicles and clothing were noticed at this time. The reflectorized vests or light colored shirts worn by an inspector contributed to the readings recorded by the device.

On March 21, 2002, John McCarthy met with Jim Eatman at the same rest area. At this meeting, the use of the ALDOT Minolta T-1 light meter was compared to the use of a Minolta TL-1 meter recently obtained by the Civil Engineering Department for use on this project. An area was marked off to get readings at replicable distances from a fixed luminaire as was used previously. A luminaire was chosen near a pavilion on the west side of the rest area. Readings were taken at ground level, which is customarily used by ALDOT, and at a height of 2 feet above the pavement to determine the effect of elevation, since work area activities such as equipment maintenance, job site preparation and note taking do not take place at ground level. Readings were taken in line with the aiming of the cobra head luminaire, which was mast arm mounted, and at 36 ft either side of the base, since a sidewalk is 36 ft south of the luminaire. Readings were taken at the luminaire base, at the curb line and at points 15 ft into the through lane of the parking lot.

Readings at seven locations were found to be in the range of 1.10 to 2.24 foot candles. Readings on the different meters were found to be within 10 percent of each

other. The ALDOT meter was previously certified as calibrated. The AU meter has not been certified. A list of these readings is presented herein. The ALDOT meter read higher than the AU meter in every case except one.

The readings were recorded using a Palm Pilot III device which was made available for this project. The Palm Pilot has internal illumination which made the recording on this device easier than it was previously with pen and paper. The device may be helpful for taking notes on nighttime projects, but the size of the device makes for a very small keyboard. The size slowed down the data entry when compared to a laptop computer.

Also at this meeting, discussions were held regarding lighting projects now underway by ALDOT. An interstate highway project on I-20 near a Honda Plant in Lincoln, AL, will create a new interchange, which will be illuminated. An existing interchange at AL 77 will also be illuminated in this project. A list of these notes was also recorded on the Palm Pilot and is as follows:

Date: March 21, 2002
Site: I-85 NB Rest Area, Macon Co, AL

Location	Ground level	2 ft high
A-base	N/A	2.01/1.90
A-curb	2.07/2.01	2.24/2.08
A-lane	1.88/1.74	2.02/1.83
B-curb	1.26/1.21	1.23/1.15
B-lane	1.57/1.50	1.63/1.53
C-curb	1.42/1.36	1.55/1.43
C-lane	1.12/1.13	1.20/1.10

Remarks:
A is at luminaire, concrete base prevents ground level reading
B is at sidewalk to pavilion
Luminaire north of base A is missing
Readings are in format of ALDOT Minolta T-1 meter,
followed by the AU Minolta TL-1 meter
Units are in foot candles

Notes:

Notes taken on current ALDOT lighting projects as of March 21, 2002
Talladega lights on I-20 & AL 77, I-20 & AL 213 are on
Honda plant main entrance lights not on
Honda employee entrance lights on
Sumter Co Welcome Center I-59 approx turn on by June/July
Lowndes Co I-65 @ Priester's Pecan to be turned on in 10 weeks
Andalusia bypass 8 miles of lighting is being designed
Birmingham I-65/59/20 bridge used generators w Light Alls
not yet inspected, waiting turn on of replacement highmast with
Holophane fixtures that melted in accident
I-65 & AL 158 is being turned on in June or July

U. S. Highway 431 Field Visit Under Traffic

A work zone field visit was conducted on the night of July 23, 2001. Dr Robert Vecellio, graduate student Emily Fuqua and John McCarthy visited the location of an ALDOT Resurfacing Project on U. S. Highway 431 in Russell County. The resurfacing project is ALDOT Number NHCN01(931) and involves nighttime work to mill, seal, resurface and restripe the four-lane median divided highway of U. S. 431 and to resurface and restripe the frontage roads on either side of U. S. 431. The three researchers met with ALDOT Resident Engineer Larry Kite and Inspector Susan Long before entering the temporary traffic control zone.

The purposes of the visit were to become familiar with the procedures and equipment used to perform the work at night and to take measurements of the amount of illumination present in the area and around the equipment. The Sequence of Construction on Sheet 7 of the project plans called for all work to be performed between 6:00 pm and 6:00 am Central Daylight Time, with no work to be performed two days prior to and or one day after the holidays of Memorial Day, Independence Day, Labor Day and Thanksgiving Day.

The Traffic Control Plan for this project deals with the main roadway separately from the frontage road. The TCP for the four-lane median divided section provides for work to be performed one lane at a time with appropriate Road Work signs, Lane Closed signs, channelizing devices and an arrow panel in the sequential chevron mode. Traffic flow is to be maintained in the lane not closed and in both lanes of the opposing direction. The TCP for the two-lane two-way frontage road provides for work to be performed one lane at a time with a pair of flaggers and a pilot car along with Loose Stone, Road Work, One Lane Road and Flagger Symbol signs. No channelizing devices nor arrow displays are provided for in this TCP. Uneven Lanes signs are also called for in the TCP at one mile intervals as directed by the Engineer. During the visitation, the TCP in effect was for work on the southbound interior lane of U. S. 431.

The equipment used for the project belongs to the contractor, East Alabama Paving Company of Opelika, AL. A milling machine, a chip spreader, a distributor truck, dump trucks, a shuttle buggy, a paver and rollers were all on site to perform the work. Most pieces of equipment had supplemental lights mounted in such a fashion as to increase the visibility of the work area. The paver also had an "Air-Star" non-glare balloon added to its platform for operator and screed visibility. Inside the balloon is a 100 watt halogen bulb. To power the balloon and bulb, a 5250 watt generator was added to the paver. Photographs were taken of the equipment in the parking area and in operation.

Illumination levels were measured using a General Electric Light Meter Type 214. This device provides an analog reading on three scales from zero to 1000 foot-candles. The meter is both color and cosine corrected and was obtained from Dr. Robert

Aderholt of the Building Sciences Department. Ten feet from the base of median support # 12 with the device aimed at the luminaire, a reading of 16 foot candles was obtained. In the closed lane, directly under the luminaire, the reading was 8 foot candles. Both of these ambient readings were taken at waist level, approximately 36 inches above the grade. In front of the shuttle buggy, the reading was 6 foot candles at ground level and 8 foot candles at the edge of the machine.

During discussions with the project engineer, the 2001 Edition of the ALDOT Specifications were discussed. The provision in Section 740 for area lighting was pointed out by the researchers. The project engineer noted the provision for "sufficient artificial lighting to permit proper construction and inspection" in Section 104.04(a).

U. S. Highway 431 runs concurrently with U. S. Highway 280 in this section of Russell County. Since U. S, 431 is Alabama Route 1 and U. S. 280 is Alabama Route 38, the mileposts in the area of the project are those of U. S. 431. This posting is based on the ALDOT policy of mileposts following the lower Alabama route number in concurrent sections. Understanding the procedure for milepost placement was important to locating the project.

I-65 Field Visit Under Traffic

A field visit was conducted at the site of a completed ALDOT lighting project at the Greenville exit of I-65 on September 10, 2001. John McCarthy met with Paul Dent and Jim Eatman of ALDOT at this location. The interstate highway goes over the crossroad at this location. The location now has lighting on the entrance and exit ramps. Measurements were taken every 100 feet along the northbound entrance ramps. The

lighting was noticeably brighter on the shoulder closest to the luminaire and less on the far side. This difference would affect the ability to perform detailed operations by workers or note-taking by inspectors. The pattern of lighting uniformity also left some areas that were considered suitable for driving but not necessarily for detailed work operations. The gore areas were noted as being particularly dark for doing any work. The purpose of the lighting design was noted as being to provide illumination to the drivers on the ramp, not for workers in the gore.

I-20 Field Visit Under Traffic

Another field visit was conducted at the site of an ALDOT lighting project under construction at the Talladega exits of I-20. On April 11, 2002, John McCarthy met with Jim Eatman of ALDOT at this project location. Two interchanges were visited, being the exits with Alabama Highway 77 and Alabama Highway 213. The interstate highway goes under the crossroads at both locations. The main entrance to a nearby Honda plant was also visited where the lights were not yet illuminated. At the employee entrance to the plant, the lights were already illuminated. Measurements were not taken at these locations as the pattern of brightness was evident. At the I-20 locations, it was noted that a different type of lighting had been installed under the structures to give some illumination there. The uniformity under the structures was not the same as it was on the roadway.

I-85 Field Visit Under Traffic

In June and July 2002, a resurfacing project on I-85 in Lee County was visited. The project consisted of daytime Interstate work north of the I-85/U.S. 280 interchange (Exit 62) and nighttime paving work south of the interchange. All work is in the city limits of Opelika and Auburn.

Plans for the work were reviewed with Ricky Tant of East Alabama Paving Co., project contractor. Actual work on the project began June 17. The project was visited numerous times during the daytime to familiarize the researchers with the sequence of construction, actual work performed and equipment used. Meetings were held with the Project Engineer, including PBSJ inspectors.

The nighttime work was delayed until after the July 4-7 holiday weekend. During the nighttime hours of July 25-26, the project was visited. Work activities included milling, chip sealing, and rolling in the northbound shoulder lane between Exit 58 and 60. The work zone speed limit was 50 mph.

Two rented units provided area lighting on the project. One unit had an Amida AL-4000 with four bulbs with circular reflectors on a telescoping pole. The second lighting unit was a Genie TML4000N. Generators from Rental Services Company of Auburn were used to provide power to each lighting unit.

Lighting devices were also present on four pieces of equipment on the project:

- The milling work was performed by a Roadtec RX-70. This unit had five lighting units on it. The other four were on the four corners of the body.
- A Roadtec Shuttlebuggy, SB-2500B, was also used on the project. This unit had a light on the front and another near the controls.
- The roller on the project was a Dynapac CC552. This unit had four halogen lights in each corner of the body.
- The spreader on the project was a Blaw Knox, PF-300. This unit had six reflectorized lights on it.

Lighting measurements were taken between 2:00 and 4:15 a.m. using the Minolta TL-1 Illuminance Meter. Measurements were made in the four compass directions (N, S, E, W) from each of the area lighting units. Measurements of light intensity were also made at 20 ft intervals in the direction of moving traffic and along the paving train.

The researchers also observed the movement of traffic through the work zone from the Advance Warning Area to the Termination Area. The behavior of drivers in merging from the closed interstate lane to the open lane was noted. The movement of truck traffic in the work zone was also monitored.

The researchers drove through the work zone in the northbound direction, sometimes isolated and other times as part of a platoon of vehicles, to check for the presence of glare or lighting discomfort that may cause driver confusion. The researchers also drove through the work zone in the southbound direction to note what the distraction might be for these drivers.

Field Visit with Georgia DOT

On the night of October 23, 2001, John McCarthy visited the location of a Georgia DOT maintenance resurfacing project for the northbound exit ramp from I-185 to Airport Thruway in Columbus, Georgia. The maintenance project was mentioned on local media and phone calls to the Thomaston District Office and Columbus Area Office of Georgia DOT were placed to gain permission to watch the operations. During this visit a mobile operation being conducted at night passed through the interchange, allowing for two Georgia DOT projects to be visited on the same trip.

Bobby Poole, resident engineer of the Georgia DOT Columbus office gave the details for planning this operation. A set of four floodlights was obtained from a local rental company and headlights were to be left on for all vehicles in the work zone. Public notice had been given to the motorists via two message boards and the media was given the information on the ramp closure three days in advance of the operation. The work was considered isolated at this one ramp and to be done at night, so no detour was planned. The ramp closure was to begin at 7:00 pm on the night of the telephone call with Mr Poole.

On the work site, McCarthy met at 11:00 pm EST with Charles Freeman, foreman for maintenance in Harris County. Also present was Michael Bates, supervisor for the Thomaston District Asphalt Crew. Three of the four trailer mounted lamp assemblies were working. The equipment was obtained from United Rental on Miller Rd, in Columbus. The failure of the one not working was attributed to the bumping and jarring of the equipment during the operation. The trailers were moved along as the work progressed, using the guidance: "Just move them up to where it looks like they need the light." Roller # 77 had one halogen spotlight mounted on it.

Measurements were made of the illumination levels using a General Electric Light Meter Type 214. This device provides an analog reading on three scales from zero to 1000 foot candles. It is both color and cosine corrected. Measurements were taken on the surface of the asphalt. Measurements were taken on the edge line and recorded at distance intervals from the trailer:

Distance (feet)	Reading (foot candles)
0	40
10	130

20	150
30	110
40	55
50	50

The height of the trailer mounted lights was not available. Measurements were also taken and recorded at distances from the roller, with differences noted for the right and left side of the equipment due to the positioning of the strobe light:

Distance from left (feet)	Meter Reading (foot candles)	Distance from right (feet)	Meter Reading (foot candles)
0	2	3	2
10	6	10	8
20	22	15	10
30	28	20	12
40	8	30	2
50	2		

The strobe on the roller was also capable of being adjusted for height, but its height above the ground was not measured.

While the visit was made to the maintenance project, another nighttime operation came into the same area. A mobile operation was taking place for bridge joint rehabilitation on I-185. A structure was present on the ramp to Airport Thruway, so George Mailot, Area Construction Engineer for Georgia DOT came by to see when the paving operation would be finished on the ramp. The bridge joint project is Project Number NHS-M000-00(885)013 according to Mr Mailot. The project was scheduled from August 9 to October 31, 2001, and all work was to be done at night on I-185.

Based on the observations on site, the workers seemed to be able to perform their tasks. There was no interference from through traffic since the ramp had been closed.

The paving should be revisited by an asphalt engineer after a time period under traffic to determine if the nighttime paving method produced a satisfactory result.

U.S. 31 Field Visit Under Traffic

On October 24, 2006, John McCarthy met with Xiyan Zhang, Assistant Research Engineer of Alabama DOT, at the District Office at milepost 247 of U.S. 31 in Shelby County. The purpose of this meeting was to document lighting equipment and to measure illumination levels on an active nighttime project under traffic.

The meeting had been arranged after phone calls to Gary Ray, District Engineer for ALDOT in Shelby County. Mr. Ray was able to arrange a meeting with the project engineer and contractor since the project engineer was working from the District Office. Project Engineer Todd Connell and the construction supervisor John Conrad of Chilton Paving and Asphalt were met on-site. The construction project visited is for the planing, resurfacing and re-striping of U.S. 31 from Calera to a location south of Alabaster. U.S. 31 is a 2-lane rural highway.

At the time of the site visit paving was being done in the vicinity of the District Office. Traffic control for this one-lane two-way operation was provided by a flagger with a STOP/SLOW paddle at each end of the work area and a pilot car to lead the traffic through the work area. Warning signs were placed at each approach to the temporary traffic control zone.

Subjective evaluations of the illumination levels were discussed. The two researchers and the two on-site personnel all felt that the illumination in the area of the flagger stations was more than adequate. In the vicinity of the paving and rolling

equipment, the lighting was considered adequate. This lighting was considered good enough for the work being done since it was a moving operation with lighting provided by devices mounted on the equipment.

Illuminance readings were taken at the flagger station for northbound traffic and around four pieces of equipment. These readings were taken twice, once at the elevation of the pavement and again at a height of 4 ft above the pavement. The 4 ft level was chosen since that is the level at which note taking can assume to be done by inspectors and researchers. An expected difference in lighting levels was noted to be a function of the luminaire orientation. Lighting levels were also taken at various distances from the flagger and the equipment in order to determine the lighting footprint of each of these items.

While taking these readings, the researchers were careful to watch out for their safety. Obtaining the readings required one member to look at the meter rather than at traffic while the device was being placed. Recording the data required the other member to look at the data form in an area of low light rather than to be watching traffic. From a worker safety point of view, it is important that two team members be present to conduct these tasks.

The readings were recorded on a form developed for this project. The form can be modified based on this experience. The initial form allowed readings to the front and rear of each item. After doing the field work it was realized that readings to the right and left would also be needed to establish contours around the equipment. The readings for the flagger demonstrated this need as they were done along the roadway center line and along the two edge lines. The first readings were taken at a zero foot distance from the

flagger, but needed to be at a distance of about two feet around the equipment before the light illuminated the roadway surface. Subsequent readings were taken at 10, 20 and 50 feet from each object until the readings appeared to be affected by other lighting in the area rather than by the source being studied. This distinction was made by watching the shadows cast at the location where the light meter was being placed before each reading.

The flagger station was illuminated by four bulbs mounted at approximately 25 ft above the pavement using an Ingersoll Rand light source. The device was located 15 ft off the edge of pavement and aimed at the flagger station when the flagger would be located on the roadway center line. The device was rented from Cowin Rental Fleet according to its markings. The flagger for northbound traffic also considered the level of lighting present to be adequate. The flagger station for southbound traffic was observed to be illuminated similarly, but the light beams were not aimed as directly on the flagger as they were for the northbound flagger.

Figure 5.1 shows the illuminance measurements taken at the flagger station. As noted, light meter readings around the flagger station ranged from 0.14 foot candle to 429 foot candles. The readings were highest at the flagger station and diminished with distance from the flagger. At the furthest distance from the flagger, the readings appeared to be influenced by the roadway lighting as much as the project illumination. The readings at 4 ft were not always higher than the readings at ground level, as previously noted about the luminaire orientation.

The equipment observed included two rollers, a paver and a dump truck. The first roller observed had lighting devices added to it. This roller was noted as Roller #1 on the notes and is an Ingersoll Rand roller owned by Chilton Paving. Roller #2 had factory

Field notes:

Lighting Specifications for Nighttime Construction Work Zones on Active Highways

Project:
EB-STPSA-003(528)

Location:
US 31 Mp 247

County:
Shelby Co

Date:
10/24/2006

Time:
10:00 PM

Observers:
JRMc & XZ

Foot Candle Readings

	Along SB Edge Line		Along Center Line		Along NB Edge Line		
	@ 4 ft	@ Ground	@ Ground	@ 4 ft	@ Ground	@ 4 ft	
50 ft	1.11	1.59	1.74	1.25			50 ft
20 ft	5.01	9.44	28.3	22.0			20 ft
10 ft	9.78	14.38	109	95			10 ft
0 ft	9.70	12.17	238	269	315	429	

Towards Work Area

Flagger
Charles

Towards Approaching Traffic

	@ 4 ft	@ Ground	@ Ground	@ 4 ft	@ Ground	@ 4 ft	
10 ft	7.24	10.02	54.3	42.7	76.1	75.1	10 ft
20 ft	61.9	65.2	14.3	11.93	9.84	8.75	20 ft
50 ft	1.03	1.08	0.78	0.42	0.32	0.14	50 ft

Notes:

Lighting Types, Make, Model, Wattage
Ingersoll Rand Lightsource, 4 bulbs, rented from Cowin Rental Fleet

Light Positions & How Mounted
15 ft off NB shoulder, approx 22 to 25 ft high

All 5 persons consider lighting as adequate for flagger to be seen
At 0.07 fc, lighting is insufficient for note-taking

Figure 5.1 Illuminance Readings at the Flagger Station

supplied lighting on it. It was noted as a Hamm HD120 Oscillator and appeared to be owned by the Wirtgen Group. The paver had two lighting devices added to it for illumination in the direction of travel and towards the hopper. The paver had four devices, two overhead and two at waist level, for workers to rake the asphalt behind it. The paver was noted as a Grayhound Cedar Rapids CR 351. Only one set of measurements could be made around this equipment while it was moving and manual operations were taking place. The dump truck was operating with only its headlights to see the direction of travel. There was no light from the dump truck contributing to the light in the hopper of the paver.

Figures 5.2 through 5.5 show the illuminance measurements taken at and around the equipment. As noted, light meter readings ranged from 0.04 foot candle to 29.4 foot candles. Illuminance was highest around the newer roller and around the paver. The lowest illuminance occurred in the vicinity of the headlights of the dump truck.

Also during this visit, discussions were held regarding area lighting in the vicinity of these projects. The project engineer and the construction supervisor moved around the project in pickup trucks. The researchers were on foot, just like most of the laborers. While walking at a distance greater than 50 feet from most equipment illumination, it was difficult to see the edge of pavement and obstacles such as a roadway cross drain that had no object markers around it. The roadway lighting in the area of the project appeared to be designed for motorists rather than for pedestrians. There is no curb and sidewalk in this rural area.

Observations made from the U.S. 31 field visit are the following:

- For lighting measurements made in the field, a two-person crew may be necessary to insure worker safety.

Field notes:

Lighting Specifications for Nighttime Construction Work Zones on Active Highways

Project:
EB-STPSA-003(528)
Location:
US 31 Mp 247
County:
Shelby Co

Date:
10/24/2006
Time:
After 10 pm
Observers:
JRMc & XZ

Foot Candle Readings

	@ 4 ft	@ Ground
50 ft		
20 ft		
10 ft		
0 ft		

@ Ground	@ 4 ft	
		50 ft
		20 ft
		10 ft
		0 ft

Front

Equipment Type:
Ingersoll Rand Roller

Roller # 1 Operating Northbound

Equipment Owner:
Chilton Paving & Ashalt

Rear

	@ 4 ft	@ Ground
0 ft	**0.645**	**1.49**
10 ft	**1.57**	**3.46**
20 ft	**1.73**	**2.16**
50 ft		

@ Ground	@ 4 ft	
		0 ft
Hot		10 ft
Asphalt Not		20 ft
Measured		50 ft

Notes:

Lighting Types, Make, Model, Wattage
Not observed

Light Positions & How Mounted
Two lights on each end, added onto existing equipment

Other measurements were affected by adjacent equipment operating nearby.

Figure 5.2 Illuminance Readings at Roller #1

Field notes:

Lighting Specifications for Nighttime Construction Work Zones on Active Highways

Project:
EB-STPSA-003(528)
Location:
US 31 Mp 247
County:
Shelby Co

Date:
10/24/2006
Time:
After 10 pm
Observers:
JRMc & XZ

Foot Candle Readings

	@ 4 ft	@ Ground	@ Ground	@ 4 ft	
50 ft	0.10	0.15	0.13	0.11	50 ft
20 ft	0.77	1.94	1.90	0.85	20 ft
10 ft	4.04	6.38	7.49	4.67	10 ft
0 ft	5.05	1.85	4.25	29.4	0 ft

Front

Equipment Type:
Newer Roller
Hamm HD120
Oscillation

Roller # 2
Stationary Positon
In Paved Lane

Equipment Owner:
Wirtgen Group

Rear

	@ 4 ft	@ Ground	@ Ground	@ 4 ft	
0 ft	10.76	3.20	4.39	6.36	0 ft
10 ft	2.35	1.23	2.42	3.72	10 ft
20 ft	2.05	3.79	5.57	1.28	20 ft
50 ft	0.35	0.49	0.22	0.11	50 ft

Notes:

Lighting Types, Make, Model, Wattage
Not observed

Light Positions & How Mounted
Light bars of 3 lights on top, pointing down, both directions

This equipment appears to be better Illuminated than Roller #1.
Lighting was installed by equipment manufacturer.

Figure 5.3 Illuminance Readings at Roller #2

Field notes:

Lighting Specifications for Nighttime Construction Work Zones on Active Highways

Project:
EB-STPSA-003(528)

Location:
US 31 Mp 247

County:
Shelby Co

Date:
10/24/2006

Time:
After 10 pm

Observers:
JRMc & XZ

Foot Candle Readings

	@ 4 ft	@ Ground
50 ft		
20 ft		
10 ft		Hopper
0 ft		Not Measured

@ Ground	@ 4 ft	
		50 ft
		20 ft
Hopper		10 ft
Not Measured		0 ft

Front

Equipment Type:
Grayhound
Cedar Rapids
CR 351

Paver
Operating Southbound

Equipment Owner:
Chilton Paving & Ashalt

Rear

	@ 4 ft	@ Ground
0 ft		Hot
10 ft		Asphalt
20 ft		Not
50 ft		Measured

@ Ground	@ 4 ft	
20.2	23.7	0 ft
5.33	1.26	10 ft
0.86	0.40	20 ft
0.15	0.04	50 ft

Along edge of pavement
While raking being done

Notes:

Lighting Types, Make, Model, Wattage
Not observed

Light Positions & How Mounted
Two lights each end, added to ex equipment, aimed forward to line & to hopper
Two overhead and two lower aimed to rear for raking, added to ex equipment

Figure 5.4 Illuminance Readings at the Paver

Field notes:

Lighting Specifications for Nighttime Construction Work Zones on Active Highways

Project:
EB-STPSA-003(528)

Date:
10/24/2006

Location:
US 31 Mp 247

Time:
After 10 pm

County:
Shelby Co

Observers:
JRMc & XZ

Foot Candle Readings

	@ 4 ft	@ Ground
50 ft		
20 ft		
10 ft		
0 ft		

@ Ground	@ 4 ft	
Truck moved		50 ft
0.64	**0.95**	20 ft
0.49	**1.64**	10 ft
0.60	**2.51**	0 ft

Along edge of pavement

Front

Equipment Type:
Dump Truck

Dump Truck Operating Southbound

Equipment Owner:
Chilton Paving & Ashalt

Rear

	@ 4 ft	@ Ground
0 ft		**Hopper**
10 ft		**Not Measured**
20 ft		
50 ft		

@ Ground	@ 4 ft	
Hopper		0 ft
Not Measured		10 ft
		20 ft
		50 ft

Notes:

Lighting Types, Make, Model, Wattage
Not observed

Light Positions & How Mounted
Headlights

Figure 5.5 Illuminance Readings at the Dump Truck

- Stationary lighting should be used for illuminating flagger stations. This lighting should be aimed at the location where the flagger will control traffic, but also should illuminate the area in which the flagger will stand while waiting for traffic to arrive.

- Vehicle mounted lighting equipment can be used to provide lighting in the immediate vicinity of the equipment.

- Area lighting should be considered where inspectors or workers will be on foot.

- Lighting levels may be significantly different at a level of four feet above the pavement than they are at the level of the pavement.

Consideration should be given to the following suggestions:

- A form could be adopted by ALDOT that will allow for measurements of illumination to be shown as a footprint around each piece of equipment to be used on a nightwork project. This footprint should be in a format like the footprint shown for various roadway lighting fixtures. This form should be used in an off-street location to make all necessary measurements prior to the equipment being moved on-site. These off-site measurements should be done before the equipment is considered suitable for use on-site.

- A similar form should be developed for flagger stations. The illumination for the flagger station can be evaluated off-site prior to being considered suitable for use on-site.

- Lighting levels need to be adopted based on the task to be performed. The task being performed should also determine the height above the roadway at which the illumination levels are measured.

- Area lighting should be considered where inspectors or workers will be on foot.

Training Courses

During the course of this research, the principal investigators had the opportunity to include material from training courses into the assembly of knowledge about nighttime work zone traffic control. One opportunity came through contacts in the research area on a national level. The other opportunity came though contacts with practitioners in Alabama.

Two important research projects have recently contributed to the state of the art of nighttime work zone traffic control. The findings of these projects have been published in the NCHRP Report Series as:

Number 475	A Procedure for Assessing and Planning Nighttime Highway Construction and Maintenance
Number 476	Guidelines for Design and Operation of Nighttime Traffic Control for Highway Maintenance and Construction

These reports were described in the literature review of Chapter 2 (32, 33).

The authors of these reports are James E. Bryden and Douglas J. Mace. Mr. Bryden is retired from New York State DOT and is now a consultant. Mr. Mace is with The Last Resource, Inc. Over the years, both have served on the Committee on Traffic Safety in Maintenance and Construction Operations of the Transportation Research Board. Mr. Bryden is now the chair of that committee, which has been renamed as Committee AHB55, Work Zone Traffic Control. Bob Vecellio has served a 12 year term on the committee; John McCarthy is now a committee member.

In 2003, Bryden and Mace were in the process of developing a training package that can be used by highway agencies to assist them in implementing the findings of their research project. To assist them in this endeavor, Vecellio and McCarthy assisted them in conducting a two-day training course on the Auburn University campus. The purpose

of the course was to permit a review of the preliminary training materials by local and state personnel who are knowledgeable in work zone traffic control. The specific program modules are:

Unit I	Night Work Decision Process and Project Conceptual Design
Unit II	Traffic Control Plan Design
Unit III	Traffic Control Devices and Safety Features
Unit IV	Night Work Operations

Enrollment to this course was restricted at the request of the instructors. The total attendance was 26 persons with the following breakdown by employers:

Transportation Consultant	8
Alabama DOT	6
City	4
Business Firm	2
Alabama T^2 Center	2
County	1
FHWA	1

The business firms included surveying and traffic safety-related firms. The diversity of the audience was highly acceptable to the instructors.

In a December 12 e-mail message, Bryden expressed the instructors' appreciation for the Alabama T^2 Center hosting this pilot training session:

> Considering this was only our second effort in presenting the entire package to a live audience, we are overall very pleased with the outcome. The feedback we received in the participant review forms is especially helpful. The consensus is that the material is on course although there are a number of specific details that can be strengthened. The impression we received was that the two-day session was generally very worthwhile for attendees, although some of the material was already familiar to some members of the audience.
>
> A major strength of the Alabama audience was its diversity in terms of experience and background. However, as would be expected, material that was new and interesting to some participants was very familiar to others. This confirms to us the value in structuring the training materials in a modular format, making it relatively easy for instructors to select a specific course content to be covered, depending upon the particular audience.
>
> I am very pleased by the professionalism and enthusiasm of the class participants, and especially by the professionalism of your staff at the University.

On March 23, 2004, the Alabama T2 Center hosted a seminar on "Awareness Training for Struck By Hazards in Work Zones" in Auburn. The seminar was sponsored by the Alabama Branch of the Associated General contractors of Alabama, Alabama DOT, Alabama Road Builders Association, Federal Highway Administration, Occupational Safety and Health Administration, Safe-State and 3-M Corporation. The one-half day seminar covered the topics of planning and setup of work zones, traffic control devices, FHWA safety involvement, need for training outside the work zone and worker visibility.

Videotapes emphasizing work zone safety were shown. The seminar was videotaped for future use by the sponsoring agencies. In addition to a set of course notes, the publication "Building Safer Highway Work Zones: Measures to Prevent Worker Injuries from Vehicles and Equipment" was distributed at the seminar. This publication was published by the National Institute for Occupational Safety and Health. The total seminar attendance was 24 persons, which was split evenly between the sponsoring agencies and individual companies and consultants.

Final Observations

The field visits and training courses were very important information to assist in understanding nighttime work zones traffic control. Specifically they provided the following insights, as researchers became able to:

- identify equipment used for area lighting and its effectiveness
- document the type of lighting used on work equipment
- measure the illumination levels of both area lighting and equipment lighting

- understand the relationship between lighting requirements and work tasks
- understand the lighting requirements at flagger stations
- understand the relationship between the needs of nighttime traffic and a nighttime traffic control zone
- understand the importance of traffic safety at the job site during nighttime work
- understand the difference between illumination levels of 5, 10 , and 20 foot candles

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

In the development of nighttime lighting specifications that would be appropriate to the Alabama DOT, one should take into account the early NCHRP research work of Ellis in 1996, the more recent research work of Bryden and Mace in 2002, and the guidelines of the Manual on Uniform Traffic Control Devices. And one should be aware of specifications that have been successfully applied by transportation agencies.

Of the agency specifications reviewed in this research, the most comprehensive were those of the Nova Scotia Department of Transportation and Public Works. To gain further insight into these specifications, discussions were held with Gerard Kennedy of the Department. It turns out that the Nova Scotia nighttime specifications have been successfully used on a number of construction projects since 2002.

On the basis of the literature reviewed, an analysis of agency specifications, knowledge of the MUTCD guidelines, and the field investigations conducted in Alabama and Georgia, the following elements are recommended to be included in an Alabama DOT Nighttime Work Specification.

1. Development of a Nighttime Work Plan

Some agencies require the contractor to develop the Nighttime Work Plan for a specific construction project. It must include a lighting plan, provisions for traffic control, and any special safety items (personal protective equipment and specified worker training).

The lighting plan must include descriptions and sketches of the layout of light towers in which the spacing, lateral placement and illumination levels are identified. It

must include a description of the lights to be used on the construction equipment. It must contain a plan for checking illumination levels in the field during the nighttime life of the project.

If the Nighttime Work Plan is developed by a contractor, it must be reviewed and approved by Alabama DOT. On the other hand, if Alabama DOT is responsible for the development of the Plan, then it is recommended that it be done by a Professional Engineer with experience in lighting applications.

2. Application of an Illuminance Specification

Based on the literature, the MUTCD, and the review of agency specifications, the following table is recommended as a guideline for horizontal illuminance on a nighttime construction project:

Level	Minimum Illuminance
1	5 foot candles
2	10 foot candles
3	20 foot candles

Level 1 illumination is required in all areas where workers and Alabama DOT personnel perform their duties. This represents a base level of illumination to cover the general tasks of setup, excavation, sweeping and equipment movement.

Level 2 illumination is needed around equipment and to cover equipment-related work activities. Examples would include paving, milling, rolling, shoulder work and guardrail work. Some agencies may specify the limiting distances ahead and behind a piece of equipment in which Level 2 illumination needs to be provided.

Level 3 illumination is needed for tasks that require increased attention to detail. Examples would include crack filling, pothole repair, soil testing and traffic signalization work. The testing duties of inspectors would be included.

3. Measurement of Illuminance

A plan for measuring illuminance in the field during nighttime hours should be developed. A uniform pattern of 15-20 ft throughout the project could be specified and/or light intensities could be measured near equipment. A calibrated light meter will be required and the operator should be trained to understand photometrics. It is important that the operator not wear reflective clothing while taking measurements as its retroreflective characteristic increases the illuminance readings.

4. Glare Checks

It is important that the location and direction of luminaries on a nighttime work site be checked periodically so as to avoid any problems with glare. Traveling through the temporary traffic control zone at night is essential to check for the presence of glare to motorists. Glare in the eyes of workers is easily corrected.

5. Lighting Maintenance

Routine maintenance of nighttime lighting units is required to adhere to an effective lighting plan. Replacing non-functioning lamps immediately and cleaning lamps routinely should be implemented.

6. Documentation

The contractor should be required to submit in writing reports of measured illumination levels. For stationary work sites, at least once every five working days is recommended. For moving work sites, daily readings should be submitted to the Project

Engineer. Any incidents or accidents should be submitted using the proper Alabama DOT forms.

On the basis of this research work, a sample specification covering lighting requirements for nighttime work is presented. It is recommended that this document be reviewed by ALDOT officials for its technical requirements as well as its presentation format.

NIGHTTIME OPERATIONS

All operations that are performed during the non-daylight hours shall be properly illuminated to allow for the satisfactory performance and inspection of the work. Proper illumination shall consist of furnishing, installing, operating, maintaining, moving and removing portable light towers and equipment-mounted lighting fixtures for nighttime operations. Nighttime operations consist of work specifically scheduled to occur after sunset and before sunrise.

A Lighting Plan developed by the contractor shall be part of the contract documents. The plan must include the following elements.

Description of Lighting Equipment

Portable light towers and equipment-mounted lighting fixtures to be used in the project shall be described. Descriptions should include power sources, wattage, placement, spacing, luminarie height and expected illuminance provided.

The lighting equipment shall provide the following minimum illumination requirements: 5 foot candles illuminance for general activities, 10 foot candles luminance for activities around equipment, and 20 foot candles illuminance for work involving high levels of precision and extreme care. Minimum illumination levels for specific work tasks are shown in the following table. The uniformity of illuminance defined as the ratio of the average illuminance to the minimum illuminance shall not exceed 5:1.

Minimum Illuminance	Application	Tasks
5 foot candles	General illumination	Project setup Equipment movement Sweeping and cleaning
10 foot candles	Specific illumination within 25 ft ahead and behind equipment	HMA milling, paving and rolling operations Base course construction Concrete pavement repair Work on bridge decks Work on culverts and drainage structures Guardrail installation and repair Traffic sign installation Striping and installation of pavement markers Note taking and inspection
20 foot candles	Specific illumination at task	Electrical work Signal work Street lighting Saw cutting Crack filling Sealing joints

Measurements of Illumination and Documentation

The contractor shall develop a plan for measuring illumination in the field throughout the life of the nighttime project. Illumination readings at 100 ft intervals in the longitudinal direction of a project and readings at 25 ahead and behind construction equipment should be made. The contractor shall furnish a calibrated meter for use by the Engineer to check the adequacy of illumination during nighttime operations. The measurements of illumination should be taken at the elevation of the work activity. A 4 ft height above ground is normally used for note taking. It is important that the light meter operator avoid wearing highly reflective or light colored clothing while taking measurements in order to avoid biased illuminance readings.

Written reports of measured illumination levels are required. For stationary work sites, written reports are required at least once every five working nights. For moving work sites, nightly reports are required. Incidents and accidents are to be reported using the proper Alabama DOT forms.

Glare Checks

The location and direction of luminaries shall be checked so as to avoid problems with glare. The contractor is advised to travel through the temporary traffic control zone at night in order to check for the presence of glare to the motorists. The contractor must eliminate problems of glare at the work site within a reasonable period of time.

Lighting Maintenance

The contractor is required to make routine maintenance checks on all lighting units. Replacing non-functioning lamps and cleaning should be implemented.

A logical placement of this specification would be a new Section 745 Nighttime Operations in the Standard Specifications for Highway Construction, 2006 Edition. This would require removal or modification of the statement found in Section 104.04:

> When the Contractor performs any operations after daylight hours, he shall provide and maintain, at his expense, sufficient artificial lighting to permit proper construction and inspection.

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