11-5-1 Roadway Lighting Infrastructure April 2024

POLICY

All roadway lighting designs on the State Trunk highway systems **shall** follow the infrastructure design guidelines described in this section. Exceptions to this policy *may* be required for non-standard installations and unique roadway settings.

WisDOT has prepared standard specifications and standard detail drawings which are available to the designer. These standards include typical details such as electrical service, light standards and bases, underground conduit installations, pull boxes, lighting control cabinets, and wiring diagrams to aid in the preparation of the roadway lighting plans.

Whenever possible, the designer **shall** utilize the standards to provide a consistent installation throughout WisDOT's system. Deviations from the standards *may* require detailed installation drawings and special provisions to be created by the designer and included in the roadway lighting plans and other PS&E documents.

REFERENCE TO STANDARDS

The installation of highway roadway lighting **shall** comply with the requirements of the latest edition of the following:

- National Electrical Code
- Wisconsin Electrical Code
- WisDOT Standard Specifications
- WisDOT Standard Detail Drawings
- WisDOT Standard Bid Items
- WisDOT Electrical Qualified Products List (e.g., Approved Products list)
- Local codes and ordinances as applicable

11-5-2 Conduit April 2024

PURPOSE

Conduit is necessary in roadway lighting design to provide a raceway for electrical conductors and access to electrical power. Installing wire in conduit versus other direct bury methods allows for easier replacement or re-routing of conductors when required by future maintenance work.

MATERIALS

Conduit installed with standard roadway projects *should* be rigid non-metallic polyvinyl chloride (PVC) unless otherwise justified for special applications. Typically, schedule 80 *should* be specified for areas with heavy loading, such as under roadways with shallow cover.

Conduit installed embedded in structures *should* be rigid non-metallic PVC schedule 40 and be verified with the standard detail drawings created by WisDOT Bureau of Structures (BOS). Rigid metallic conduit is often used at transition points from structure to ground because of its strength and resistance to shearing and settling.

Reinforced thermosetting resin conduit and rigid metallic conduit are typically used when conduit is mounted externally on structures and specialized applications due to their durability. Consult with BOS and the Region Lighting Engineer to confirm which conduit type is preferred for external structural applications.

High-density polyethylene (HDPE) is typically used for intelligent transportation systems applications only.

DESIGN CONSIDERATIONS

Conduit **shall** be sized as necessary for wire fill capacity of proposed conductors according to applicable tables in the National Electrical Code (NEC) Chapter 9.

Designers *should* attempt to maintain some standardization of conduit sizing throughout the project. This practice allows for more cost-effective bid pricing if the contractor has to purchase fewer types of conduits, allows for easier installation/constructability, and provides consistency for maintenance of conduit systems.

Designers *should* consider using a larger conduit size, as well as including empty conduit runs, when exiting control cabinets to allow for future expansion of the branch circuiting.

Conduit **shall** be connected between each light base to the nearest pull box or light base, from pull box to pull box, from pull box to controller cabinet, and wherever the design requires conductors be installed.

Conduit at major intersections *should* be designed in a ring fashion surrounding the intersection, regardless of whether all runs will include live conductors, to provide sufficient raceways for any future work.

Designers *should* consider providing additional redundant conduit routes with pull wire only occasionally throughout the system so future maintenance can more easily troubleshoot failure points and back-feed from adjacent circuits.

Conduit connections **shall not** be provided between systems with separate electrical services to ensure safety of maintenance staff which could be compromised if one of the systems is not properly decommissioned.

When crossing underneath a railroad, designers **shall** coordinate directly with railroad officials during the 60% design to obtain approval and applicable design standards. Permitted conduit installations below rail lines can reach depths of 15' and greater depending on the standards set forth by the governing rail agency.

Other considerations for conduit design include:

- The proximity to private and other utility facilities.
- Adjustments *may* be needed to avoid guard rail and sign posts.
- Parallel conduit routing with other WisDOT electrical infrastructure (i.e., signals, ITS).
- Sloping of roadway and drainage into pull boxes.
- Conduit depth when crossing roads with sub-base improvements.
- Minimizing conduit bends to less than 360 degrees between pull points.

CONSTRUCTION

Installation methodology **shall** be considered when designing conduit routing. Conduit to be installed under existing pavement, or with minimal ground disturbance, *may* be installed via directional boring under Conduit Special bid items. Designers *should* consider bore pit and rig locations when including directionally bored conduit with a roadway lighting design. In urban settings, a temporary limited easement *may* be required to accommodate boring operations.

11-5-3 Pull Boxes — April 2024

PURPOSE

Pull boxes are necessary in roadway lighting design to serve as pull points between continuous runs of conduit. Pull boxes are also necessary for conductor coiling for future maintenance at poles susceptible to knockdowns and for other various maintenance reasons.

MATERIALS

Roadway lighting designs typically utilize 24" x 42" pull boxes for all applications. If a smaller pull box is desired, sizing must adhere to requirements defined in NEC Article 314. Pull boxes *should* also be sized to ensure compatibility with quantity of entering/exiting conduit, evaluate constructability whenever more than four (4) conduits enter a pullbox, especially with larger conduit sizes, additional pull boxes *may* be required.

Pull boxes are typically non-conductive polymer concrete to eliminate any potential issues with grounding.

Steel pull boxes *may* be used in unique applications per direction from the respective Regional Lighting Engineer. Steel pull boxes must have the ground wire tied into the roadway lighting system ground.

DESIGN CONSIDERATIONS

Along continuous runs of conduit, pull boxes for roadway lighting systems *should* be spaced at a maximum of 300 feet to provide access points to assist with pulling wire. Distance between pull boxes *should* be reduced as wire sizes and conduit bends increase. Significant grade and alignment changes will also warrant closer spacing of pull boxes. Conduit **shall** not turn more than 360° without providing a pull box.

Pull boxes *should* be located to avoid placement in pavement or sidewalk. Final locations *should* attempt to maintain a two-foot minimum clearance from any other infrastructure to allow for compaction after installation, and to provide enough space for grass and landscaping to grow.

Pull boxes *should* be installed in these situations:

- 300-foot maximum intervals along continuous conduit runs.
- On either side of a roadway crossing.
- At the intersection of three (3) or more conduits.
- Immediately exiting a control cabinet.
- For slopes and other areas with non-linear conduit alignment.
- Adjacent to concrete bases for roadway lighting poles susceptible to knock-downs.
- As a provision for future expansion.

11-5-4 Concrete Bases — April 2024

PURPOSE

Concrete bases serve as the foundation for above ground electrical infrastructure for light poles and control cabinets.

MATERIALS

Concrete base details and compatible infrastructure are specified in the WisDOT standard specifications, standard detail drawings, and in TEOpS 11-3. Verification of compatibility is essential to ensure structural integrity.

DESIGN CONSIDERATIONS

Standard concrete bases have capacity for two 2-inch conduit and one 1-inch conduit for grounding. Design scenarios with more than 2 or larger conduit than listed above *may* require an adjacent pull box or re-design of conduit routing.

Concrete bases for roadway lighting infrastructure **shall** be located with consideration to the following factors:

- Placed adjacent to the roadway in accordance with all applicable lateral clearance and clear zone standards.
- Designed in accordance with drainage features and grade changes as shown on proposed cross-sections.
- Changes in mounting height on steep slopes.
- Conflicts with utilities.
- Structure mounting attached to bridges, retaining walls, and median barriers.
- Potential rock excavation for shallow bedrock.

Some design scenarios such as restricted geometry, utility conflicts, or bedrock discovery *may* warrant alternative concrete base designs. Any alternative base designs **shall** be approved by the Region and BOS.

11-5-5 Electrical Conductors — April 2024

PURPOSE

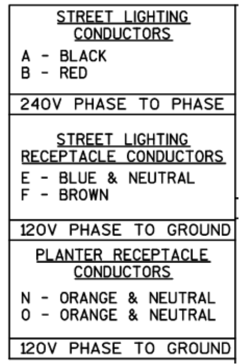
Electrical conductors are necessary to transmit electrical power and operational controls for roadway lighting systems.

MATERIALS

Typical roadway lighting designs **shall** utilize cross-linked polyethylene insulated (XLPE), underground service entrance rated wire as defined in Section 655 of the WisDOT Standard Specifications. Multi-conductor or direct burial cable *may* be required with some design scenarios and *should* be verified with the Regional Lighting Engineer.

Roadway lighting system conductors *should* follow conventional black/red color coding. Subsequent circuiting, such as receptacles, *should* utilize the next available color coding according to the NEC to easily differentiate between circuits. WisDOT Regions *may* have unique preferences for conductor color coding. Figure 1 shows an example of conductor color coding used on a state highway lighting system.

Figure 1. Example Conductor Color Coding



Slack cable **shall** be provided in the following electrical applications per Table 1 below.

Table 1. Cable and Wire Measurement Lengths

CONDUCTOR TYPE	APPLICATION	LENGTH	COMMENTS
SIGNAL CABLE	Cabinet	15'	Vertical rise to enter cabinet, length to terminate cable in cabinet, extra cable as necessary
	Pull Box	15'	2.5' to exit pull box, 2 loops (5' each), 2.5' to re-enter pull box
	Signal Base	8'	5' vertical rise in concrete base to access point, 3' at access point for splicing
	Pole & Arm	8'	3' at access point for splicing, 5' at signal head for termination
LOOP LEAD IN CABLE	Cabinet	15'	Vertical rise to enter cabinet, length to terminate cable in cabinet, extra cable as necessary
	Pull Box	0'	No extra lead in cable required in pull boxes
	Lead in Cable	8'	Slack is only required in the terminus pull box for splicing with loop detector wire
	Loop Detector Cable	8'	Slack is only required in the terminus pull box for splicing with lead in cable
EVP CABLE	Cabinet	15'	Vertical rise to enter cabinet, length to terminate cable in cabinet, extra cable as necessary
	Intermediate Pull Box	0'	No extra EVP cable required in intermediate pull boxes
	Terminus Pull Box	20'	Slack required for potential knockdown
	At EVP	2'	Exiting bracket for termination (pending different types of mounting brackets)
ELECTRICAL WIRE FOR LIGHTING	Cabinet	15'	Vertical rise to enter cabinet, length to terminate cable in cabinet, extra cable as necessary
	Pull Box	15'	2.5' to exit pull box, 2 loops (5' each), 2.5' to re-enter pull box
	Light Base	8'	5' vertical rise in concrete base to access point, 3' at access point for splicing
	Pole & Arm	8'	3' at access point for splicing, 5' at luminaire for termination
	Junction box	Varies	Depends on size of junction box. Typically, 2 times of the largest dimension of the box.

Conductors *should* be minimally sized according to the voltage drop calculations defined in this chapter. Designers *should* attempt to maintain some standardization of conductor sizing throughout the project to allow for more cost-effective bid pricing and to provide consistency for maintenance. If WisDOT is not the maintaining authority, the designer **shall** coordinate with local officials to determine if there is a preferred wire size and circuiting patterns that *may* govern the design.

DESIGN CONSIDERATIONS

The designer *should* consider alternating circuits along each run or branch. This provides a factor of safety in the event of a fault, where every other luminaire *should* remain operable. In providing proper operations of alternate circuiting, 120V circuits *should not* share a neutral, and *should* be terminated on single pole breakers.

Festoon receptacle branch circuits *should* be circuited independently from roadway lighting circuits.

Underground splicing **shall not** be permitted in pull boxes. Splices **shall** be made in poles and/or in aboveground junction boxes.

Wire sizing for roadway lighting circuits *should* be calculated with a target of 3% voltage drop per branch circuit, and a maximum of 5% for the total of service/feeder and branch circuit. Consider any potential for future expansion when calculating voltage drop for a roadway lighting circuit.

The voltage drops and related wire sizing for roadway lighting circuits and festoon receptacles **shall** be calculated in conformance with the NEC, along with any additional requirements of the applicant agency. Designers **shall** maintain documentation of voltage drop calculations of roadway lighting circuits using spreadsheets or other software applications. Use the voltage drop calculation spreadsheet.

Table 2. Voltage Drop Calculations (Example)

VOLTAGE DROP CALCULATIONS

EXAMPLE

Project ID: XXXX-XX-XX
Project Description: Example Voltage Drop
Lighting System # Example L49-2XXX

Date: 8/18/2020
Comps By: Engineer
Checked By:

Note: Example is based on a 250 Watt HPS Fixture in a 240 Volt System (304.8 Watts Input Each Luminaire)

Circuit #	Wire Segment From	Wire Segment To	Conductor Size (AWG)	Adjusted Voltage Through Line (VOLTS)	Total Watts (AT SOURCE)	Length of Cable Run In Segment L (ft)	Current At Source I (AMPS)	M	K	CM	Segment Voltage Drop (VD)	Segment Percentage Voltage Drop (% VD)
1	LCC-A	LP-1	4	240.00	3658	20	15.24	2	12.9	41740	0.19	0.08
1	LP-1	LP-2	4	239.81	3353	175	13.98	2	12.9	41740	1.51	0.63
1	LP-2	LP-3	4	238.30	3048	170	12.79	2	12.9	41740	1.34	0.56
1	LP-3	LP-4	4	236.96	2743	166	11.58	2	12.9	41740	1.19	0.50
1	LP-4	LP-5	4	235.77	2438	173	10.34	2	12.9	41740	1.11	0.47
1	LP-5	LP-6	4	234.66	2134	168	9.09	2	12.9	41740	0.94	0.40
1	LP-6	LP-7	4	233.72	1829	165	7.82	2	12.9	41740	0.80	0.34
1	LP-7	LP-8	4	232.92	1524	175	6.54	2	12.9	41740	0.71	0.30
1	LP-8	LP-9	4	232.21	1219	175	5.25	2	12.9	41740	0.57	0.24
1	LP-9	LP-10	4	231.64	914	170	3.95	2	12.9	41740	0.41	0.18
1	LP-10	LP-11	4	231.23	610	185	2.64	2	12.9	41740	0.30	0.13
1	LP-11	LP-12	4	230.93	305	155	1.32	2	12.9	41740	0.13	0.05
										Totals =	9.20	3.90

Voltage Drop Equation

$$VD = \frac{(M \times K \times I \times L)}{CM}$$

Wire Specifications	
Size (AWG)	Area (CM)
4	41740
6	26240
8	16510
10	10380
12	6530

VD = Voltage Drop (- Volts)

M = Phase Multiplier
(Use 2 for Single Phase Alternating or Direct Current)
(Use "Square Root of 3", or 1.732 for 3-Phase Circuit)

K = Direct Current Constant
(Use 12.9 for Copper Wire)
(Use 21.2 for Aluminum Wire)

I = Current of Circuit in (Amps)
(At Source Along Circuit)

L = Length of Circuit (Ft)
(One-Way Length of Segment of Wire - - Source to Source, including anything coiled in Pull Boxes / Bases / Etc)

CM = Cross-Sectional Area of Wire (Circular Mils)
(Circular Mils = kcmil x 1000)

Notes: **1)** The NEC recommends a Maximum of 5% Voltage Drop for a Branch Circuit. It is also suggested in other references to design up to 3% Maximum Voltage Drop, which would then allow for some limited expansion of the Lighting System in the Future.
2) WisDOT's Teops Guide indicates that for Lighting, circuits should be calculated with a Target of 3% Voltage Drop per Branch Circuit, and a Maximum of 5% for the Total of Service / Feeder and Branch Circuits.

11-5-6 Cabinets, Metering and Controls — April 2024

PURPOSE

Control cabinets are necessary to distribute electrical power to the roadway lighting infrastructure. Cabinets also typically house the operational controls for the roadway lighting system.

Meter pedestals are necessary to receive power from the utility company to energize the control cabinet.

MATERIALS

Roadway lighting control cabinets are typically ground mounted enclosures that come in a variety of sizes and capacities as warranted by the project. The roadway lighting designer **shall** coordinate with the WisDOT Region Lighting Engineer for the appropriate cabinet size (24" or 30") and voltage (120V/240V or 240V/480V).

Cabinet size *should* be determined by the requirements of the project and potential for future expansion. Typically, a 480V cabinet would be installed on freeways or expressways when circuits must cover larger distances. The use of a 480V voltage cabinet **shall** be approved by the local and utility authorities.

Meter pedestals *should* be included with new roadway lighting control cabinets and *may* have a main breaker, or main lugs only, depending on the application. Meter breaker pedestals are favored in urban settings because they allow for power to be disconnected from the entire control cabinet for safer working conditions during routine maintenance, as well as afford the flexibility of being able to easily change out control cabinets which involve the utility. Typically, electrical service meter breaker pedestals are installed with 120/240V roadway lighting systems, while electrical service main lugs only meter pedestals are most often installed with 240/480V roadway lighting systems. The designer **shall** coordinate with WisDOT on the appropriate type to install.

DESIGN CONSIDERATIONS

Roadway lighting systems **shall** be photocell controlled unless directed otherwise. Photocells are typically installed with the roadway lighting cabinet and will control each circuit via contactor.

Electrical service meters for roadway lighting systems *should* be located in coordination with the local electric utility company and the respective WisDOT Regional Lighting Engineer, with consideration of the following factors:

- The cabinet *should* be located such that it is not vulnerable to traffic. A distance of 20 feet back of curb or 30 feet off the edge of pavement is desirable for offsetting the control cabinet.
- Proximity to electric utility.
- A maintenance vehicle *should* be able to park close to the cabinet and out of the traveled lanes.
- The cabinet **shall not** be in a drainage ditch or in an area which could be under water.
- The cabinet **shall not** obstruct sidewalks, multi-use trails, curb ramps, or driveways.
- The cabinet **shall** be located in right-of-way and accessible to provide maintenance without entering private property.
- Cabinet **shall** be oriented such that the photocell will sufficiently detect light.
- Snow storage and removal *should* be considered when determining cabinet location and orientation.

The local utility **shall** be contacted early in the design stage. Electrical service locations *should* be established by the DT1078 submittal to ensure the local electrical utility has adequate time to review the proposed locations. Verify with the utility the available fault current at each service location prior to final design and installation.

The electrical service **shall** be provided in accordance with the standard specifications and standard details.

Provide service grounding as detailed in the standard specifications and details unless otherwise noted on plans.

CONSTRUCTION

Meter breaker pedestals are typically installed directly adjacent to the control cabinet to minimize the distance between the service lateral and the main breaker, mitigating potential losses due to voltage drop and resistance.

The utility company will dictate the conductor size of the service lateral based on the service requested and distance from their power source. Conduit from the power source to the meter pedestal is typically provided and installed by the utility company unless directed otherwise to be included as part of the project design.

The contractor **shall** provide roadway lighting circuit identification plaques and roadway luminaire sequence decals suitable for outdoor construction for control cabinets, light poles, sign bridges, underdeck luminaires and high mast lighting as the plans show and per WisDOT Standard Detail Drawings: SDD 09H11, SDD 10A2, SDD 10A3 and SDD 10A4.