Precast concrete parking structure lighting study

Donald R. Monahan

There is a perception among some members of the design community that lighting of precast concrete parking structures is not as efficient as lighting of post-tensioned concrete (PT) parking structures. This perception occurs because one assumes that there is more light blockage from the closely spaced, precast concrete double-tee stems (5 ft [1.5 m] spacing) compared with the wider spacing of beams (18 ft to 24 ft [5.5 m to 7.3 m] spacing) in a PT concrete parking structure.

The Colorado Prestressers Association retained Walker Parking Consultants to perform a study comparing lighting systems for precast concrete parking structures versus PT concrete parking structures. This study indicates that there is no difference (within the accuracy of the calculation procedure) in horizontal illuminance on the floor, or vertical illuminance on the perimeter walls, for identical lighting configurations in precast concrete and PT concrete parking structures. This conclusion requires that the bottom of each luminaire in the precast concrete parking structure is pendant-mounted and that the luminaires are no more than 6 in. (150 mm) above the bottom of the double-tee stem and centered between the 5 ft double-tee stem spacing (**Fig. 1**).

This report describes the configuration of the two parking structures, the lighting configuration, the design methodology, and the results of the analysis.

Editor's quick points

- Walker Parking Consultants project no. 23-7072.00
- This research was funded jointly by the Colorado Prestressers Association and the Precast/Prestressed Concrete Institute.
- The research objective was to dispel commonly held myths regarding lighting of precast concrete parking structures.
- This study indicates that there is no difference in horizontal or vertical illuminance for identical lighting configurations in precast concrete and post-tensioned parking structures.

Parking structure configuration

The most common parking structure configuration throughout the United States consists of a row of 90-degree parking spaces at 8 ft 6 in. to 9 ft (2.6 m to 2.7 m) wide by 18 ft (5.5 m) long on each side of a two-way traffic aisle in a 60-ft-wide (18 m) parking module. The parking structure typically has two parking modules with one sloping floor for vertical circulation and one flat floor usually positioned along the street frontage. Therefore, the width of the parking structure is approximately 120 ft (36.5 m) plus the thickness of perimeter walls.

The length of the parking structure is typically limited by the length of a city block (approximately 350 ft [107 m]) or the maximum ramp slope and floor-to-floor height in the parking structure. An 8 ft 2 in. (2.5 m) clearance is required for handicap parking, which is usually provided on the ground level. The code-required clearance in all other

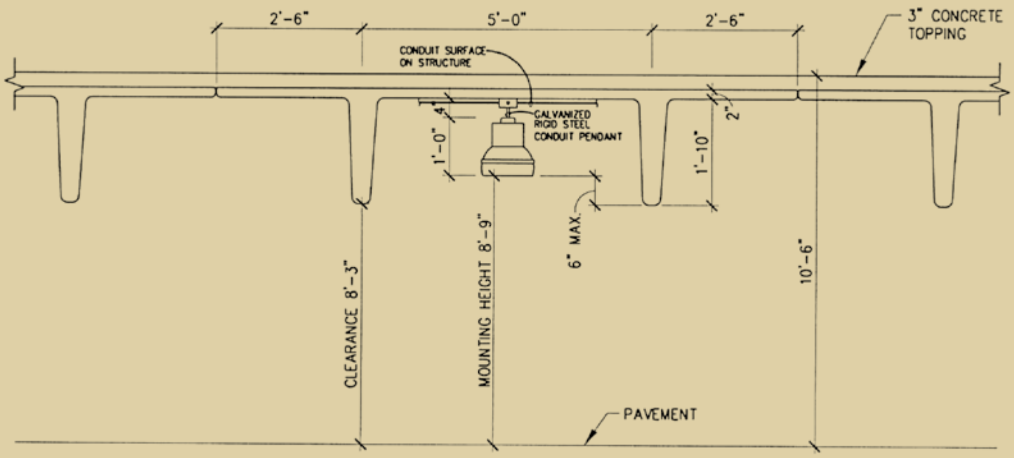

Figure 1. Light fixture configuration in precast concrete parking structure. Note: 1" = 1 in. = 25.4 mm; 1' = 1 ft = 0.3048 m.

areas is 7 ft (2.1 m). Typically, columns are located at the perimeter and at the center of the two parking modules. The parking area is then unimpeded by columns (in other words, it is clear-span construction). The depth of the structure necessary to span 60 ft (18 m) is about 3 ft (0.9 m). Therefore, the minimum floor-to-floor height is 11 ft 2 in. (3.4 m) at the ground floor and 10 ft (3 m) on upper floors. For user comfort and additional construction tolerance, the design includes an extra 6 in. (150 mm) of ceiling height in the parking structure model. The ramped floor with parking is limited to a maximum slope of 1:15 (6.67%) by the *2006 International Building Code*.[1] The ramp slope in some local jurisdictions (for example, Los Angeles, Calif.) and for accessible parking is limited to 5%. For the ground-floor height of 11 ft 8 in. (3.6 m), the length of the ramp must be at least 233 ft (71 m) at a 5% slope. Allowing 42 ft (13 m) at each end for crossover aisles and end parking results in a total length of about 320 ft (98 m).

The intent of this study was to create two parking structures that were as identical as possible except that one would have a PT concrete structural system while the other would have a precast concrete structural system. The column spacing in a PT parking structure is typically on the order of 18 ft to 24 ft (5.5 m to 7.3 m). The column spacing in a precast concrete parking structure is typically 30 ft (9.1 m). A 20 ft (6 m) column span was used for the PT parking structure so that it could be modular with the precast concrete column spacing. The end spans were set at 15 ft (4.6 m) to accommodate end parking. The length of the parking structure was then set at 330 ft (100 m) so that it would be compatible and modular with each structural system. **Figures 2** through **4** and the appendix illustrate schematic design drawings of the two parking structures.

Lighting configuration

There is not a code requirement for general parking area lighting; however, owners may be at risk for damages in the event of personal injury lawsuits that allege poor lighting was a contributing factor. Therefore, the lighting must meet industry

Table 1. Recommended maintained illuminance for parking structures

		Minimum horizontal illuminance, FC*	Horizontal uniformity ratio, maximum:minimum†	Minimum vertical illuminance, FC‡
Basic		1.0	10:1	0.5
Ramps**	Day	2.0	10:1	1.0
	Night	1.0	10:1	0.5
Entrance areas††	Day	50		25
	Night	1.0	10:1	0.5
Stairways		2.0		1.0

Source: Data from *Lighting for Parking Facilities*
Note: FC = footcandle.
*Depreciated (maintained) illuminance in footcandles at the time of lamp replacement calculated on the parking surface without any shadowing effect from parked vehicles or columns.
†Highest horizontal illuminance divided by the lowest horizontal illuminance should not be greater than the ratio indicated.
‡Measured or calculated at 1.5 m (5 ft) above the parking surface.
**Applies to clearway ramps (no adjacent parking).
††Includes daylight infiltration plus electric lighting for a distance of 20 m (66 ft) inside the entry portal of the parking structure to facilitate the transition from bright daylight into the darker parking facility.

Figure 2. The exterior of a precast concrete parking structure is used for illuminance comparison.

Figure 3. The interior of a precast concrete parking structure is used for illuminance comparison.

Figure 4. The interior of a post-tensioned parking structure is used for illuminance comparison.

standards. The Illuminating Engineering Society of North America (IESNA) is considered the authority for lighting of interior and exterior spaces. The recommended practice for parking facility lighting is contained in IESNA publication RP-20-98, *Lighting for Parking Facilities*.[2] **Table 1** contains recommended illuminance values.

Light sources commonly utilized in parking structures consist of 150-watt, high-pressure-sodium (HPS) lamps; 150- to 200-watt metal halide (MH) lamps; and 32-watt, linear T8 fluorescent lamps. Experience indicates that equivalently maintained illuminance has been achieved with 150-watt HPS fixtures or 175-watt MH fixtures or a fluorescent fixture consisting of four T8 lamps with a high-frequency, high-light-output, electronic ballast. Also, the most economical lighting system utilizes the highest wattage practical at the largest spacing that achieves the IESNA-recommended illuminance in order to minimize the number of fixtures, which minimizes cost.

The color of the light source is also a consideration. HPS lamps produce a yellowish glow, while metal halide lamps produce a bluish-white light. Fluorescent lamp colors can range from warm white to cool white. Recent research indicates enhanced benefits of white light sources for better peripheral vision and better visibility at low light levels. Therefore, the trend in the industry is toward white light sources.

Fluorescent light sources are affected by temperature, whereas MH and HPS lamps are not affected by temperature. Therefore, MH lamps are recommended where winter conditions at the location of the project result in temperatures that are frequently below freezing.

Therefore, a 200-watt metal halide fixture was chosen for this study at a 40 ft (12.2 m) longitudinal spacing and 30 ft (9.1 m) lateral spacing. The fixture consisted of a Lithonia PGR luminaire, though equivalent fixtures would consist of a Kim PGL1HP or PGL4 luminaire or Gardco Quadra GP1 luminaire. **Figures 5** through **7** illustrate these fixtures. Other recommended fixtures consist of a Quality Lighting Design 430 and Kim PGL5/6.

The lighting configuration was designed to comply with IESNA parking facility lighting standards and is illustrated in the appendix. Two rows of luminaires were provided in each parking module at the quarter points of the parking module (in other words, 15 ft [4.6 m] to either side of the drive aisle centerline). The longitudinal spacing of the luminaires in each row was 40 ft (12.2 m), such that the luminaires were centered between PT beams or precast concrete double-tee stems. One row of luminaires was staggered 20 ft (6.1 m) with respect to the row on the opposite side of the drive aisle. This configuration results in illumination of more of the ceiling soffits, providing a brighter perception of the entire space.

The lighting configuration was identical to the configurations used in the precast concrete parking structure and in the PT parking structure. The only variable was the mounting height of the luminaires. The depth of the fixture was about 12 in. (300 mm), so luminaires that were flush-mounted to the ceiling have the bottom of the fixture 12 in. below the ceiling. The mounting height was then varied at 16 in., 19 in., and 22 in. (406 mm, 483 mm, and 559 mm) below the ceiling to determine the variation in illuminance at those mounting heights in the two parking structures. Because the precast concrete double-tee stems were 22 in. deep, the fixture mounting heights were 10 in., 6 in., 3 in., and 0 in. (250 mm, 150 mm, 75 mm, and 0 mm) above the bottom of the double-tee stems.

Lighting calculations

The lighting calculations were performed by computer modeling using the software AGI32 by Lighting Analysts of Littleton, Colo. This software allows the designer to build a three-dimensional model of the parking structure and lighting system and calculate the illuminance on any surface or plane within the facility. The effect of light blockage of the physical structure is included in the analysis. Reflectance of light from ceilings, walls, and floors is also included. Photometrically correct renderings are produced with this software (Fig. 2–4).

As indicated previously, four different luminaire mounting heights were considered for use in each parking structure. In addition, the illuminance was analyzed on level 1 and level 2 due to the difference in floor-to-floor height at those levels (11 ft 8 in. [3.6 m] at level 1 and 10 ft 6 in. [3.2 m] at level 2). The horizontal illuminance was determined on the floor at a calculation point spacing of 5 ft (1.5 m) in each direction over the entire floor area, and the vertical illuminance was determined at a lateral point spacing of 5 ft at an elevation of 5 ft above the floor along the perimeter walls.

Figure 5. A Lithonia PGR luminaire can be used for lighting in precast and post-tensioned concrete parking structures.

Figure 6. A KIM PGL luminaire can be used for lighting in precast and post-tensioned concrete parking structures.

Figure 7. A Gardco GP1 luminaire can be used for lighting in precast and post-tensioned concrete parking structures.

Light-loss factors were included for lumen depreciation (0.65), luminaire dirt depreciation (0.9), and a design factor of 0.8 as recommend by the lamp manufacturer (General Electric). The light-loss factors represent the fraction of light available at the time of lamp replacement per IESNA-recommended practice.

Owners of parking structures typically do not replace the lamps until they expire. Therefore, the light-loss factors must be determined at the end of the rated life of the lamp. The total light-loss factor is determined by multiplying all of the individual light-loss factors together, resulting in a total light-loss factor of 0.47 for this design.

The light source consisted of a 200-watt, pulse-start metal halide lamp. Pulse-start metal halide lamps have 25% greater light output than standard metal halide lamps and 50% longer lamp life than standard metal halide lamps (15,000 hours compared with 10,000 hours). Also, the orientation of the lamp affects the light output and lamp life. A horizontal lamp orientation has lower light output and a shorter lamp life than a vertical orientation. The fixtures selected for this study had a vertical, base-up lamp orientation.

Results

Tables comparing the results of the generated lighting calculations between the precast concrete parking structure and PT parking structure are included in the Appendix. The comparisons are made at each different luminaire mounting height in order to compare identical lighting configurations.

The results indicate that there is significant light blockage in the precast concrete parking structure when the luminaires are mounted directly to the ceiling, as expected. However, when the luminaires are pendant mounted with the bottom of the fixture at 6 in. (150 mm) or less above the bottom of the double-tee stems (22 in. [559 mm] below the ceiling), then there is no light blockage.

Other considerations

Painting of the ceilings, beams, walls, and columns enhances the brightness perception of the interior of the parking structure as well as increases the illuminance values about 10% to 20% due to increased reflectance. The reflectance of plain concrete typically ranges from 30% to 40%. When the surfaces are painted white or off-white, the reflectance increases to approximately 70% to 80%. While the illuminance values are only increased 10% to 20%, the brightness perception is doubled as the eye sees reflected light, not direct light.

References

1. International Code Council (ICC). 2006. *2006 International Building Code.* Delmar Cengage Learning.
2. Illuminating Engineering Society of North America (IESNA). 1998. *Lighting for Parking Facilities.* IESNA publication RP-20-98. New York, NY: IESNA.

Appendix

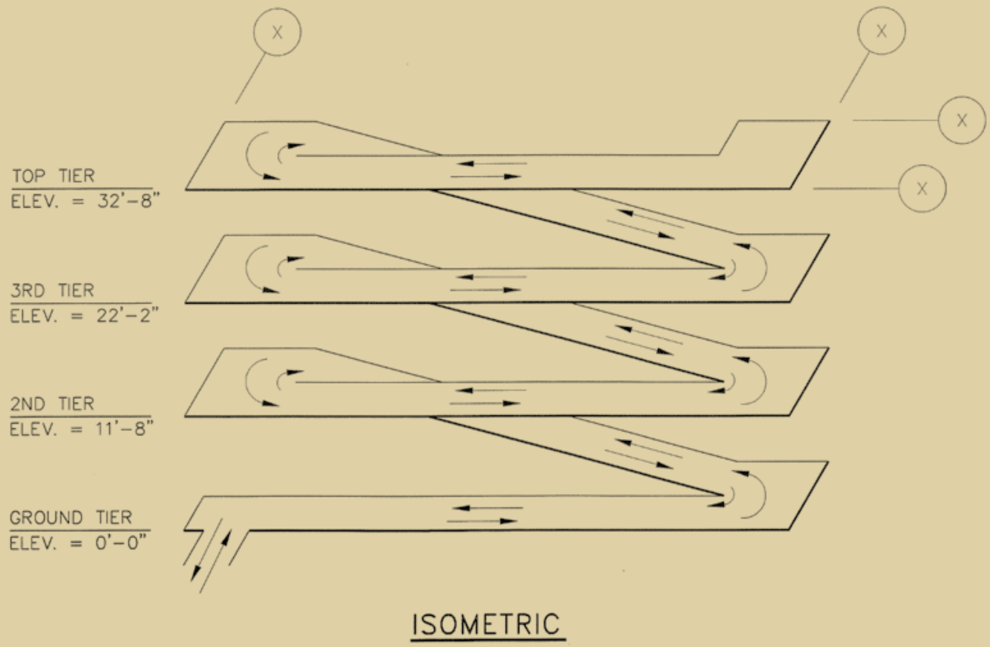

Figure A-1. Isometric for illuminance comparison between precast concrete and post-tensioned garages.

Table A-1.1. Comparison of precast concrete and post-tensioned illuminance at level 1 with bottom of luminaire at 12 in. below ceiling

	Precast concrete, FC	Post-tensioned concrete, FC	Ratio of PC to PT, %
Horizontal illuminance on pavement			
Average	5.3	5.9	90
Maximum	12.2	11.3	108
Minimum	1.4	2.9	48
Vertical illuminance at 5 ft, south wall			
Average	6.8	8.0	85
Maximum	22.7	22.4	101
Minimum	0.5	0.6	83
Vertical illuminance at 5 ft, center wall			
Average	6.7	8.5	79
Maximum	13.3	13.2	101
Minimum	0.7	1.9	37
Vertical illuminance at 5 ft, west wall			
Average	1.6	10.7	15
Maximum	2.0	12.8	16
Minimum	1.1	8.3	13
Vertical illuminance at 5 ft, east wall			
Average	1.7	10.8	16
Maximum	2.0	12.8	16
Minimum	1.3	8.3	16

Note: FC = footcandle; PC = precast; PT = post-tensioned. 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Table A-1.2. Comparison of precast concrete and post-tensioned illuminance at level 1 with bottom of luminaire at 16 in. below ceiling

	Precast concrete, FC	Post-tensioned concrete, FC	Ratio of PC to PT, %
Horizontal illuminance on pavement			
Average	6.3	6.2	101
Maximum	13.0	12.6	103
Minimum	3.2	3.1	103
Vertical illuminance at 5 ft, south wall			
Average	6.0	5.8	104
Maximum	14.6	14.5	101
Minimum	0.8	0.7	114
Vertical illuminance at 5 ft, center wall			
Average	6.5	6.5	100
Maximum	10.4	10.3	101
Minimum	2.0	2.0	100
Vertical illuminance at 5 ft, west wall			
Average	11.1	11.1	100
Maximum	15.6	15.5	101
Minimum	5.8	5.8	100
Vertical illuminance at 5 ft, east wall			
Average	11.3	11.2	101
Maximum	15.6	15.5	101
Minimum	6.0	5.8	103

Note: FC = footcandle; PC = precast; PT = post-tensioned. 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Table A-1.3. Comparison of precast concrete and post-tensioned illuminance at level 1 with bottom of luminaire at 19 in. below ceiling

	Precast concrete, FC	Post-tensioned concrete, FC	Ratio of PC to PT, %
Horizontal illuminance on Pavement			
Average	6.3	6.3	101
Maximum	13.3	12.9	103
Minimum	3.2	3.1	103
Vertical illuminance at 5 ft, south wall			
Average	5.2	5.0	104
Maximum	12.3	12.3	100
Minimum	0.7	0.7	100
Vertical illuminance at 5 ft, center wall			
Average	5.7	5.7	100
Maximum	8.9	9.0	99
Minimum	1.8	1.8	100
Vertical illuminance at 5 ft, west wall			
Average	10.6	10.6	100
Maximum	14.8	14.8	100
Minimum	5.1	5.1	100
Vertical illuminance at 5 ft, east wall			
Average	10.8	10.7	100
Maximum	14.8	14.8	100
Minimum	5.3	5.2	102

Note: FC = footcandle; PC = precast; PT = post-tensioned. 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Table A-1.4. Comparison of precast concrete and post-tensioned illuminance at level 1 with bottom of luminaire at 22 in. below ceiling

	Precast concrete, FC	Post-tensioned concrete, FC	Ratio of PC to PT, %
Horizontal illuminance on pavement			
Average	6.4	6.3	101
Maximum	13.7	13.2	104
Minimum	3.1	3.1	100
Vertical illuminance at 5 ft, south wall			
Average	4.5	4.4	104
Maximum	10.8	10.7	101
Minimum	0.7	0.7	100
Vertical illuminance at 5 ft, center wall			
Average	4.9	4.9	99
Maximum	7.6	7.6	100
Minimum	1.7	1.7	100
Vertical illuminance at 5 ft, west wall			
Average	9.8	9.8	100
Maximum	13.7	13.7	100
Minimum	4.5	4.5	100
Vertical illuminance at 5 ft, east wall			
Average	10.0	9.9	101
Maximum	13.8	13.7	101
Minimum	4.8	4.7	102

Note: FC = footcandle; PC = precast; PT = post-tensioned. 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Table A-2.1. Comparison of precast concrete and post-tensioned illuminance at level 2 with bottom of luminaire at 12 in. below ceiling

	Precast concrete, FC	Post-tensioned concrete, FC	Ratio of PC to PT, %
Horizontal illuminance on pavement			
Average	5.4	6.2	87
Maximum	13.9	12.6	110
Minimum	0.5	2.9	17
Vertical illuminance at 5 ft, south wall			
Average	4.3	5.8	75
Maximum	9.7	15.2	64
Minimum	0.4	0.6	67
Vertical illuminance at 5 ft, center wall			
Average	4.6	6.5	71
Maximum	10.7	10.7	100
Minimum	0.7	1.2	58
Vertical illuminance at 5 ft, west wall			
Average	1.6	11.3	14
Maximum	2.0	15.5	13
Minimum	1.1	6.1	18
Vertical illuminance at 5 ft, east wall			
Average	1.6	11.4	14
Maximum	2.0	15.5	13
Minimum	1.1	6.1	18

Note: FC = footcandle; PC = precast; PT = post-tensioned. 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Table A-2.2. Comparison of precast concrete and post-tensioned illuminance at level 2 with bottom of luminaire at 16 in. below ceiling

	Precast concrete, FC	Post-tensioned concrete, FC	Ratio of PC to PT, %
Horizontal illuminance on pavement			
Average	6.5	6.6	98
Maximum	15.0	14.5	103
Minimum	1.2	2.9	41
Vertical illuminance at 5 ft, south wall			
Average	3.1	3.0	104
Maximum	7.1	7.0	101
Minimum	0.7	0.7	100
Vertical illuminance at 5 ft, center wall			
Average	3.3	3.4	99
Maximum	5.1	5.0	102
Minimum	1.4	1.3	108
Vertical illuminance at 5 ft, west wall			
Average	6.9	6.9	100
Maximum	8.7	8.7	100
Minimum	3.3	3.2	103
Vertical illuminance at 5 ft, east wall			
Average	6.9	6.9	100
Maximum	8.7	8.7	100
Minimum	3.3	3.2	103

Note: FC = footcandle; PC = precast; PT = post-tensioned. 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Table A-2.3. Comparison of precast concrete and post-tensioned illuminance at level 2 with bottom of luminaire at 19 in. below ceiling

	Precast concrete, FC	Post-tensioned concrete, FC	Ratio of PC to PT, %
Horizontal illuminance on pavement			
Average	6.7	6.7	100
Maximum	15.5	15.0	103
Minimum	2.8	2.8	100
Vertical illuminance at 5 ft, south wall			
Average	2.8	2.7	103
Maximum	6.0	5.9	102
Minimum	0.7	0.7	100
Vertical illuminance at 5 ft, center wall			
Average	2.9	3.0	98
Maximum	4.3	4.3	100
Minimum	1.3	1.3	100
Vertical illuminance at 5 ft, west wall			
Average	5.9	5.9	100
Maximum	7.4	7.4	100
Minimum	2.9	2.8	104
Vertical illuminance at 5 ft, east wall			
Average	5.9	5.9	100
Maximum	7.4	7.4	100
Minimum	2.9	2.8	104

Note: FC = footcandle; PC = precast; PT = post-tensioned. 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Table A-2.4. Comparison of precast concrete and post-tensioned illuminance at level 2 with bottom of luminaire at 22 in. below ceiling

	Precast concrete, FC	Post-tensioned concrete, FC	Ratio of PC to PT, %
Horizontal illuminance on Pavement			
Average	6.7	6.7	100
Maximum	16.0	15.5	103
Minimum	2.7	2.7	100
Vertical illuminance at 5 ft, south wall			
Average	2.5	2.4	103
Maximum	5.0	4.9	102
Minimum	0.7	0.7	100
Vertical illuminance at 5 ft, center wall			
Average	2.6	2.6	98
Maximum	3.7	3.8	97
Minimum	1.2	1.3	92
Vertical illuminance at 5 ft, west wall			
Average	4.8	4.9	99
Maximum	6.2	6.3	98
Minimum	2.6	2.6	100
Vertical illuminance at 5 ft, east wall			
Average	4.8	4.9	100
Maximum	6.2	6.3	98
Minimum	2.6	2.5	104

Note: FC = footcandle; PC = precast; PT = post-tensioned. 1 in. = 25.4 mm; 1 ft = 0.3048 m.

About the author

The computer modeling, illuminance calculations, and report were prepared by Donald R. Monahan, P.E., vice president of Walker Parking Consultants in Denver, Colo. Monahan is chair of the Off Roadway Lighting Subcommittee of the Illuminating Engineering Society of North America and is chair of the task force that is preparing an update to IESNA's RP-20-98, *Lighting for Parking Facilities*. He has authored numerous magazine articles as well as lectured at parking-industry seminars and conventions with regard to parking-facility lighting issues. He is also coauthor of the textbook *Parking Structures: Planning, Design, Construction, Maintenance and Repair*, third edition, published in 2001 by Kluwer Academic Publishers. He can be reached at don.monahan@walkerparking.com.

Synopsis

There is a perception among some members of the design community that lighting of precast concrete parking structures is not as efficient as lighting of post-tensioned concrete (PT) parking structures. This perception occurs because one assumes that there is more light blockage from the closely spaced, precast concrete double-tee stems (5 ft [1.5 m] spacing) compared with the wider spacing of beams (18 ft to 24 ft [5.5 m to 7.3 m] spacing) in a PT concrete parking structure.

The Colorado Prestressers Association retained Walker Parking Consultants to perform a study comparing lighting systems for precast concrete parking structures versus PT concrete parking structures. This study indicates that there is no difference (within the accuracy of the calculation procedure) in horizontal illuminance on the floor, or vertical illuminance on the perimeter walls, for identical lighting configurations in precast concrete and PT concrete parking structures. This conclusion is provided that the bottoms of the luminaires in the precast concrete parking structure are pendant-mounted and that the luminaires are no more than 6 in. (150 mm) above the bottom of the double-tee stem and centered between the 5 ft double-tee stem spacing.

This report describes the configuration of the two parking structures, the lighting configuration, the design methodology, and the results of the analysis.

Keywords

Double-tee, illuminance, lighting, light-loss factor, lumen depreciation, luminaire dirt depreciation, luminance, parking structure, post-tensioning.

Review policy

This paper was reviewed in accordance with the Precast/Prestressed Concrete Institute's peer-review process.

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