IPRF Research Report
Innovative Pavement Research Foundation
Airport Pavement Technology Program

Report IPRF 01-G-002-03-1

Constructing In-Pavement Lighting, Portland Cement Concrete Pavement

Programs Management Office
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Skokie, IL 60077

March 14, 2008

An ***IPRF*** Research Report
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Constructing In-Pavement Lighting, Portland Cement Concrete Pavement

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This report has been prepared by the Innovative Pavement Research Foundation (IPRF) under the Airport Concrete Pavement Technology. Program Funding is provided by the Federal Aviation Administration (FAA) under Cooperative Agreement Number 01-G-002-03-1. Dr. Satish Agrawal is the Manager of the FAA Airport Technology R&D Branch and the Technical Manager of the Cooperative Agreement. Mr. Jim Lafrenz is the IPRF Cooperative Agreement Program Manager.

The IPRF and the FAA thank the Technical Panel who so generously gave of their expertise and time for the development of this report. They were responsible for the oversight and the technical direction, and provided valuable input on important issues. The following individuals constitute the Technical Panel:

Mr. Roger Hall	**FAA Project Technical Advisor**
Mr. Gary Fuselier	**Metropolitan Washington Airports Authority**
Mr. Stan Herrin	**Crawford, Murphy & Tilly, Inc.**
Mr. Bill Schai	**Jaquith Industries**
Mr. Hugh Weaver	**HNTB**

ACKNOWLEDGEMENTS

This document was prepared by the following project team members:

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The project team would like to acknowledge the contributions of the following:

- Manuel Bejarano (Tigerbrain), for his evaluation and input to the report on pavement panel stress and load transfer.
- Representatives from airports and airport agencies, who gave of their time and provided valuable insight, including: Bill Ernst and Mike Widdison (SLC); John Ohanian (IAD); Rodney Long and Frank Hayes (ATL); Adel Wehbi (DET); Frank Barczak (MCO); Jake Adams and Mark Vicelja (LAX); Mike Tebaue (STL); and members of their respective organizations.
- Contractors, manufacturers and suppliers, who generously offered their experiences and expertise: Gary Konyha (Rauhorn Electric); Frank Pruitt (H. L. Pruitt); Carroll Edwards (EAS Contracting); Jack Lansdowne and Ken Prince (Lane Construction); Bob Kern (Minnich Mfg.); Kevin Klein (Gomaco); Carlos Wood (Libra Electric Co.); Bill Schai (Jaquith); Dan Geary (DACO Construction); Skyline Electric.
- AE firms and Consultants who kindly offered their vast expertise and experiences: Gene Barnes and David Greene (HNTB); Carl Johnson II (AVCON).
- To those in the industry not mentioned above, but who shared their thoughts and opinions in passing discussion or otherwise.

Additionally, acknowledgement is extended to the pioneers who over the years have contributed to development of in-pavement lighting and methods for installation in concrete pavement, and to those who still are experimenting with and refining techniques.

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READER'S GUIDE TO THIS DOCUMENT

This document should be used to gain an understanding of the issues related to improved performance of portland cement concrete (PCC) pavement that incorporates in-pavement lighting. Topics presented in this Guide include:

- Installation issues.
- Coordination between disciplines.
- Survey needs and tolerance requirements.
- Installing in-pavement lights with new PCC pavement construction.
- Installing in-pavement lights in existing PCC pavement.
- Products and materials.
- Installation deficiencies and correction alternatives.

Following the main sections of this document is a list of references and additional sources for information. These sources were particularly valuable in developing this guide and provide a wealth of additional information, particularly relating to paving.

Additional information that may be useful to the reader is provided in the appendices, including information on layout tolerances and light base accessories, pavement stress and load transfer, installation impact on light photometrics, and corrosion.

Photographs and graphics are used for clarification whenever possible. Certain items important for good practice or as a caution are highlighted for the reader. The following convention is used:

(light yellow shading)	Shading only is used to highlight important points.
(shading with border)	Shading with border is used to highlight a specific note, caution, recommendation.

References

References in general are not cited in this document, except where the reader is directed for additional information. This manual is a best practices document and the information presented is compiled from many sources, both published and non-published.

EXECUTIVE SUMMARY

The placement of in-pavement lighting is critical to the operations of an airport. The visual acquisition of the lights by the airplane pilot provides a message, that when interpreted, will assure that the operation of the aircraft is safe. The safe operation of aircraft can only be assured if the pavement and in-pavement lights each perform according to their intended function. But, those independent functions are linked to each other by construction. Failure to satisfy criteria for one results in the potential of less than expected performance of the other. Failure to allow for the tolerances established for in-pavement lights can result in deficient photometric performance. Failure to recognize the performance requirements of the pavement results in high maintenance demands.

There can be a perception that in-pavement lights are an encroachment on production paving for new airfield pavement because the process of design and construction appears to give primary consideration to factors involved with paving. But, giving priority to pavement criteria without recognition of in-pavement light criteria gives way to the potential for a deficient light base installation. And, when tolerances for the light base installation appear to ignore the grade and smoothness requirements for the pavement, the perceptions hold true. Only when the performance requirements of each system are given consideration can both systems be designed and constructed in a manner that assures that visual messages, from correct light installation, are correct.

For in-pavement light installation in existing PCC pavement there must be consideration to the impact on pavement performance as a result of the intrusion of the lights and the supporting infrastructure. The installation is intrusive and restoration procedures and material selections significantly impact performance of both the light base and the pavement surface.

This document identifies several issues associated with in-pavement light installation. It provides information on techniques, methods and procedures proven successful at airports with installations in both new and existing concrete pavement. Recommendations are provided on tolerances critical to the performance of light bases and fixtures. Methods and means for field checks are offered that provide a tool where official guidance is mostly silent. Light base structure and load transfer at pavement joints are discussed. Functional areas, where better coordination between disciplines, will result in better performance at the interface of pavement and a light are identified.

The information in this Guide is intended to:

- Encourage engineers to better coordinate and define construction documents and thus minimize the quantity of field adjustments.
- Encourage cross-discipline understanding between the civil and electrical engineer and between contractor and subcontractors.

- Document means or techniques that enhance work efficiency and result in a higher probability of attaining the goals set by standards for both pavement and in-pavement lights.
- Providing alternatives for mitigating deficient construction into practice.

Owners, engineers, contractors, and manufacturers all agree that workmanship is instrumental for achieving the intended performance for both pavement and in-pavement lights. A project's Quality Control (QC) plan should reflect the recommendations and practices identified in this document and minimize the workmanship issues that could arise.

> Locating a light base too close to a pavement joint, setting it at the wrong height or setting it at an angle with respect to plumb will usually result in a deficient installation. The solution is removal and replacement.

1. INTRODUCTION

1.1 BACKGROUND

The standards for the construction of airfield pavement and in-pavement lights are different. They are often interpreted as not being compatible. However, when the functions of each are recognized as being on different orders of magnitude, with respect to tolerance, then it is possible to understand that the systems are compatible.

Pavement standards are a function of structural requirements, i.e., load, thickness and panel size. Pavements have surface smoothness and cross slope tolerances that are intended to assure positive drainage. In-pavement lights are established to convey the optimum photometric so that a pilot can visualize a pattern which provides information critical to the safe operations of aircraft. Lights set to the proper height, azimuth, and level criteria will provide the necessary visual message. The lights must continue to provide that visual during impact from aircraft tires, striking by snow plow blades and the effects of ambient environment.

A typical 10,000-foot (3,048M) runway with centerline lights, touchdown zone lights, and taxiway centerline lead-off/on/across lights may have more than 800 in-pavement lights. A major airport could have as many as 5,000 individual in-pavement lights. Those numbers represent significant investments in resources and maintenance requirements.

In-pavement light fixtures are mounted in load-bearing light bases. That base is set on a concrete foundation. The light base holds the light fixture in the proper orientation, provides a routing for cabling and conduit, and provides housing for components such as the isolation transformer. The light base is the interface between the light fixture and the surrounding pavement.

Locating the light base close to a planned pavement joint, or setting the base at the wrong height or at an angle with respect to plumb usually, results in a deficient installation. Either the photometric will be deficient or the light base installation will adversely impact the pavement and generate excessive maintenance requirements. The solution for an improper light base installation is removal and replacement. That involves removal of pavement. Proper installation of the light base in the pavement is the most critical element for the performance of the light as well as that of the pavement.

1.2 LIGHT BASE INSTALLATION ISSUES

The following items are identified as “issues” that directly influence the workmanship of the installation of the light base. The issues relate to both civil and electrical disciplines. They apply to the design phase, the construction phase and can be used as a check list for those persons that are assigned responsibility for quality control.

1.2.1 Light Base Installation (New Pavement)

Light base location and configuration.

- Avoid pavement joints when locating a light base. The light base must be located within the tolerance provided in the Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5340-30, Design and Installation Details for Airport Visual Aids.
- The light base should be located so that the distance from the planned joint to the light base edge is at least two feet.
- Special light base configurations. Lights that identify the touchdown zone, approach light bars, centerline lights set on arcs, runway guard lights and stop bar lights at hold positions are configurations that are defined in FAA documents and they may require special pavement construction techniques.

Using a pavement boxout.

- Is a boxout necessary?
- If used, is there a correct geometry?
- Necessary details.

Use of embedded steel.

- Embedded steel for the light base.
- Embedded steel for pavement.

Alternative drainage techniques.

- Drainage for the light base/conduit system.
- Alternatives to drain systems.

Construction drawings and specifications.

- Coordinate light locations and planned pavement joints as a part of the design process. This process is iterative in nature. It is not a one time activity accomplished during the design process. It will involve looking at base locations and planned joint types. Encroachment on construction joints may be a consideration; but, encroachment on contraction joints is not.
- Specify tolerances and, when allowed, mitigation criteria.
- Special products and materials

Coordinating light base installation with paving operations.

- The survey for paving; and, the survey for the light base.
- Conflict between construction traffic and light bases.
- Coordinate paving techniques with the light base installation.
- Light base installation for pilot and fill-in paving lanes.
- Light base height.
- Consolidation of plastic concrete at the light base.
- Concrete finishing at the light base. What are the Core or Cookie Cutter techniques?

- Finishing the light base installation. What do you do at the annular space?

Acceptance considerations for the pavement and the light base.

- Pavement tolerance and light base installation.
- Checking compliance rather than accepting deficiency.
- Mitigation of a deficiency.

1.2.2 Light Base Installation (Existing Pavement)

Selecting an installation technique.

- Shallow or deep light base?
- Options for conduit installation.
- Pavement coring or pavement replacement?

Providing for light base drainage.

- Identifying the need to drain light base /conduit system.
- Alternatives to drain systems.

Construction drawings and specifications.

- Specify tolerances and mitigation criteria.
- Special products, materials, and installation methods

Coordinating light base installation with pavement repairs.

- Coordination of the survey for the light base.
- Light base height (relative to pavement), level and azimuth.
- Finishing the light base installation. What do you do at the annular space?

Accepting the pavement and the light base.

- Pavement profile tolerance and light base installation.
- Checking compliance rather than accepting deficiency.
- Mitigation of a deficiency.

1.3 LIMITATION ON USING THIS DOCUMENT

“Glue-in” type light fixtures installed directly in concrete pavement are still in use and installation of a light base in pavement with continuous reinforcement may be required.   Neither are discussed in this document.

1.4 DISCLAIMER

This document represents a compilation of practices. It is not a construction specification or a standard. This document should not be used in lieu of a properly documented set of construction drawings and specifications.

The methods, products, and techniques that are being used at airports with successful installations of in-pavement lights are documented. The practices associated with the installation of lights in new pavement and "retrofit" projects for existing pavement are presented.

Proven construction practice(s) is presented. Included are recommendations for achieving compliant installation and suggestions for determining "correctness" in the field during construction. There are cautions provided where experience has documented an installation practice found to result in performance less than successful.

Pavement construction is discussed herein only as it relates to the installation of light bases.

1.5 ATTAINING QUALITY IN CONSTRUCTION

A successful installation of an in-pavement light is directly dependent upon the installation of the light base. The quality of the installation begins with a well coordinated design followed by attentive craftsmanship by the installer. This becomes more important where time constraints require construction activities to be performed at an accelerated schedule or phased in a way to minimize impact of construction or repair on airport operations.

Steps in the process found to have influence on a successful installation are:

1. Selecting the right materials. Be sure the materials will perform in the way that they are intended. Research on the historical performance of proprietary products is critical. An in-pavement light installation in an airfield pavement is not the proper venue to determine the performance characteristics of "new" products.

2. Maintain a proper setback from planned pavement joints. This applies to the selection of the pavement panel size as well as using the allowable tolerances for placement of a light base to the advantage of the project without sacrifice of workmanship.

3. Setting and the orientation of a light base to within allowable tolerances for location, height, azimuth, and level.

4. Securing and protecting the light base during the placement of the concrete anchor.

5. Finishing the pavement surface around the light base.

6. Protecting the light base throughout the paving process to include placing, finishing, saw cutting, grooving and marking.

People that are experienced with light base installation understand that it is not uncommon for a light base to be set too high, too low, or that they can be knocked out of alignment during the construction process. They also understand that there are acceptable corrective measures for the light base that has slight misalignment provided mitigation action is implemented before paving. Identifying an incorrectly installed light base before concrete paving will result in a significant savings in resources. The replacement of a light base after paving is not an economical option. Applying expedient corrective measures to an improperly installed light base usually results in a “lesser” installation. That installation will provide a reduced long-term performance and there will usually be an increase in maintenance requirements.

2. IN-PAVEMENT LIGHT BASICS – LOCATION, CONFIGURATIONS AND INSTALLATION (NEW PAVEMENT)

2.1 LIGHT BASE BASICS

2.1.1 Light Base Structure

A light base used in new pavement construction is usually a deep base, i.e., one that is longer than the pavement thickness. The initial installation involves setting the bottom of a deep base in concrete for the purpose of providing an "anchor." The anchor provides stability to the light base during the paving operation. An embedded steel cage integrates the anchor and the concrete pavement. Confinement of the light base with concrete slightly increases the cylinder strength of the light base by bracing it against buckling.

Figure 2.1(a) illustrates the anchor for an installed light base. The anchor is critical towards preventing movement during paving by maintaining correct base orientation with respect to height, azimuth, and level.

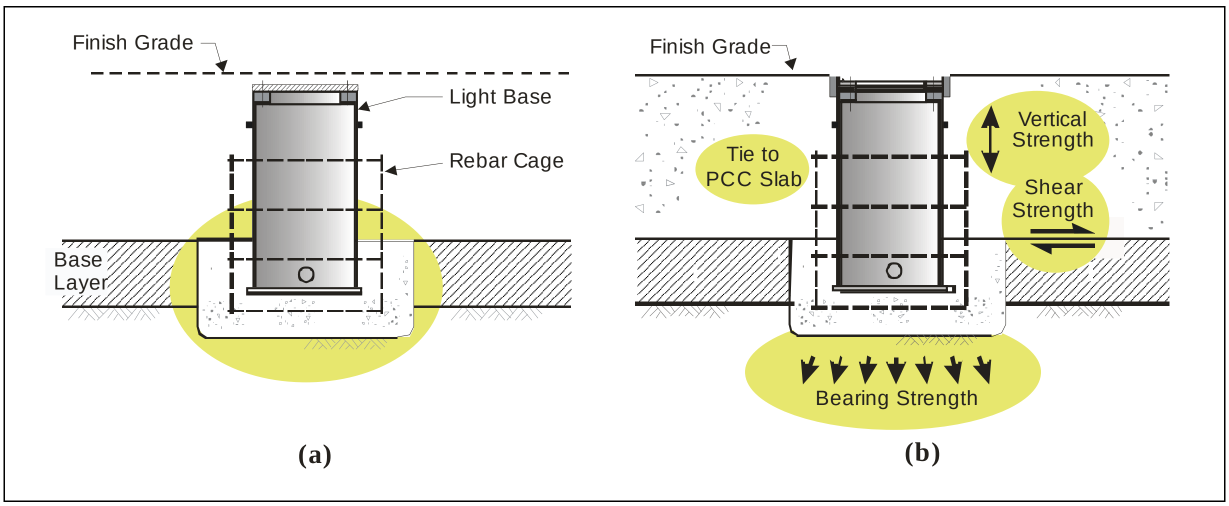


Figure 2.1 – Light Base Basics.

Figure 2.1(b) illustrates the contributions of the concrete pavement and the light base to a system that supports aircraft traffic. The anchor provides bearing capacity for point loads on the light base and it provides edge support for the pavement that surrounds the light base. The embedded steel cage ties the anchor to the pavement

(a) **(b)**

Figure 2.2 - Light Base(s) Ready for Concrete Anchor Placement.

2.1.2 Load Transfer

The conventional technique used to provide load transfer at constructed pavement joints is to use dowel bars. Guidance for using dowels in concrete pavement is provided in FAA AC 150/5320-6, Airport Pavement Design and Evaluation.

Load transfer is an important consideration for those joints between a pavement and a pavement penetration such as a drainage structure, under ground conduit cleanout, fuel hydrant, etc. The conventional design solution for load transfer at a pavement penetration is to provide an isolation joint coupled with a thickened edge pavement. Special pavement panel geometry may also be incorporated. The light base is a pavement penetration; however, it is not feasible to implement the conventional solution for load transfer.

Precise data that allows for a detailed analysis of the mechanism of load transfer between a light base and the concrete pavement is not available. But, there is information available that enables an assessment of the physical parameters.

1. "Resistance to Punch-through". Tires on the main gear tire of a large aircraft have a surface contact area 50 to 100 percent larger than the area of an in-pavement light fixture. When the aircraft tire is on the light, there is no differential vertical stress on the light base relative to that on the surrounding pavement. And, the tire load is transferred directly to the concrete placed as the light base anchor. The light base anchor provides the support to the pavement that allows the stress reduction normally available with the thickened edge. A similar argument can be made for the tire on the pavement only and adjacent to the light base. These scenarios recognize that there is minimal load transfer between the light base and the pavement.

2. "Load in Proximity to Light Base – Slab Interior Traffic Load." As the tire moves away from the light base location, and towards the pavement slab interior, the warping of the panel due to the tire load is influenced by the light base. A static analysis will show that the light base may in fact decrease the induced stress because the anchor, in

combination with the re-bar cage will limit the vertical deflection of the panel as the load moves to the slab interior. The influence of the light base on induced stress for an interior load is to reduce the stress.

"Load in Proximity to Light Base – Slab Edge Loading." FAA criterion is that the light base edge be placed not closer than two feet from a planned pavement joint. The embedded steel cage is spaced 3-inches outside of the light base and the anchor extends a minimum of 12-inches outside the light base. The geometry allows for a clearance for pavement construction of nominally 20-inches from a constructed joint to the light base configuration. In that dimension, there is ample distance to install dowel bars for load transfer across the planned joint. Traffic that loads the light base and the pavement does not violate the design assumptions for load transfer and free edge loading.

2.1.3 Omit the Steel Cage - What Happens?

The cage surrounding the light base integrates the pavement and the light base anchor. Movement, induced by load or thermal change, causes both to respond to the stress. If the anchor and the pavement were not integral, it is probable that differential responses to imposed forces would result.

As concrete hardens it shrinks. Where there is a circular pavement penetration, the result is usually shrinkage of the concrete away from the light base and the possibility that radial shrinkage cracks will develop. When a light base is close to a planned joint, the radial cracking could extend to the joint. The cage acts to keep the shrinkage cracks closed preventing the intrusion of debris and subsequent development of a working crack.

2.2 LIGHT LOCATION AND TOLERANCE FOR AJUSTMENT

To achieve a proper installation of in-pavement lights it is necessary that both light fixtures and concrete pavement be constructed within specified tolerances. And, light bases supporting the light fixtures must be placed exactly with respect to the required location, height (relative to the finished pavement surface), level and azimuth.

2.3 LIGHT LOCATION

A particular lighting configuration, and location of individual lights within that configuration, are dictated by the intent of the lighting pattern. Information on configurations and purposes for runway and taxiway lights is provided in FAA AC 150/5340-30. A summary of allowable tolerances with respect to the exact locations for the runway and taxiway in-pavement lights is provided in the Advisory Circular. A summary of the configurations and tolerances is also provided as Appendix A. The user of the information available in Appendix A has a responsibility to confirm that the information is consistent with current criterion.

An individual light location is dependent upon: (1) the beginning, end, and spacing for a configuration of lights intended to send a certain visual message to a pilot; (2) specified offsets from pavement joints or specified lines of geometric alignment; and (3) allowable deviation based upon tolerance from a specified geometric configuration. FAA Advisory Circulars do not provide tolerances for all situations that may develop as a result of the design process. The designer of the lighting layout must be prepared to make judgments about some of the criterion when developing the design.

2.3.1 Adjusting Light Locations

There are situations that often arise during the design of the light layout and the determination of individual light locations that exemplify the considerations that must be made during lighting and pavement layout.

1. <u>Distance from Pavement Joints</u>. Pavement centerline light bases are offset from the longitudinal pavement joint by 2 feet (0.6M). That distance is from the pavement joint, both constructed and contraction, to the outside edge of the light base. For a specific configuration of lights, in this instance a straight line, the spacing of lights and where the light group begins and terminates with respect to pavement joints should be compared. Depending upon the joint spacing selected by the pavement designer, and the required light base spacing, it is possible to adjust the beginning and end light locations and avoid a compromise of the offset restriction at a contraction joint. The tolerance of ± 2 feet (0.6M) with respect to where a light configuration begins will usually allow for implementing this type of solution. However, it is incumbent upon the pavement designer to be aware of the required in-pavement light spacing as part of the process of determining the planned joint spacing.

2. <u>Touchdown Zone (TDZ) Lighting</u>. A touchdown zone light barrette includes 3 lights at 5-foot (1.5M) centers. To maintain a two feet from planned joint offset at each end of the bar, the panel size would optimally be 19-feet. However, this panel size is not compatible with conventional construction techniques. Pavement panel sizes are of nominal dimension of 20, 18.75, 15 or 12.5 feet. These panel sizes are compatible with geometric configurations required for standard pavement widths and construction techniques. The 3-light barrette configuration could be constructed across a single 20 foot panel or across two panels of 15 or 12.5 feet joint spacing. There must be consideration in the selection of the light bar construction for compatibility with the allowed tolerance for the configuration offset distance with respect to the pavement centerline. For any configuration, there must be consideration for load transfer and isolation of the light bar from the panel.

3. <u>Lead-off Taxiway Centerline Lights on Arcs</u>. Lead-off taxiway centerline lights are closely spaced, and usually follow an arc path that does intersect pavement joints at different angles. In most instances it is not practical to adjust the beginning and end points of the configuration and there by avoid the pavement joints by the required two feet. For those instances where the offset from a joint cannot be maintained, the

pavement and the type of joint must be examined to determine if the light base can be closer to the joint or if unique jointing patterns must be considered. Joint patterns that are substantially different than the main pavement, and adopted for the accommodation of the arc lighting, should be avoided. Changes in slab configuration in a continuous lane of paving will require an adjustment to the paving machine or the use of hand placed concrete. Changing the paving machine set-up to accommodate an irregular panel size is not cost effective. The use of hand placed concrete in areas of traffic must be avoided because the concrete will not be the same quality as machine placed mixes.

2.3.2 Mitigation of a Conflict Between a Light Location and a Pavement Joint

Situations will arise where a light base must be closer than two feet to a planned joint. The options are: locate the light closer than two feet using a modified typical installation detail; or, construct a pavement boxout.

Documented field performance of in-pavement light systems installed closer than 2 feet (0.6M) to a paving joint is not conclusive with respect to pavement performance. However, it has been documented that pavement maintenance is usually required in those instances where light bases are installed closer than two feet and / or unusual and odd shaped patterns of jointing were adopted.

> A light base should not be installed closer than 2 feet to a transverse contraction joint unless a boxout is used.

A light base should not be installed closer than two feet to a contraction joint under any circumstance. The contraction crack that forms as a part of the concrete hydration process will propagate to the location of a pavement penetration when the penetration is less than two feet from the intended location of the crack. The only option for installation of a light base within two feet of a contraction joint is to use a boxout. When longitudinal contraction joints are used, additional spacing from the joint to the light base should be considered.

A light base can be installed closer than two feet to a construction joint provided that provisions for paving machine clearances and load transfer are considered. The embedded steel cage surrounding the light base must be at least 6 inches (152mm) from the joint. The steel cage cannot cross over the joint. The latter would result in continuous reinforcement and resulting uncontrolled cracking. When the light base is closer than 12-inches to the construction joint, the dowel bars within a 12-inch distance of the light base must be omitted. An adjustment of the dowel spacing along the joint will aid in keeping dowel bar deletions to a minimum. This is not detrimental to the load transfer efficiency of the joint. If it is necessary to omit two dowels, the anchor concrete for the light base should be extended across the joint and thereby support the joint edge for the two panels in the vicinity of the light base.

2.4 HEIGHT

The +0 inches to -1/16 inches (+0mm to -1.6mm) tolerance that is used to set light fixture height with respect to finish pavement provides balance for concerns related to height. When a light fixture is installed too high, it is likely to be damaged by snow plows, there could be increased abrasion of the lens from blowing sand (thus reducing the photometric) and the light could be a bump for smaller aircraft. When installed too low the light beam will be partially blocked by the pavement thereby degrading the photometric.

> There is confusion about the height tolerance as applied to the light fixture (plus 0 to minus 1/16 inch) and the finish pavement vertical elevation tolerance (1/2 inch plus or minus from established grade). The light tolerance is applied to the difference in elevation between the light fixture and the established pavement. The pavement may be above or below design elevation but the light fixture is installed to the finish pavement surface regardless of pavement elevation.

When setting the height of a light base it must be set relative to the pavement finished grade. And, there must be an adjustment of the elevation of the light base to account for the thickness of the light fixture, the flange and spacer rings. For example, if the installation required using a light fixture that is ¾-inch (19mm) thick at the edge, a 3/8-inch (10mm) flange ring and a 3/8-inch (10mm) spacer ring, the top of the light base should be 1.5 inches (38mm) below pavement finished grade at the low side of the pavement slope. The individual(s) doing construction layout and installation need to know how many flange and spacer rings and their thickness that are allowed by the contract documents. No more than three (3) spacer rings, including the flange ring with pavement dam, should be used on top of a light base to achieve proper height. An example of how height may be determined is shown in **Figure 2.3**.

> Placing a light base to the proper height is more accurate when an existing paved surface is available for use as a reference to the setting jig. That paved surface is usually a pilot lane. When a light base is set “in space,” with no adjacent pavement reference, the allowable limits of spacer rings needed to establish the light fixture at the proper height relative to the pavement could change from the design intent. The placed elevation of the finished pavement may be above or below the design grade.

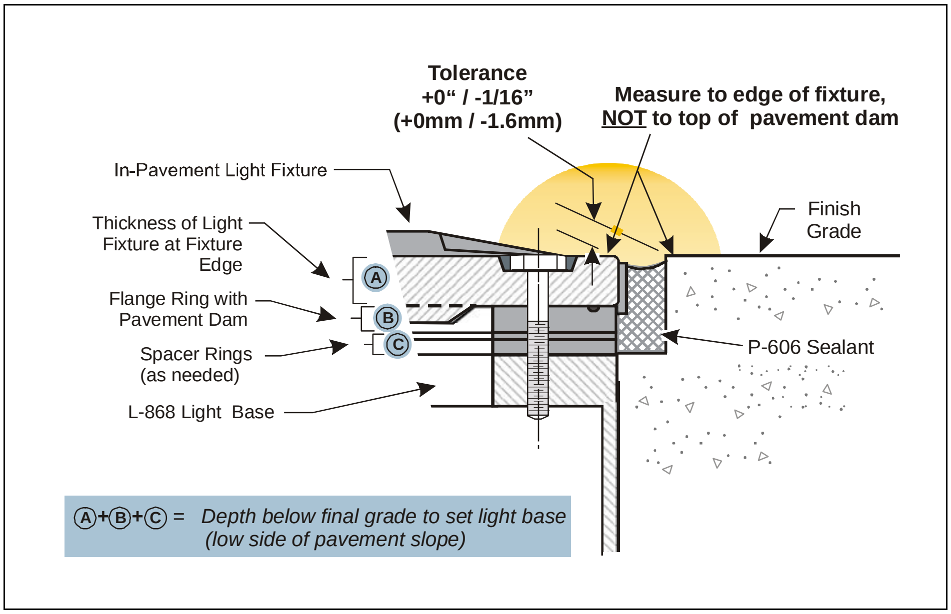


Figure 2.3 - Determining Height for Setting Light Base.

There are situations that could result in a need to adjust the layout height of the light base. These include:

- Light fixtures other than ¾-inch (19mm) thick at the edge. The L-850C runway edge light intended for a 15 inches (381mm) diameter base is usually 1.25-inch (32mm) thick at the edge.
- Individual preference of the airport owner regarding flange ring thickness and limits on the use of spacer rings.
- The contractor may intentionally set a light base slightly low knowing that setting a base too high may require removal and re-setting of the light base.

There is no standard method for measuring compliance with fixture height relative to pavement. However, **Figure 2.4** provides a technique that can be used for checking height.

A **transverse measurement** establishes compliance with the +0 to -1/16 inches (+0mm to -1.6mm) height standard. The determination is made by placing a straight edge, two feet in length, transverse to the direction of traffic on the down slope side of the light fixture. Slide the straightedge towards the light fixture until it is at the outside edge of the light. When the light pushes the straightedge up off the pavement, the fixture is high. When there is a gap between the straightedge and the light of more than 1/16-inch, then the light fixture is low. The gap can be measured using an Allen wrench.

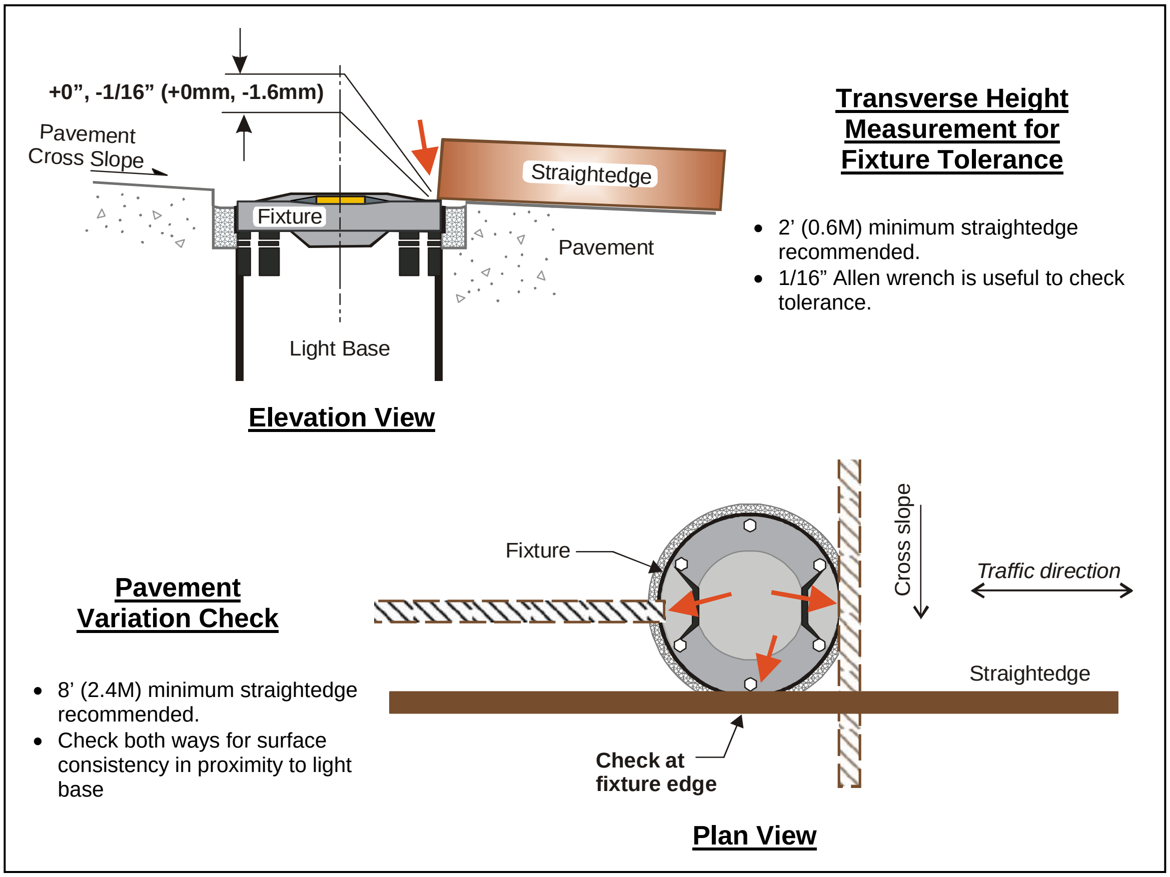


Figure 2.4 - Measuring Height Tolerance at an In-Pavement Light.

Pavement placed using slipform techniques often results in cupping or mounding of the concrete at the light base location. The reason that the phenomena occurs is not known. A good practice is to make a longitudinal measurement along the light orientation and determine if the pavement surface as finished will interfere with a light photometric. To perform the measurement, an 8-foot (2.4M) straightedge is recommended. The straightedge must be notched at the center. The notch is on one edge and centered so that the straightedge, when placed directly over and centered on the light fixture, will sit on the paved surface without contact with the light fixture. Position the straightedge in the same orientation as the light. If there is space beneath the straightedge greater than ¼-inch anywhere along the straightedge other than over the light fixture, the pavement surface must be evaluated for the possibility of the light beam being blocked.

2.5 AZIMUTH

If the light fixture is not properly aimed, the light will not be functional. The light may come on, but the beam will not be cast in the direction it is intended. The required tolerance of aim is ± ½ degree; slightly less than 1-foot (0.3M) in 100 feet (30.5M). The bolt orientation of the light base is used to determine the aim. A setting jig that is constructed properly will have a mechanism for setting and holding the light base in the orientation set by the layout.

The person setting the jig must fully understand reference marks that are provided by the surveyor. Azimuth must be checked by survey before the concrete anchor is placed and again before paving. An on-site representative of the light base manufacturer should be on-site at the beginning of a job and verify that the installation crew understands proper orientation.

Azimuth correction rings are available from light base manufacturers. However, an in-pavement light using a ring for azimuth correction is considered a “lesser” installation. The result is an increase in the maintenance burden.

2.6 LEVEL

A light that is not level will not have the desired photometric properties. If a light fixture is tilted from level into the pavement grade, light output will be blocked by the pavement. **Figure 2.5** is an example of a light fixture that is level (*slope and grade exaggerated for clarity*).

There is no quantitative tolerance for the determination of level. The construction documents should include a tolerance. Typical controls are ± ½ degree from level. A tilt of ½ degree from level lowers the uphill side of the light about 0.1-inch (1.6mm) from the measured edge on the down slope side. A tilt of 1 degree lowers the light 0.2-inch (5mm). Using the higher tolerance can reduce the visual signal.

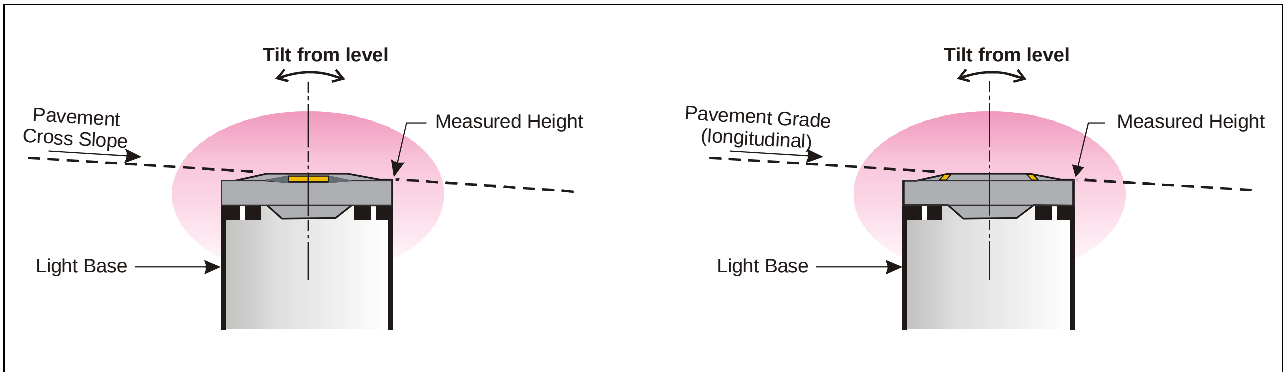


Figure 2.5 - Pavement Slope and Light Tilt from Level.

Typically, a light base setting jig will be checked for level. This practice assumes that if the jig is level, the light base will be level and, subsequently, that the light fixture will be level. The light base should be checked for level immediately prior to paving. A small level, 8-inches to 12-inches (203mm-305mm) long, should be placed on the cover of the light base before concrete paving. The light base should be checked for level in the direction of paving and at 90 degrees from the initial measurement.

Do not check for level across the pavement dam of the flange ring. The pavement dam portion is not always manufactured precisely, and can vary in height above the fixture seating surface of the flange ring.

3. CONSTRUCTION ITEMS SUPPORTING LIGHT BASE INTSALLATION

3.1 BOXOUT

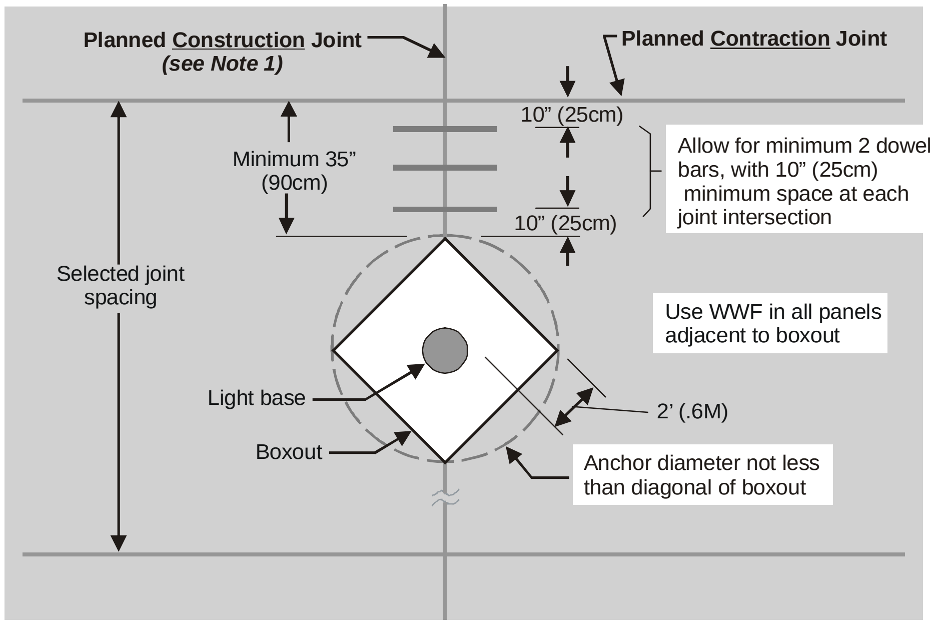
The term "boxout" describes a technique where, during pavement construction, an isolated area is formed that precludes the placing of concrete by mechanical means. After pavement construction, the forms are removed and concrete is placed in the boxout to complete the pavement surface. The boxout is intended to provide continuity at a pavement penetration and a jointed geometry that will minimize the potential for uncontrolled cracking.

> A boxout is not required when an in-pavement light base is installed at or more than two feet from a planned joint. A boxout must be used when a light base must be located closer than two feet to a planned contraction joint. The boxout is an option when locating a light closer than two feet to a construction joint provided that the results of analysis allows for the clearance of construction equipment.

Various geometric shapes can be used for boxouts (diamond, circular, square, rectangular, etc.). The most efficient boxout geometry for an in-pavement light is a diamond or a square. A circle is the optimum shape but finding forming material in a circular shape, sufficiently tall and rigid, is usually cost prohibitive.

A boxout used with an in-pavement light must have a minimum dimension of two feet from the side of the light base plus the diameter of the light base. **Figure 3.1(a)** illustrates a typical layout for an interior boxout used when a light base encroaches on a planned joint and the light is not closer than approximately 6 feet to the respective panel corner. **Figure 3.1(b)** is a typical boxout used when the light base is within 6 feet of a pavement panel corner. When the latter layout is used for a light base, and it is more than two feet from a construction joint, but closer than two feet to a contraction joint, the boxout must incorporate all of the panel distance between the construction joint and the light base. Do not leave an isolated panel section between the boxout and the planned construction joint. Do not cross a planned construction joint with the boxout when there is at least two feet from the light base to the planned construction joint.

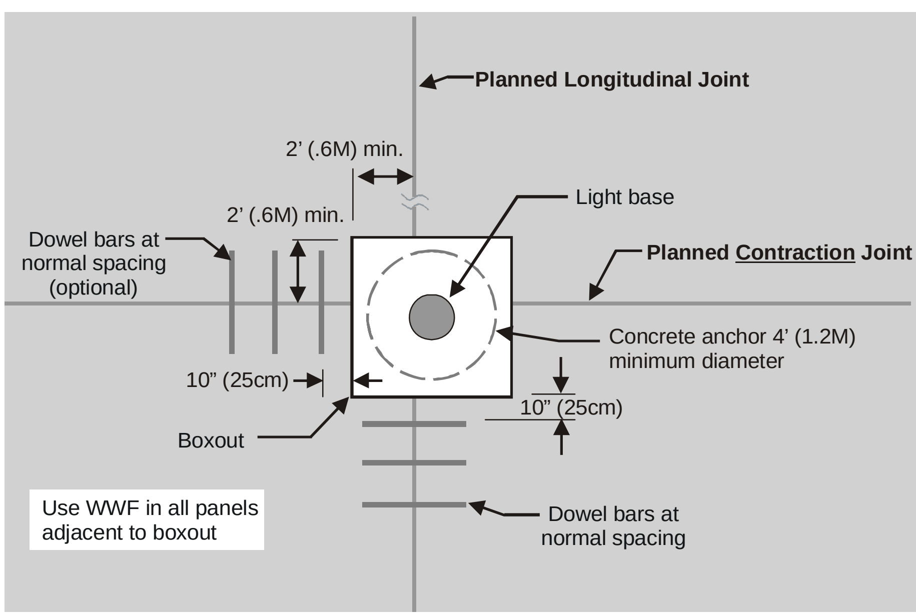
A boxout formed using irregular geometry should not be used. Irregular geometry increases the probability that uncontrolled cracking will occur. Dowels should not be used as a load transfer device between the boxout and the pavement unless considerations for pavement movement are made. Where dowels have been used without consideration of differential movement the result is uncontrolled cracking. The "birdhouse" shaped boxout shown in **Figure 3.2** is an example of dowels restraining movement of an irregular shaped geometric.



NOTES:

1. When boxout is used on a planned contraction joint, the joint will be changed to a construction joint.
2. As the location of the light base moves away from the joint, the size of the boxout will increase.

(a) – Interior Boxout at PCC Construction Joint



(b) –Boxout at PCC Joint Intersection.

Figure 3.1 – Typical Boxout at PCC Joints.

Load transfer at the interface of the pavement and the boxout must be evaluated from the perspective of the actual pavement loading and not what is common practice. For example, the interface between the pavement and boxout is a free edge. The interface should have a thickened edge on both the boxout and the pavement. However, the construction of a boxout with a thickened edge is not practical and usually not warranted.

The use of dowels along the joint between the interior boxout and the pavement is normally not required for in-pavement light installations parallel to centerlines. The interior boxouts along a pavement centerline are usually located on the aircraft nose gear traffic path. Since the aircraft nose gear load is about 5% of the gross load, there is minimal impact on the pavement and the boxout.

The dowel can be considered for use when the boxout and adjacent pavement are subject to main gear loading by slow moving traffic that is fully loaded for aircraft departure. A departure load is the maximum take-off weight of the aircraft used for the pavement design. An example would be a light along a lead-off radius onto the centerline of a taxiway that is parallel to the runway or a light barrette.

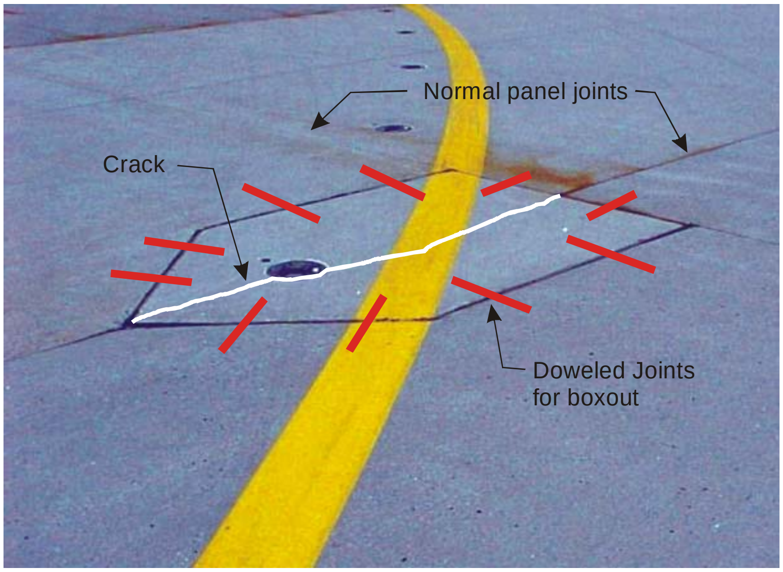


Figure 3.2 – Defective Boxout - Doweled Joints All Sides.

When dowels are used along the joint of the boxout:

- Align dowel bars with the direction of traffic only.
- Do not align dowel bars at oblique angles to the pavement planned joint orientation. Dowel bars are not used with an interior boxout.
- Dowel bar spacing along a pavement construction joint has precedence over dowel bar spacing along the boxout joint. A dowel placed along a boxout joint must be located at

least 12-inches from the end of a dowel bar placed along the intersecting pavement joint.

The perimeter joint of the boxout should be a conventional construction joint that incorporates a joint seal reservoir compatible with the recommendations of the manufacturer of the sealant (see **Figure 3.3**). When a planned pavement joint intersects the boxout perimeter of a light bar (two lights or more), an isolation technique, such as the use of expansion board, should be incorporated. Isolation will minimize the potential for the formation of sympathy cracking. Light bars, such as in-pavement approach lighting barrettes, are usually installed in a boxout that incorporates the barrette perimeter. Expansion board is used along the perimeter joint that crosses a planned longitudinal joint. Isolation is not used with the interior or single light boxout.

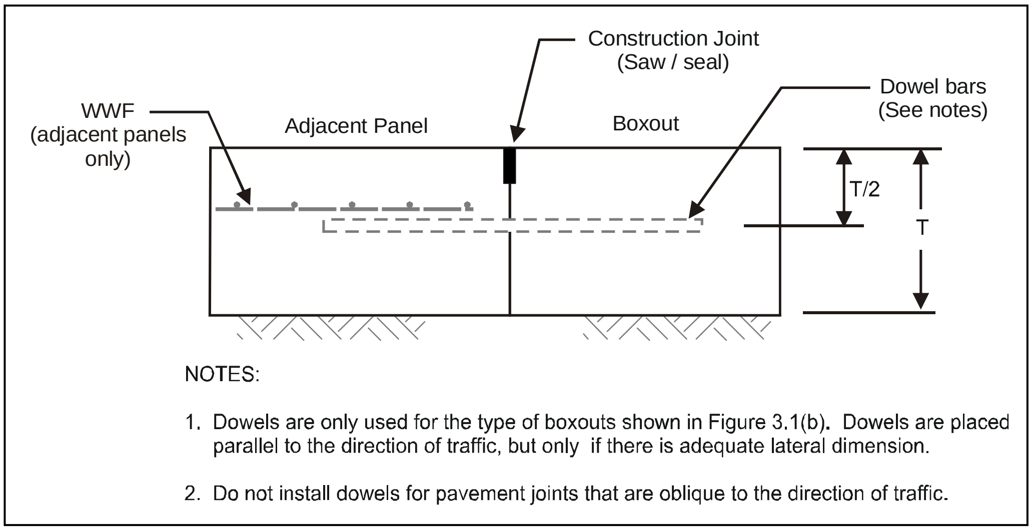


Figure 3.3 – Typical Joint Detail at a Single Light Boxout.

3.2 EMBEDDED STEEL

Airfield pavements are designed and constructed as “plain” concrete pavement. They are not designed using reinforcing steel in the tension face usually used with structural concrete. Plain concrete pavement thickness is determined using the tensile strength of the concrete to resist flexural loading. The steel that is used in airfield concrete pavement is embedded steel. Embedded steel is used to retain the matrix of the concrete if a crack does occur.

There are two types of embedded steel used with in-pavement lights in airfield concrete pavement. The two types are deformed steel, used to construct the light base cage, and welded wire fabric used in irregular panels located adjacent to a boxout.

3.2.1 Light Base Cage Construction

A cage constructed of deformed steel is used in conjunction with a deep light base. The cage adds confinement strength to the light base and it provides a tie between the anchor and the pavement.

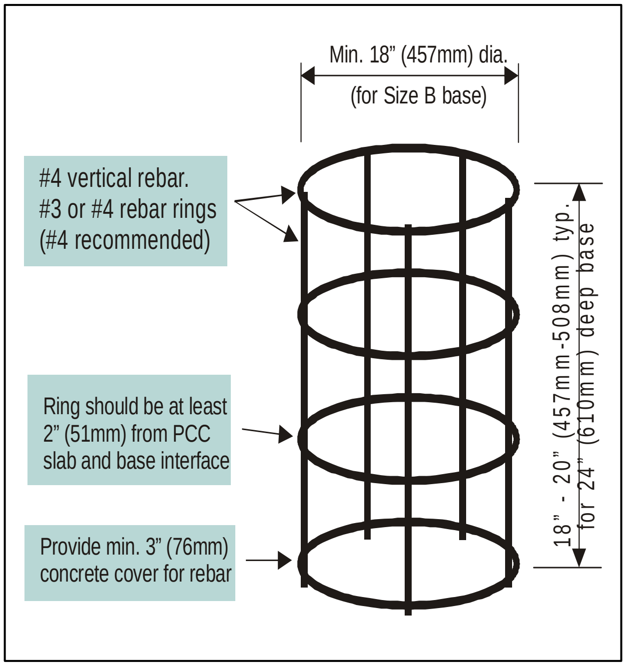


Figure 3.4 – Light Base Cage.

Figure 3.4 shows a typical cage. Number #3 or #4 deformed bars (rebar) are typically used. The #4 bar is the most popular choice because of the rigidity. The cage is typically sized so that the steel rings are at least 3 inches, but not more than 4 inches, (76-102mm) from the light base wall. The top ring of the cage is positioned in the upper third of the pavement and not closer than 3 inches to the pavement surface. The top ring must not be placed higher than the light base or it could interfere with the paving operation.

Vertical members terminate in the light base anchor. The vertical bars may have an "L" bend at the bottom or terminate with a ring. The termination ring, or "L," must be at least two-inches below the top of the anchor but not closer to the anchor bottom than 3-inches. The number of vertical members must be sufficient so that the cage will hold its shape as plastic concrete is placed against the light base and the cage.

3.2.2 Welded Wire Fabric (WWF)

Embedded steel, in the form of welded wire fabric (WWF), is used in pavement panels adjacent to a boxout that have irregular shapes as a result of the boxout construction. Embedded steel is used in boxouts that are odd shaped such as barrettes. The WWF does not "reinforce" or contribute to the strength of the panel. The WWF does keep the concrete tied in the event that a crack would form in the panel. The WWF is placed in the top one third of the panel thickness. The WWF is placed for the entire area of the panel but not closer than two-inches to pavement edges or joints.

3.3 CONCRETE ANCHOR

FAA Specification P-610, Structural Concrete, is commonly used for the anchor of the light base. The mix may incorporate air entrainment, accelerators, and other additives as required.

There should be a minimum of 12-inches (152mm) of concrete encasement outside the perimeter of the light base. The minimum thickness of the anchor is 8-inches. If the diameter of the anchor is increased, a thicker section may be required. A larger diameter encasement is used when subgrade conditions are marginal.

Often, the anchor for the encasement is formed by coring into the subbase using a 36-inch (1M) diameter core. Other anchor configurations have been used but they usually require more effort to construct. There is less effort involved to make a circular core in the subbase, instead of excavating a square hole, when a core bit is available.

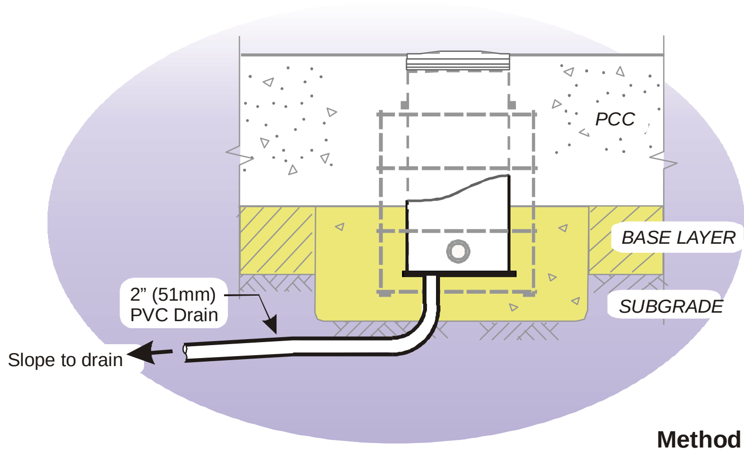
The use of pre-cast concrete sections as the anchor is usually not successful. Pre-cast shapes are difficult to place because of the irregular surface of the subgrade that is the result of construction. If the subgrade is not level and uniform in bearing, rocking of the pre-cast installation during paving can result. The end result is a light base that is not level.

3.4 DRAINAGE CONSIDERATIONS

Not every airport, or every in-pavement light installation, requires drainage provisions for a light base/conduit system. In many cases it is only necessary to drain a light base to a hand hole or manhole that is outside the pavement system. Sumps, or other provisions, for getting the water out of the light system may also be effective.

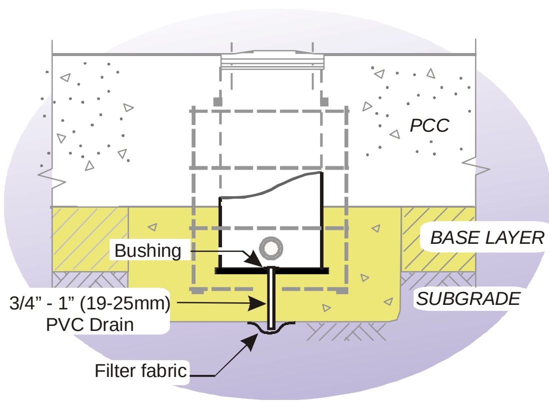
When drainage is required, different practices have been used. But all of those different variants of systems can be categorized into one of the examples illustrated in **Figure 3.5**. Method 1 is preferred but will normally be more expensive than Methods 2 and 3. The cost for Method 1 is dependent on the frequency of drain connections and the length of the drain. A drain is not normally used at every light base in a line of lights. Method 1 is usually the most effective when employed at conduit low points. Many pavement construction projects include edge drains along the side, presenting an opportunity for applying Method 1. Light base drains should be a minimum diameter of 2-inches when freezing conditions exist.

Methods 2 and 3 are economical but the effectiveness depends on permeability of the soil underlying the pavement or the pavement drainage layer.

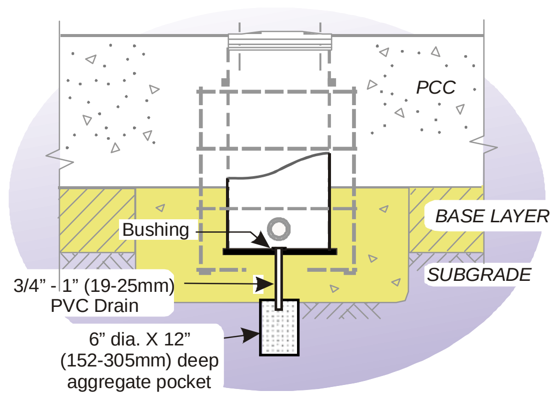


Method 1

Method 1 is typically used at low points on the conduit system, or at select points along the conduit system for a line of lights. It is not practical to apply this method at each light base. This method is best if the pavement structure does not include a drainage layer or the subgrade is prone to perched or high ground water.



Method 2



Method 3

Methods 2 and 3 are most effective where there is adequate subgrade drainage or if there is a drainage layer as part of the pavement structure.

Figure 3.5 – Alternatives Methods for Draining Light Bases and Duct Systems.

4. ENGINEERING - COORDINATING PAVING JOINTS AND LIGHT LAYOUT

4.1 COORDINATION IN DESIGN

The pavement engineer determines the pavement thickness based upon aircraft traffic. Subsequently, jointing dimensions and maximum panel sizes are determined. The jointing pattern, i.e., the arrangement of the panels, is determined based upon the pavement geometry and the maximum panel size. The techniques for determining the jointing pattern are described in FAA AC 150/5320-6, Airport Pavement Design and Evaluation.

The airfield lighting engineer determines the in-pavement lighting configuration(s) and the supporting electrical distribution system. The standards used are described in FAA AC 150/5340-30, Design and Installation Details for Airport Visual Aids.

It appears that it is common practice that construction documents are supplied to the Contractor without the pavement jointing plan and the lighting plan being coordinated. This practice is based upon the assumption that the Contractor, and the respective sub-contractors, can resolve conflicts between pavement joints and light base locations in the field. It is inevitable that poor construction will be the result of that assumption. This is not good practice.

It is the responsibility of the engineer of record to enforce the coordination of pavement jointing and lighting layout plans. Conflicts must be resolved before the construction documents are made available to the Contractor. The pavement engineer should be aware of light base spacing, beginning and end locations for different configurations and respective tolerances as a part of the jointing layout process. The airfield lighting engineer should be aware of conventional jointing patterns and how light base spacing can be accomplished using the typical nominal dimensions. Coordinating light locations with paving plans during design will reduce the probability that significant field changes will be required during construction.

When there is conflict between a pavement joint and a light base, the use of a boxout to expedite project design should be avoided. Using a boxout in a new runway pavement for centerline and/or touchdown zone lights should be rare because the tolerance for the starting locations of configuration is forgiving. It is expected that there will be a conflict at pavement intersections because of the close light spacing, curved alignment and changes in jointing patterns. Design disciplines should closely coordinate their effort and resolve conflict within FAA tolerance. If the tolerance is not sufficient to resolve a conflict, a modification of the FAA standard should be considered before using a boxout. The result will benefit the owner because there is a higher probability that there will be better construction and reduction in long term maintenance and repair needs.

A summary of light spacing and the applicable tolerance is provided in **Appendix A** for convenience. Standards do change so it is incumbent upon the design engineer to assure that the standards are reviewed and Appendix A updated when necessary.

4.2 LIGHT LOCATION AND PAVEMENT JOINT CONFLICTS

The following examples represent situations where conflict between in-pavement lights and a pavement joint are often encountered. The examples are provided as representative of conflict resolution that has been used with success. The examples should not be used as a design standard because each airfield pavement layout is different and therefore a different solution will usually be required.

(a) **(b)**

Figure 4.1 - Taxiway Centerline Light Base Installation at Intersecting Taxiways.

The difficulty that can be expected when trying to avoid conflict between a pavement joint and a light base is illustrated in **Figure 4.1.**

4.2.1 Technique for Resolving Pavement Joint and Light Base Conflict

Step 1. Overlay the lighting plan onto the pavement joint plan.

Step 2. Adjust one or both of the plans until lighting layout tolerance is within the allowable and the light base at all locations is not closer than two feet from the edge of the light base to the planned joint. When a light base is within two feet of a pavement joint there are specific design considerations.

a. The two feet dimension may be infringed if the light base is adjacent to a construction joint and is not closer than two feet to a contraction joint. The two feet spacing from the contraction joint is an absolute. When the contraction joint is also a longitudinal joint, larger spacing from the joint may be required.
b. The two feet spacing from the light base to a construction joint may be less provided that the steel cage does not interfere with the paving operation (9-inches from construction joint to the outside of the re-bar cage). The load transfer device

spacing must be adjusted along the joint and no device should be closer than 10-inches to the rebar cage. This option is preferred. However, it requires that the engineer obtain a modification to standards.

Step 3. When a light base is located closer than two feet to a pavement joint, and the edge of the light base is at least 6 feet from a pavement panel corner – use a diamond boxout (viewed in plan with orientation in the direction of traffic). WWF is placed in the upper one-third of the two panels that incorporate the boxout.

Step 4. When a light base is located closer than two feet to a pavement joint, and the edge of the light base is closer than 6 feet to the pavement panel corner – use a box shaped boxout. The minimum dimension of encroachment into any panel is 2 feet. The longest side of the boxout is not to exceed 1.25 times the length of the shortest side. WWF is placed in the upper one-third of each of the four adjoining panels (two panels when the boxout is placed within two adjacent panels). Load transfer devices may be considered if the boxout is located where it would be subject to frequent loading by main gear of departing aircraft.

4.2.2 Runway Centerline Lights

The standard spacing for runway centerline lights is 50 feet (15M). The beginning of the light string and/or the distance from the runway threshold can be adjusted based upon the standard tolerance. Adjusting the starting point of the light configuration should offset the lights from successive transverse joints.

The lights along the centerline are located two feet from the runway centerline to the edge of the light base. This should be established relative to the true pavement centerline as determined by survey. The center pavement joint may not be coincident with the survey for the centerline.

4.2.3 Touchdown Zone Lights

The touchdown zone lighting includes two light bars symmetrically located with respect to the runway centerline. Each light bar includes 3 lights, at 5 feet spacing, with longitudinal spacing of each bar at 100 feet. The tolerance allowed by FAA from the threshold to the first light bar station is 25 feet. Therefore, it is relatively easy to adjust the bars so that the light bases can be placed in a concrete panel with each base located two feet from a planned transverse joint. But, conflict with a longitudinal joint is normal because the offset distance of the light bar from centerline is 36 feet and the tolerance is only 6-inches.

Most jointing dimensions that are used will result in one of the touchdown zone light bases being closer than 2 feet (.6M) from a planned longitudinal joint. For example, when longitudinal joints are placed at 18.75 feet (5.72M) the second longitudinal joint from the centerline is 37.5 feet (11.4M) off of centerline, which is between the first and second touchdown zone light. The best that can be achieved using the allowable 6-inch (15cm) tolerance for the light is 1.5 feet (46cm) clearance between the inner light base and the longitudinal pavement joint. Alternatives are using a closer spacing to a construction joint which may require a modification to standards from FAA, adjusting the jointing if practical, or using a boxout (not preferred option).

If a boxout is used, the edge of the bar should begin at a distance from the centerline that allows for two feet from the outside light base to the boxout joint. The transverse joint between the boxout and the adjacent panel must be isolated to preclude the propagation of a sympathy crack at the planned longitudinal joint. Dowel bars between the boxout and the adjacent pavement should be used for load transfer. The panel that includes the boxout must be designed and constructed to include WWF for crack control when the length of the long side (transverse joint) is more than 1.25 times the length of the short side (longitudinal joint not including the boxout).

4.2.4 Displaced Threshold with Runway Centerline Lights and Approach Light Bars

A concrete runway with pavement prior to the runway threshold end can have centerline lights and approach light bars through the displaced portion of the runway. Longitudinally, there should be sufficient tolerance to allow the approach light bars and runway centerline lights to be spaced so as not to conflict with transverse joints. The guidance provided for touchdown zone lights with respect to longitudinal joints is applicable.

4.2.5 In-pavement Runway Guard Lights (RGLs) and Stop Bar Lights

These light configurations are closely spaced (nominally 10 feet (3M)) and they extend across a taxiway 2 feet (0.6M) to the taxiway side of the hold position. For maintaining the offset distance from transverse pavement joints the alternatives are: (1) move the hold markings back from the runway while still maintaining required distance from runway centerline and de-conflict the line of lights and the pavement joint, or (2) construct a boxout for the full width of the taxiway. When a boxout is used, joints must be isolated and dowels used for load transfer. WWF is used in those concrete panels that include a boxout.

4.3 DEFINING LIGHT LOCATIONS ON CONSTRUCTION DOCUMENTS

4.3.1 Minimum Definition Elements

The following elements should be defined in construction documents that are prepared for use by the contractor for installing an in-pavement light base.

- Limit the number of rings used to establish height, azimuth and level. An example specified item for height adjustment would be “No more than three (3) spacer rings, including the flange ring with pavement dam, should be used on top of a light base to achieve proper height relative to the adjacent pavement” If additional rings are required, replacement of the light base should be considered.

- Define maximum and minimum width of the annular space used for sealant between a light base and the adjacent pavement. A dimension more than or less than the defined annular space width would require light base removal and replacement. An example might be “where a ¾-inch (19mm) annular space should result from the construction, any portion of the annular space measuring less than ½ inch (13mm) or more than 1-inch is not accepted.”

- If, and the extent to which, grinding may be allowed in front of a light where paving deficiencies prevent achieving photometric performance. It is common practice to allow grinding of up to 1/4-inch depth off a high spot.

- For those instances where light base removal is required, define the method and extent that surrounding pavement must be removed (i.e., large core, half panel, full panel, etc.).

4.3.2 Defining Light Base Locations

One of the following techniques should be used to define light base locations on construction documents.

(1) Coordinates. Requires an established coordinate system for the airport that includes complete and accurate survey benchmarks. Coordinates are useful for curved segments of lighting, where the line of lights is not rectilinear with respect to the jointing pattern. It is difficult to check for errors with tabulated coordinates for each fixture when there are numerous light bases.

(2) Baseline and Offsets. Typically established by the pavement engineer, baselines are useful in laying out the light locations if the baseline coincides with the true centerline of a runway or taxiway. This method makes it easy to evaluate light locations relative to the pavement joints.

(3) Scaled Layout Drawing. A drawing showing light locations and pavement joints, at the same scale, with defined separation dimensions. This may only need to be done for a portion of the layout, such as 300 – 400 feet of runway to establish centerline and touchdown zone light locations relative to uniformly spaced pavement joints. A drawing at 10 or 20 engineering scale will adequately show the lights relative to the jointing pattern.

An item that is not normally specified in construction documents, and which can and has been a source of project dispute between owner and contractor, is the remedial method to be used if a light base installation does not meet specifications. While remedial measures are normally defined for pavements, it is rare to find construction documents that define when a faulty light base installation is to be replaced (or if additional or special rings can be used to adjust for height, azimuth and level). Having remedial techniques specified when deficient installations occur is good practice.

5. PAVING AND LIGHT BASE INSTALLATION, NEW CONSTRUCTION

5.1 GENERAL

Placing a concrete airport pavement involves the delivery of massive quantities of heavy concrete to a machine that places, strikes consolidates, and finishes the concrete on a prepared subbase. The time available from the mixing through finishing is a limited window of activity. Once paving begins it does not stop and start at will and either stopping or starting requires considerable preparation. If stopping is necessary, it requires lead time to shut off the supply of concrete and terminate the placement. To start, there is lead time in building a stockpile of fresh material in front so that the paver can move forward without variance in the forward speed.

If a light base is unintentionally disturbed directly in front of the paving operation, the paving will usually continue. If the survey crew is late starting and the placement catches-up, checking the light bases ceases and the paving operation will usually continue.

The placing of concrete as pavement has prevalence over the light base. The reason is the cost of operations. For a typical concrete placement, as airfield pavement, the expenditure of resources for materials, not including crew and equipment, is approximately $375 per minute (based upon 16-inches of concrete placed at 3 linear feet per minute of forward travel). Therefore, when the pavement requires the installation of a light base, the work had best be done, checked and re-checked before paving operations begin.

Any of the above will usually result in a deficient light base installation.

5.2 COORDINATING LIGHT BASE INSTALLATION WITH PAVING

Coordination of the paving plan and the light layout during the design is a critical first step. However, the relationship between the paving contractor and electrical contractor is just as critical towards achieving a success. The installation of conduit and light bases must be coordinated with the subbase preparation. The pavement placement schedule must be coordinated with the setting of light bases and anchors. And all functions require involving the surveyor.

The electrical contractor relies on the surveyor to locate and reference orientation of light bases so that conduit may be placed in the subbase and light base anchors formed. When the anchors are being placed, the surveyor must check locations, elevation and orientation of light bases. The paving contractor relies on the surveyor to establish a finish pavement elevation that is coordinated with the allowable spacer rings and light fixture specified and the clearance requirements of the paving machine. The surveyor must also establish the location of the paving lanes. Most of the deficiencies observed on projects that incorporate in-pavement lighting can be avoided if all participants take time and effort to coordinate their individual activity.

5.2.1 Survey Requirements

An accurate survey is critical to the successful installation of a light base. Contractors that have good experience will typically have a survey accomplished three times.

A survey at three stages of installation is recommended to minimize the potential for light base installation error:

1. An initial layout will establish the location for each in-pavement light base. Initial layout for lights is accomplished after the pavement subbase layer is placed and graded to finish elevation.

2. A second survey will establish height, azimuth, and level when setting the jig and light base in preparation for placing the concrete anchor.

3. The third survey is a check on height, azimuth and level just prior to concrete pavement being placed.

> There are benefits to the paving contractor that are measured in time and cost savings when light base installation deficiencies are detected before concrete paving. It is relatively cost free to check a light base before paving. It is an expensive proposition to remove a light base after the pavement is placed and finished.

Sources of error in performing the survey function include:

- Performing a survey using data that has not been coordinated with all stakeholders will usually result in an installation error.
- Survey crews that are affiliated with the contractors involved in the project and do not have a working history of similar projects will usually be the cause of installation error.
- A survey crew foreman without experience for establishing line and grade for construction projects will usually be the cause of an installation error.
- Surveying that is accomplished by more than one crew is usually a source of error when they begin work from different monuments and do not tie their work at the end of the work day.

5.2.2 Construction Traffic Control

There must be a planned traffic pattern established and enforced for the vehicles that supply concrete to the paving train. Conflicts between paving operations and light base locations do occur. Mitigation of the conflicts must be resolved before paving begins.

For most situations, one of two conditions must be broached.

1. When concrete is not placed in front of the paver by a placer and a truck is used, a light base presents an obstacle. The truck axle must be high enough to assure that the axle clears the light base or there must be sufficient clearance within the paving lane that would allow the truck to by pass the light base. In the event of no resolution, the light base must be omitted and installed later using a boxout. The boxout must be in place before paving begins. WWF must be used within the panel that includes the boxout.
2. A light base may be located in the track area of the paving train. About 3 feet (0.9M) of clearance outside the paving lane is adequate to allow for the tracks of paving equipment. If a light base is located within the track area the light base should be installed after paving the adjacent lane. In the interim, a boxout is used or the base protected with a device placed on the base and slightly below the pavement elevation.

5.3 SETTING THE LIGHT BASE AND ANCHOR

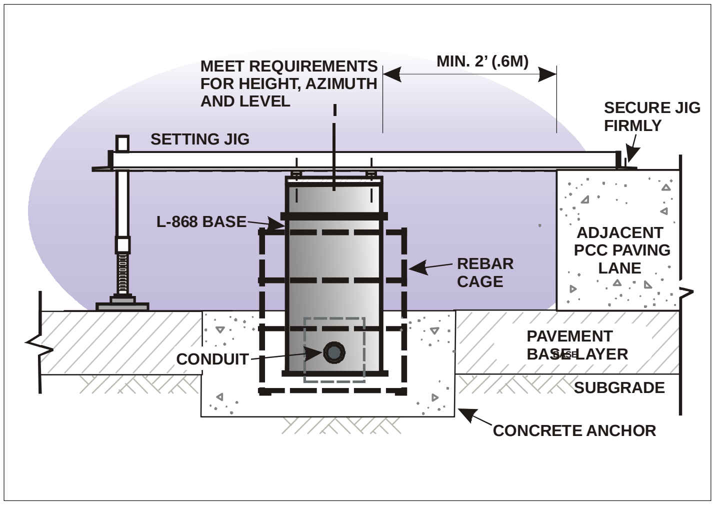
Before the concrete anchor is placed, the light bases is supported by using a jig. The jig is removed after the anchor concrete has cured. A proper jig allows for aiming, leveling, and adjusting the height of the light base and holding those settings during placement of the concrete anchor. **Figure 5.1** illustrates three basic conditions for setting up the jig-mounted light base.

Case 1 illustrates installation within a fill-in paving lane. The paved lane provides the height reference. Case 2 illustrates installation "in space" where there is no adjacent pavement that can be used as a reference for elevation control. Case 3 may apply if a light base must be omitted to accommodate paving operations (boxout).

Setting the height of a light base is the most common cause of a deficient installation. When the light base is set too high there is no satisfactory mitigation other than remove and replace. Therefore, checking the height before concrete paving is a critical step. Setting the light base height relative to an adjacent pavement is the best practice. There is more opportunity for error when the light base is set "in space."

5.4 PAVING OPERATIONS

A paving train typically includes spreader equipment, a strike-off to establish the concrete to a uniform elevation, vibrators to consolidate the concrete and an extrusion pan to shape the pavement. The elements of the train may be incorporated into one machine or the train may include individual machines. The diagram in **Figure 5.2** illustrates the basic elements of a slipform paver. The spreading auger in front is followed by a grout box, where consolidation occurs, and the finishing pan that includes the strike-off (tamper) and the extruder.



CASE 1:

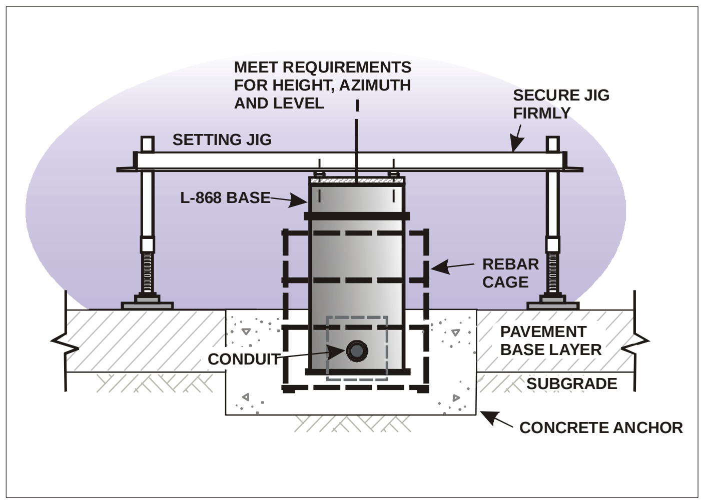
Adjacent PCC paving lane is available as a height reference.

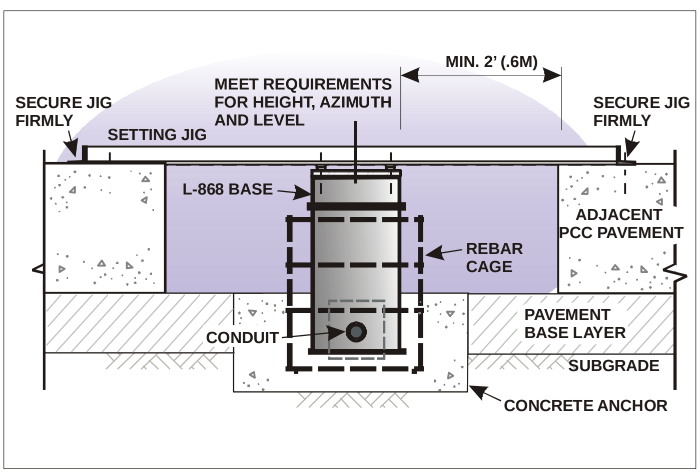
The adjacent PCC lane will establish line and grade.

CASE 2:

Adjacent pavement is not available for height reference. Base is "set in space".

Line and grade is more difficult to establish. Variation in PCC pavement height must be accommodated.





CASE 3:

PCC pavement is available for height reference.

Typical where core, cut, or partial slab removal is used to install base in existing pavement, or boxout method is used to install base in new PCC pavement

Figure 5.1 - Installing Light Bases for PCC Pavement.

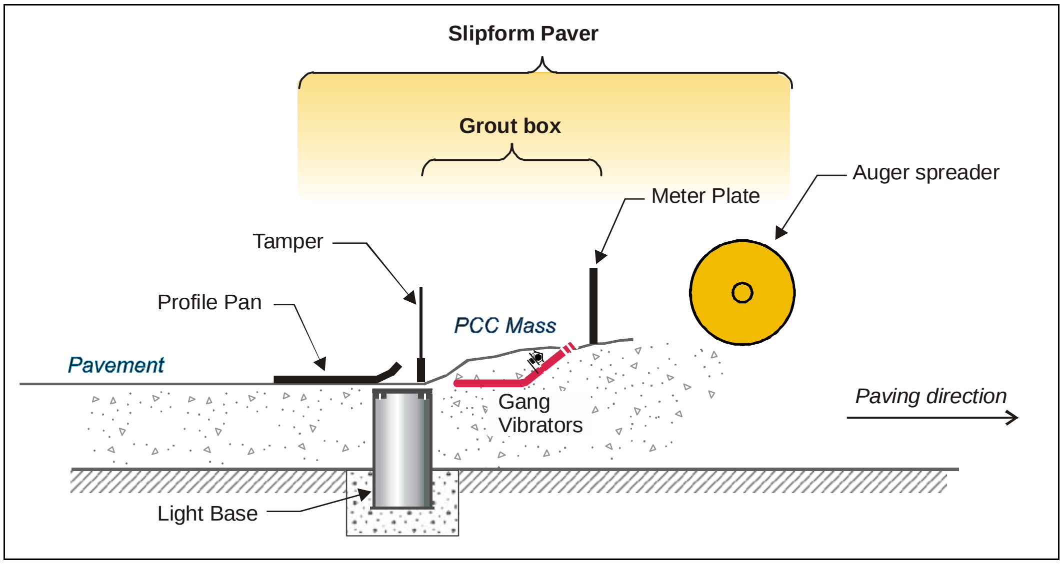


Figure 5.2 - Slipform Paver Functional Diagram.

The slip-form paver is usually set up so that the machine and components pass over the light base. This includes gang vibrators that have been constructed to uniformly consolidate concrete around the light base for the full pavement depth. Gang-mounted vibrators, located in the grout box of the paver, are normally positioned just below finish grade (for most pavers) and they pass over the light base without lifting. If the paving train is not set-up to allow clearance, the paving machine must be stopped, and the vibrators lifted. This practice usually results in a pavement rise or dip in front of or after the light base.

On some projects the uniformity of the concrete surface surrounding the light base has been seen to be distorted to the extent that height tolerances become difficult to establish and high spots block the light beam. The specific cause or causes of this problem are not known and the condition is only detected during inspection after paving is complete. The surface of the concrete around light base locations must be carefully inspected immediately after pavement finishing and during the time that the concrete is plastic.

There are paving machine set-ups that place the tips of vibrators deeper into the pavement section. These set-ups require that the vibrator be lifted in advance of the light base location. Lifting the vibrators early or lowering them late will impact the efficiency of the consolidation of the concrete. Lifting the vibrators too late could result in damage to the vibrators or the light base.

For smaller projects, or pavement sections too small to pave using slipform machines, lanes may be paved using motorized roller screeds preceded by spreader equipment. The roller screeds can have gang-mounted immersion vibrators or concrete is consolidated using hand operated vibrators.

Figure 5.3 illustrates paving operation using a roller screed. **Photo (a)** shows the spreading equipment used in advance of the roller screed. **Photo (b)** shows the front of the roller screed with vibrators inserted into the concrete mix. **Photo (c)** shows the vibrators lifted to pass over a light base within the mix. **Photo (d)** is a view of the back of the roller screed and shows the straightedge finishing that is required to maintain a uniform surface.

(a)

(b)

(c)

(d)

Figure 5.3 - Roller Screed Paving Operation.

5.5 SURFACE FINISHING

Two basic techniques are used for finishing the concrete surface and establishing an annular space around the light base. The two methods are: coring the hardened concrete down to the top of the light base; or, using the "cookie cutter" (or hoop tool) to remove concrete while it is sufficiently plastic. For each method, a "mud plate" is bolted to the light base before paving to preclude filling the base with concrete.

5.5.1 Core Method

The basic approach is:

- The concrete is allowed to harden.

- Coring equipment is used to remove concrete and expose the protective mud plate on top of the light base. The core is typically 13.5-inch to 14-inch (343-356mm) diameter for a 12-inch (305mm) diameter light base.

When using the core method, the quality of the pavement surface is not dependent upon hand finishing. However, coring is usually more expensive and coring operations could damage the light base when there is uncertainty with respect to the light base location.

5.5.2 "Cookie Cutter" Method

The basic approach is:

- After the paving machine passes over a light base a "cookie cutter" is pressed into the plastic concrete by a workman sitting on a bridge suspended over the pavement.

- After the concrete sets (sufficient rigid for the reservoir to retain its shape but plastic enough to allow surface finishing) the cookie cutter is removed, the concrete inside the cookie cutter impression **is removed and discarded**, and the surrounding surface is hand finished.

The cookie cutter method is the economical choice of the two methods. However, the durability of the surface could be compromised by the finisher.

(a)

(b)

Figure 5.4 – Poor Practice When Using "Cookie Cutter" Method

Pavement surface quality in the proximity of an in-pavement light is important. Poor hand-finishing usually results in corrective action or replacement of the concrete in the vicinity of the light base construction. It is for this reason that many airports require that the core method be used.

Figure 5.4 illustrates a poor practice commonly observed when the "cookie cutter" technique is used. The plastic concrete removed from the cutter perimeter is scattered around the light on top of pavement. The finisher works the "extra concrete" into the surface thereby causing a high spot around the light. The concrete removed from the cookie cutter should be discarded.

5.5.3 Considerations for Surface Finishing

1. Off-Center Core: There is no "off-center" tolerance standard for the annular space dimension above a light base that is formed by coring. Some contractors use a guide rod attached to the "mud plate". The rod provides a guide to the location of the light base for the person operating the core drill and thus reduces location error.

   It is recommended that the design engineer state a tolerance for the annular space dimension in the construction documents. For example, a core intended to provide a ¾-inch (19mm) annular space around the light base could be defined as not acceptable if the annular space measures less than ½-inch (13mm) on any side.

2. Surface Variation: Surface variation is an issue when hand-finishing as part of the "cookie cutter" method. Some paving projects have identified excessive surface variation in the immediate proximity of the installed light. This is usually detected during photometric testing of the installed lights after paving is complete. Paving criteria was not violated; however, unevenness of the pavement surface from one side of a light fixture to the other prevented compliance with lighting criteria. When using the "cookie cutter" the concrete surface should be checked for smoothness and corrections made while the concrete is still workable.

6. LIGHT BASE INSTALLATION IN EXISTING PAVEMENT

6.1 GENERAL

There are three techniques used by contractors to install light bases in existing concrete pavement. There are advantages and disadvantages, usually related to cost, for each technique. They include:

1. Install the light base by placing in a core hole in existing pavement. Conduit for electrical distribution is placed in a pavement surface saw kerf between light base locations. This technique is also used to replace a defective light base installed during construction. For the latter, connection to the electrical distribution is the existing conduit at the defective light base. A saw kerf is not required.

2. Core the concrete pavement where the light base is to be installed. Directionally bore under the existing concrete pavement at an elevation below the new light base. Install the electrical conduit to the bottom of the light base at each light location.

3. Remove the pavement full depth within a perimeter framed by the existing planned joints and the limits of work required to have room for the installation. This may involve a full panel or partial panel removal. The light base is installed and the pavement replaced. The conduit for electrical distribution may be placed in a surface saw kerf or installed under the existing pavement using directional boring.

6.2 CORE EXISTING PAVEMENT, CONDUIT IN PAVEMENT SURFACE SAW KERF

6.2.1 Installation Procedure Description

1. Establish light base locations by survey.

2. Extract, by coring, a 36 inch (0.9M) diameter concrete section in the existing pavement. The depth of the core must be sufficient to provide the vertical clearance required to install the light base. For a deep base, where the light base is longer than the pavement thickness, the core hole will extend through the concrete and into the subbase. For a shallow light base, the diameter and depth of the core must be sufficient to set the light base in a mortar bed.

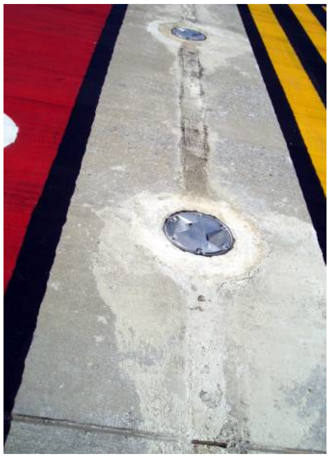
3. Diamond cut saw kerfs in the surface of the concrete pavement are sized to accommodate installation of the conduit used for housing the electrical wires that will connect the light base with the electrical system.

4. Position the light base using a setting jig. Complete connections to the conduit and check the base for elevation, level and azimuth. Place the deep base anchor or the set the mortar bed for shallow light bases.

5. Restore the pavement and finish using either the core or “cookie cutter” technique.

6.2.2 Kerf Construction

Figure 6.1 illustrates a completed installation of a light base with surface saw kerf.



(a)

(b)

Figure 6.1 – In-pavement Runway Guard Lights with Conduit in Saw Kerf.

The pavement performance with this type of installation is directly dependent on matching the cross section dimensions of the kerf to the expected performance specifications of the material used to backfill the kerf. A brittle backfill material will not perform as well as a material with some ductility and resilience to environmental change. Brittle materials will crack and debond from the sidewalls when ambient temperatures fluctuate between freezing and high summer temperatures. An elastic material will usually pull away from the kerf sidewall when the cross section dimension is excessive in width for the depth of material.

The two sections in **Figure 6.2** are representative of practices being used. Each method has a history of success in both cold and warm climates.

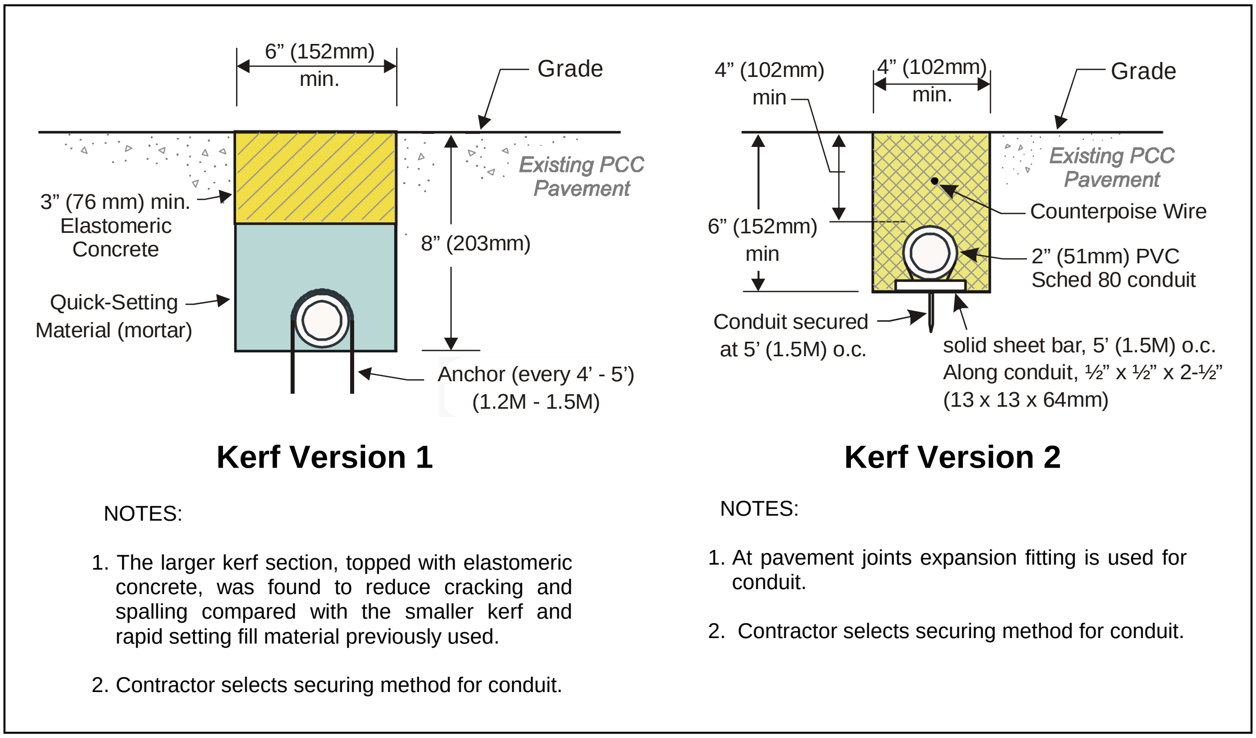
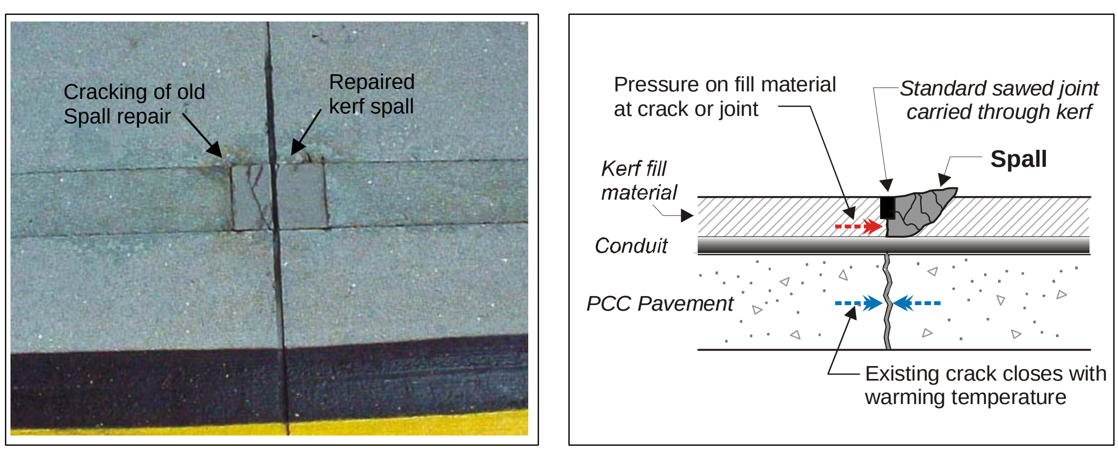


Figure 6.2 – Typical Conduit Installation in Pavement Kerf.

There must be careful attention to detail where a saw kerf crosses a pavement joint. The pavement joint must be maintained and encompass the entire cross section of the kerf. Brittle material in the kerf section will crack and spall when the joint closes as ambient temperature rises. This situation is illustrated in **Figure 6.3**.



(a) **(b)**

Figure 6.3 – Kerf Failure at Pavement Joint.

6.3 CORE EXISTING PAVEMENT, DIRECTIONAL BORE FOR CONDUIT

Directional boring is a common technique and used at several airports in Canada and in northern Europe. The installation technique cannot be used for a shallow light base installation.

1. Establish light base locations by survey.

2. Extract, by coring, a 36 inch (0.9M) diameter concrete section in the existing pavement. The depth of the core must be sufficient to provide the vertical clearance required to install the light base. The core hole will extend through the concrete and into the subbase.

3. Directional bore. The process requires that the boring begin or end at a light base on an angle and / or large radius. Where a directional bore begins at a light base, a pavement area significantly larger than that required to install the light base must be removed. The area removed is dependent upon the physical characteristics of the machine employed.

4. The light base is positioned with a setting jig. Connect the conduit into the bottom of the light base. Place the anchor and check the height, level and azimuth of the light base.

5. The core or cut in the pavement is restored, and the surface finished using the core or "cookie cutter" method.

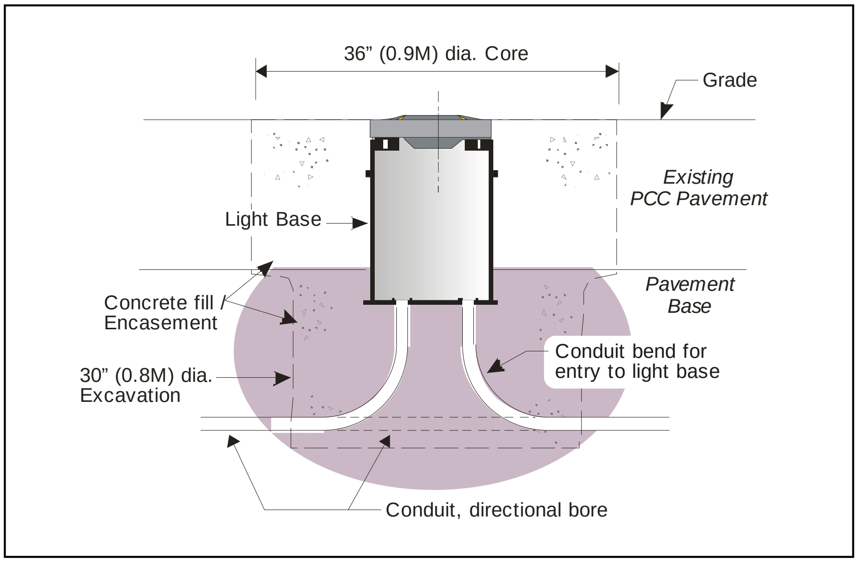


Figure 6.4 – Typical Light Base Installation Using Directional Bore.

Figure 6.5 is an illustration of the directional bore process. Photo **(a)** represents the pavement removal to accommodate the directional bore machine. The typical equipment used for directional bore is shown in Photo **(b)**. Photo **(c)** shows a straight through conduit with sweep elbows attached. Photo **(d)** shows the pavement surface after concrete is placed.

(a)

(b)

(c)

(d)

Figure 6.5 – Directional Bore Method for Installing Light Bases.

6.4 FULL DEPTH PAVEMENT REMOVAL FOR LIGHT BASE AND CONDUIT

6.4.1 Installation Procedure Description

1. Establish light base locations by survey.

2. Saw cut pavement full depth and remove debris.

   a. Full Panel Removal. When full panel removal is necessary, full depth saw cuts are required at the perimeter joints. A second full depth sawcut is made parallel to and 18-inches inside the perimeter joints. The interior sawcut is a relief cut that will allow pavement removal and minimize the potential for wedging the concrete against adjacent pavement. If relief cuts are not made, damage to the edges of the adjacent pavement is expected

.

b. Partial Panel Removal. Partial panel removal must incorporate a minimum of two intersecting planned joints as two of the perimeter sides of the removal. The maximum dimension on one side of the removal is less than or equal to one-half of the existing panel. The minimum dimension of a partial panel removal is 2-feet. Partial panel removal is not to be used to isolate removal within the interior of a planned panel, i.e., such as a trench cut. When removal of trench cut or isolated shapes within the panel interior are necessary, the perimeter is to be expanded to include at least two adjacent planned joints.

3. Excavate subbase for the light base anchor and connecting conduit.

4. Set light bases on jigs and connect conduit. Verify the location, height, level and azimuth of the light base. Place the concrete anchor.

5. Install load transfer devices, tie bars and, when specified, embedded steel.

- Dowel bars are smooth steel bars used as load transfer devices. The aircraft gear load must be transferred across joints of concrete pavement. Dowel bars are smooth for the purpose of allowing joint opening and closing during ambient temperature changes.
- Tie bars are deformed steel bars, usually Number 5, used to “tie” a partial panel replacement to the original pavement. By tying the repair section to the original panel, the function and load capacity of the original panel is restored.
- Dowel bars and tie bars are not interchangeable. Tie bars are not used to tie adjacent panels across planned joints.
- Embedded steel, usually WWF or small deformed bars at equal spacing to form a mat, is usually installed in odd shaped full panel replacement. The WWF, or bar mat, is installed in the upper one-third of the pavement leaving a minimum of 2-inches between steel and pavement joints. An odd shaped panel is one where the long side of the panel is more than 1.25 times longer than the short side. A panel that is a shape other than approximately square (e.g., triangle, octagon, parallelogram, etc.) is also odd shaped. Odd shaped slabs will crack. Embedded steel is used for crack control. It does not provide reinforcement for the panel.

a. Full Panel replacement. The full depth saw cut along the joint of an existing panel will cut through dowel bars. Therefore, load transfer must be reestablished along joints where dowel bars were previously used; and, load transfer must be established at a joint that previously functioned as a “contraction joint.” Dowel bars should be expected in existing pavement along a construction joint (usually the longitudinal joint for a runway or taxiway). Dowel bars may or may not be present along an existing pavement contraction joint (usually the transverse joint on a runway and taxiway). Holes for new dowel bars are drilled half way between existing dowel bar locations. Dowel bars are not installed closer than 12-inches to planned joint intersections and 12-inches must be maintained between dowel bar ends near joint intersections. The preference for dowel bar spacing is to the construction joint. Embedded steel is used when the panel is odd shaped.

b. Partial Panel replacement. The intent of a partial panel replacement is to restore the functions of the original panel. Load transfer is established at existing planned joints in the same manner as for full panel replacement. The difference is new concrete must be "tied" to the existing panel. Smooth dowel bars, placed using the spacing criterion for full panel replacement, are used for the load transfer at existing planned joints. Deformed steel bars are used to tie the concrete together at the interior joints. Isolation joints are not used. Embedded steel is used when the panel is odd shaped. **Figure 6.6** shows a typical partial panel replacement detail. **Figure 6.7** shows a typical partial panel replacement.

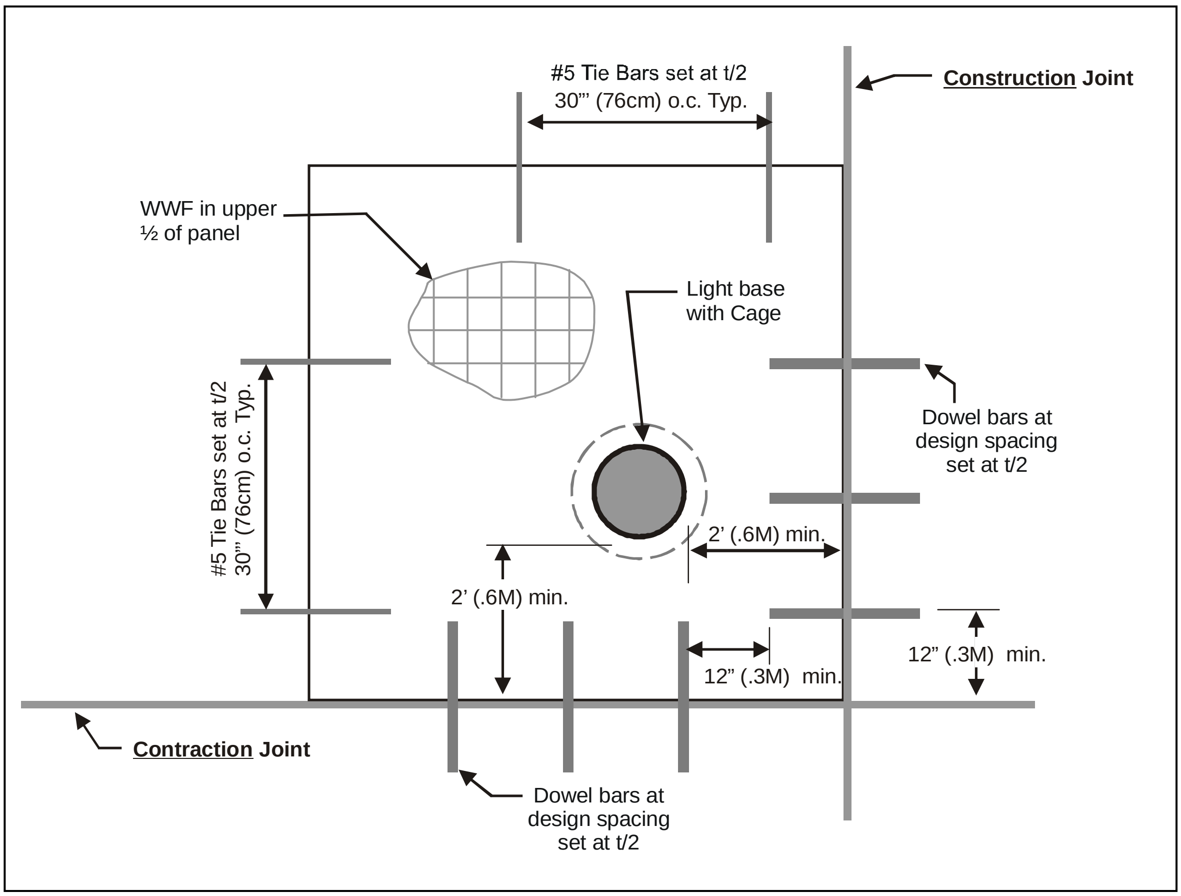


Figure 6.6 – Full Depth Partial Panel Replacement.

(a) (b)

Figure 6.7 - Installation of Light Base by Partial Slab Removal.

6. Place the concrete and finish. Finishing at light base locations is accomplished using either the core or "cookie cutter" method.

6.4.2 Light Installation When Individual Slabs Are Defective

When an in-pavement light base will be installed in existing panel that is cracked, or when the light base is installed in a panel adjacent to a cracked panel, the cracked panel should be replaced.

6.5 COMPARATIVE SUMMARY OF THE THREE TECHNIQUES

6.5.1 Core with Conduit Placed in Saw Kerf

When using shallow light bases this method is preferred. There are usually minimal quantities of concrete to remove so installation time is minimal. However, the saw kerf on the pavement surface presents numerous challenges to the people that must maintain them.

6.5.2 Core With Conduit Placed by Directional Bore

This method incorporates the advantages of the core method with the added advantage of not having a saw kerf to maintain. However, some materials in the pavement section make directional boring very difficult if not impossible. The cost of directional boring is higher than that of using the kerf.

6.5.3 Full Depth Pavement Removal

This method does require pavement closure for extended periods of time and the cost is considerably higher than the other two expedient methods. However, this method does provide for the best pavement performance after light installation provided that concrete replacement is accomplished correctly. The installation is consistent with new facility construction. Drainage provisions for the light base and conduit is easily incorporated.

6.6 MATERIAL SELECTION FOR RESTORATION OF EXISTING PAVEMENT

6.6.1 General

The replacement of concrete pavement must include using the proper materials. Part of the selection process is finding a material that will have strength within the time available between the pavement repair and the opening to traffic. This is the most critical item with respect to how the pavement performs. Finding materials to use is not the problem. Finding one that will not create high maintenance requirements is usually a challenge.

Most engineers and contractors select a repair material that achieves very rapid strength gain. The intent in that selection is to achieve a design opening strength in the shortest time. The most common mistake in that process is made determining what design strength is required. It is not necessary to have conventional design strength at all locations where pavement restoration is accomplished. The correct selection is based upon the type of pavement repair being affected, i.e., full depth or partial depth restoration, and where on the pavement, with respect to traffic load, is the repair located.

A full depth pavement repair, within the traffic path of main gear, requires that the design strength of the pavement repair is attained prior to opening to traffic. That strength should be determined based upon the actual aircraft that will be using that pavement. The design strength is not based upon the traditional aircraft mix. But, a partial depth pavement repair, i.e., kerf or light base annular space backfill, will only be subject to the compressive load of the tire pressure of the using aircraft. A partial depth repair does not require the design flexural strength to support traffic.

The proper repair material used for pavement restoration is portland cement concrete. The concrete should be one that is locally available and proportioned to minimize shrinkage. The problem with this material is the strength gain. However, adjustments to mixes can be made that will provide strength if the correct strength is specified.

Most in-pavement light base locations are within four feet of the pavement centerline. At this location, the traffic load will be from the nose gear. Therefore, the load is calculated based upon the nose wheel loading, or, 5% of the aircraft gross load or the nose gear tire pressure.

6.6.2 Cementitious Products and Materials

6.6.2.1 Portland Cement Concrete

The following are useful sources for information about proportioning and construction for portland cement concrete:

- IPRF-01-G-002-1, *Best Practices for Airport Portland Cement Concrete Pavement Construction (Rigid Airport Pavement).*
- Portland Cement Association Engineering Bulletin 001, *Design and Control of Concrete Mixtures,* Fourteenth Edition.

Type III cements and admixtures that incorporate calcium chloride should not be used as pavement repair materials. The potential for early cracking is very high.

6.6.2.2 Proprietary and Specialty Cementitious Materials

There are numerous cementitious products developed by industry that can be used to attain the "too strong – too fast" concretes that are necessary for repairs. The products are available from numerous sources and each usually has documentation for high early strength. Before using the materials, each should be evaluated for the following characteristics.

1. Good workability – can the material be mixed, placed and finished without exotic mechanical methods being employed?

2. Quick mixing time – Is the mixing time compatible with field applications?

3. Fast setting time – Is the set time compatible with the time required to place and finish? A material maybe compatible with small repairs but inappropriate with the volume of placement.

4. Rapid strength development – All materials gain strength rapidly. But, what are the shrinkage and bond capacities within the time necessary to gain that strength?

5. Low shrinkage – The hydration temperature necessary to attain the strength may result in excessive shrinkage.

6. Strong bonding capability – If the material does not bond to the concrete, then the repair is not effective. In many fast set materials, the shrinkage results in repair material pulling away from the parent material.

7. Durability – If it is not compatible with the environment, then it is not a repair.

8. Thermal compatibility with concrete – many proprietary materials have thermal expansion characteristics that are not compatible with portland cement concrete. An epoxy, as an example, will usually expand and contract more aggressively than portland cement concrete during the same change in ambient temperature. That difference in thermal response results in loss of bond and the repair fails.

All of the proprietary materials have common chemical make-ups that can be used to place the products into different groups. The following is a generic profile of each material.

Gypsum-based (calcium sulfate)

- Gain strength rapidly
- Working temperature between 32 ° and 110 °F
- Does not perform well when exposed to moisture and freeze-thaw

Magnesium phosphate and Magnesium ammonium phosphate

- Set time can be controlled
    - Normal set has a working time of about 10 minutes at temperatures below 81°F.
    - Retarded set is used when ambient temperature is above 85 °F.
    - Intermediate set has a setting time between the extremes of normal and retarded.
- Low permeability
- Good bonding to clean and dry surfaces
- Strength sensitive to concrete moisture content
- Does not work well with limestone aggregates

High-alumina

- Susceptible to a conversion of some of its calcium aluminate hydrate components
- Not recommended

Alumina powder

- Difficult to control in the field
- May reduce bond strength and patch abrasion resistance
- Use shrinkage-compensating cement (ASTM C 845, Type K)

Polymer concrete

- A combination of polymer resin, aggregate, and a set initiator
- Aggregate size from sand to 3/8 in. stone

Epoxy-resin mortars or epoxy concrete

- Available since 1950s
- Excellent adhesive properties and low permeability
- Properties vary widely for different epoxy mixtures
- Laboratory evaluation recommended prior to use
- Not thermally compatible with concrete
- Larger aggregate increases volume stability

Polyurethane concrete

- Two-part polyurethane resin mixed with aggregate

6.6.2.3 Sealants, Adhesives, Epoxies, and Similar Products

FAA Specification P-606 (FAA AC 150/5370-10) provides the requirements for the two-component adhesive used to seal the small annular space around the in-pavement light fixture. The small annular space is typically ¾-inch to 1-inch (19-25mm) wide and extending from the pavement surface to the top flange of the light base. For larger and deeper annular space around a light base P-606 does not have the rigidity to adequately support the light base and would therefore be impractical to use.

P-606 is different from the P-605 joint sealing filler material used with PCC pavements. The P-605 is not a substitute for P-606. P-606 specifies important material properties such as: tensile strength, elongation, expansion, dialectric, arc resistance, and adhesion to PCC, asphalt concrete and steel. Clean surfaces must be provided, and the material must be mixed and placed under conditions specified for proper performance.

7. CORRECTING THE IMPROPERLY INSTALLED LIGHT BASE

7.1 GENERAL

A deficient installation exists when a correction, allowed by the owner, is accomplished and the result in the finished work is not within the allowable tolerance(s) specified. The solution for a deficient installation is to remove and replace the light base.

Figure 7.1 - Fate of Deficient Light Base Installation.

Some corrections may be acceptable but each situation, for both new and retrofit projects, will have trade-offs. Those trade-offs must be examined and a determination made if expedient corrective methods, that do not compromise the visual acuity of the light, could be allowed.

Special rings may be available from the light base manufacturer for correcting azimuth and level deficiencies but the result may be below standard. Thicker spacer rings can be used to correct for a light base set too low. There are no good options for a light base set to high. The use of any of these types of correction options must be acceptable to the airport owner because they do impact light maintenance and repair budgets.

7.2 CORRECTIONS FOR HEIGHT, LEVEL, AZIMUTH

7.2.1 Height Correction

7.2.1.1 Light Base Low

A Light base installed too low can be corrected using a different size of flange ring or a different mix of spacer rings. To preserve integrity of the bolt torque, do not use more than 3 rings total. Rings are usually available in increment thicknesses of 1/16-inch (1.6mm). The typical flange ring (with pavement dam) will vary in thickness from ¼-inch to ¾-inch (6-19mm).

When a 2-piece base is used, a different size of top section may be available that would allow a height adjustment. This option must allow for lead time for parts.

When an adjustable-type base is approved for use, the adjustment upwards has a limit that will be stated by the manufacturer. An adjustable type base will not allow lowering subsequent to the paving.

7.2.1.2 Light Base High

A height correction technique used at some airports outside the U.S. is illustrated in **Figure 7.2**. The method is adopted from a repair technique for a Class IA light base where corrosion has weakened the top of the light base. Use of this Technique will result in a light base installation that will usually require high maintenance of the pavement or the light base.

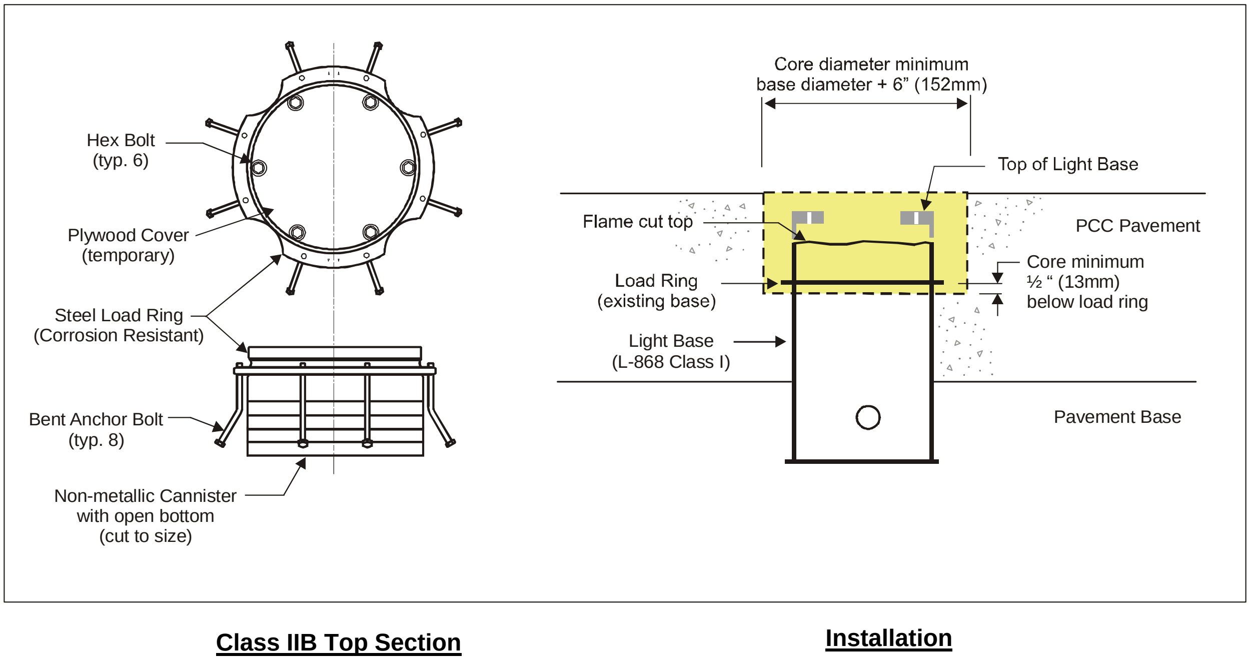


Figure 7.2 - Adjusting Height or Repairing Damaged Light Base.

The deficient light base is first cut down using a cutting torch. When using the torch, heat disbursement is a concern that must be considered. A core is made that extends slightly below the depth of the light base cut. A high strength plastic top section fitted with a corrosive resistant steel flange ring and concrete anchors is fastened on top of the light base. The concrete anchors tie the top flange to the pavement. The plastic sleeve is the form for the concrete backfill. The concrete will function as the portion of the light base that is removed.

If the height reduction technique is allowed, the following criteria applies:

- The pavement core should be at least 10 inches (254mm) below finish grade and a minimum of ½ inch (13mm) below the load ring of the existing light base.

- The existing light base must be flame cut and removed.

- Concrete back fill must be non-shrink. There must be provisions for bond to the core walls of existing pavement.

7.2.2 Level Correction

A beveled ring can be manufactured to compensate for level. Questions that must be answered are:

- Can the ring space available accommodate a bevel ring?
- Is the use of a beveled ring acceptable to the airport owner?

7.2.3 Azimuth Correction

An azimuth correction ring may be available. Use of an azimuth correction ring is preferred in lieu of remove and replace provided use of the ring will result in acceptable correction. The ring must be a minimum ¾-inch thick. This could require height adjustment of the light base.

7.2.4 Stripped Bolt Hole

Stripped threads could result in a bolt becoming debris on the pavement surface. Loose light fixtures or bolts are a hazard to aircraft. The stripped hole can be drilled and the defective hole tapped. There are also threaded inserts available in the marketplace useful for correcting this type of problem.

7.3 PAVEMENT DEFECTS

7.3.1 Uneven Pavement Surface at Light Fixture

It is not uncommon to find an uneven pavement surface at a light fixture when the “cookie cutter” technique for finishing pavement is used. The condition can exist with bidirectional lights where both sides of the fixture must meet photometric requirements. When the pavement surface is high, and the pavement interferes with the light beam, surface grinding in the immediate vicinity of the fixture lens may correct the problem. The grinding should be the minimum required. Excessive grinding may result in surface water collection in the vicinity of the light.

7.3.2 Pavement Cracking

Some radial shrinkage cracking should be expected in the immediate vicinity of in-pavement lights, as shown in **Figure 7.3**. These are normal. The cause of this type of cracking is attributed to side friction at the light base as the concrete hydrates. The steel cage around the light base will hold the crack tight. Repairs of this type of cracking are not required. The cracking is not detrimental to the pavement performance.

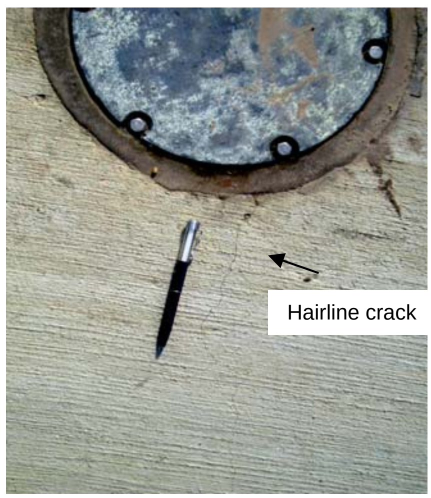


Figure 7.3 - Early Cracking in Pavement

7.3.3 Early Cracking With Retrofit Light Base Installation Close to Joint

Figure 7.4 illustrates some of the problems that can be expected when installing retrofit lighting. In this case, the concrete backfill of the core hole overlapped a planned joint. The retrofit construction should be at least two feet from a joint or installed using a boxout.

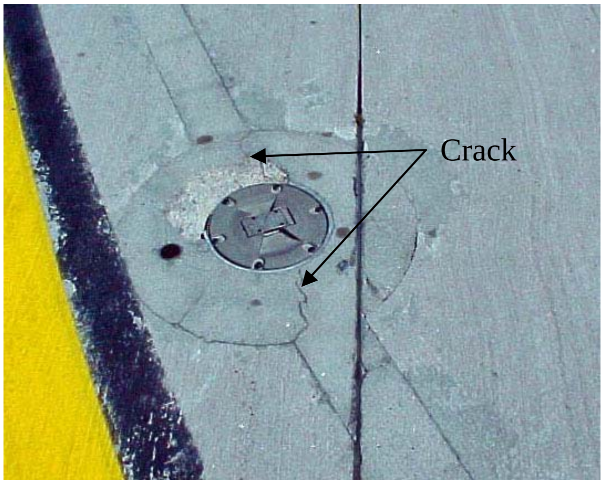


Figure 7.4 - Deficient Kerf and Light Location.

ADDITIONAL INFORMATION SOURCES AND REFERENCES

1. FAA AC 150/5320-6, "Airport Pavement Design and Evaluation," Federal Aviation Administration, Washington, DC.

2. FAA AC 150/5340-1, "Standards for Airport Markings," Federal Aviation Administration, Washington, DC.

3. FAA AC 150/5340-30B, "Design and Installation Details for Airport Visual Aids," Federal Aviation Administration, Washington, DC.

4. FAA AC 150/5340-42E, "Specification for Airport Light Bases, Transformer Housings, Junction Boxes, and Accessories," (draft version) Federal Aviation Administration, Washington, DC.

5. FAA AC 150/5345-53, "Airport Lighting Equipment Certification Program," Federal Aviation Administration, Washington, DC.

6. FAA AC 150/5370-10, "Standards for Specifying Construction of Airports," Federal Aviation Administration, Washington, DC.

7. Report IPRF-01-G-002-1, "Best Practices for Airport Portland Cement Concrete Pavement Construction (Rigid Airport Pavement)", April 2003

8. Report IPRF-01-G-002-02-1, "Stabilized and Drainable Base in Rigid Pavement Systems – Report of Findings," October 2005

9. ACPA TB016.01P, "Early Cracking of Concrete Pavement--Causes and Repairs," *Concrete Paving Technology*, ACPA, Skokie, Illinois.

10. ACPA TB017P, "Airfield Joints, Jointing Arrangements and Steel," *Concrete Paving Technology*, ACPA, Skokie, Illinois.

11. ACPA TB002.02P, "Full Depth Concrete Repair Manual" (Reprint from UFC 3-270-003, May 2003), ACPA, Skokie, Illinois.

12. ACPA JB003P, "Concrete Pavement Repair Manual" (Reprint from UFC 3-270-003, May 2003), ACPA, Skokie, Illinois.

13. Publication FHWA NHI-02-018, "Construction of Portland Cement Concrete Pavements," December 2000.

14. "The Design, Installation, and Maintenance of In-Pavement Lighting," by Arthur Schai, 1986.

15. Unified Facilities Criteria (UFC) 3-260-02, "Pavement Design for Airfields" (for military airfields).

APPENDIX A. LIGHT BASE, LAYOUT TOLERANCES AND CONDUIT INFORMATION

A.1 LIGHT BASE AND ACCESSORIES

An L-868 load-bearing light base and accessories (FAA AC 150/5345-42E) is used for mounting in-pavement light fixtures and to provide access for a cable connection. The deep-type base extends below the PCC pavement where conduit for the circuit cable connects. The deep-type light base will usually house the isolation transformer for the fixture and in some installations, a remote or local control unit to individually control and monitor a light fixture.

The shallow light base does not extend below the PCC pavement usually will not house the isolation transformer. Secondary cables are routed into the base for connection of the light fixture. Connecting conduit is normally installed in a pavement saw kerf.

1. FAA Size Designation. Size B (12-inch (305mm) diameter) is most common. Size C (15-inch (381mm) diameter) is used with older, wide-diameter, runway edge light fixtures. A smaller diameter base (Size A, 8-inch (203mm) diameter) can be used with smaller light fixtures when the isolation transformer is located remotely (only secondary cables enter the smaller base), but this is not common in the domestic market.

2. Height. Bases can be manufactured to any specified height but the typical deep base is 24 inches (0.6M). Twenty four inches is common also for the multiple section light base. Shallow bases can from 4 inches (102mm) to 16 inches (406mm) tall. The shallow base is usually used in retrofit projects. Taller bases are also available, e.g. 30 inches (762mm), where conditions warrant going deeper.

   Additional height can be obtained by using extensions. Height-adjustable load bearing light bases do not appear on the FAA list of certified airport lighting equipment.

3. Class. FAA AC 150/5345-42E specifies Class as follows:

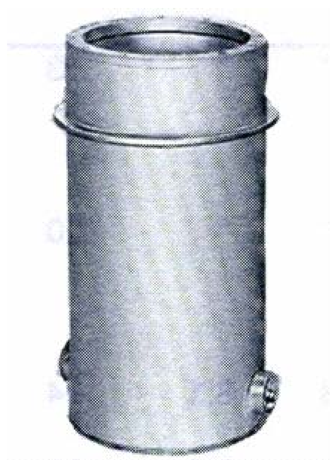
   Class IA – Bases and extensions, fabricated from metal, in exact conformance with dimensions and requirements necessary for standardization between parts. This includes the most common type -- galvanized steel.

   Class IB – Bases and extensions fabricated from metal in exact conformance with dimensions and requirements necessary for standardization between parts and resistant to corrosion due to deicing fluids containing potassium acetate. Stainless steel is an example.

Class IIA – Bases and extensions fabricated from non-metallic materials in exact conformance with dimensions and requirements necessary for standardization between parts.

Class IIB – Bases and extensions fabricated from non-metallic materials in exact conformance with dimensions and requirements necessary for standardization between parts are subject to corrosion due to deicing fluids containing potassium acetate.

The most common L-868 light base is the Class IA fabricated from steel and galvanized to a specified standard. Other materials such as stainless steel or non-metallic materials are available and have been used where corrosive conditions present a problem for galvanized steel. Powder paint, epoxy bituminous coatings applied to the Class IA light base (by the manufacturer), have also been used when corrosive conditions exist. The current FAA-certified products list should be consulted (FAA AC 150/5345-53).



L-868 Light Base, Class IA (galvanized steel)

Figure A.1 - FAA L-868 Light Base, Class IA.

The Class I steel light base may be obtained as a 1-piece or multiple-piece base, i.e., 2-piece (top and bottom sections), or 3-piece (top, middle, and bottom sections). **Figure A.1** shows a 1-piece Class I L-868 light base. The Class IA base as 1-piece is normally used for installation in concrete pavement. The two-piece light base is used where a 1-piece base would interfere with a paving operation.

A three-piece base is used where a bottom section of an existing multi-section base is reused and the upper portion reconstructed with the pavement. This is common with bituminous pavements.

Several options are available for the Class I L-868 light base, as well as accessories for completing the installation in concrete pavement and adjust or correcting the installation to meet tolerance requirements. Illustrations of Class IB and IIB light bases are at **Figure A.2**. **Figure A.3** shows the elements of an installed light base for a 2-piece Class IA or IB. Indicated options include conduit entry, drain pipe and ground lugs.

L-868 Light Base, Class IB
(stainless steel)

L-868 Light Base,
Class IIB (plastic)

Figure A.2 - Examples of FAA L-868 Light Base Class IB and IIB.

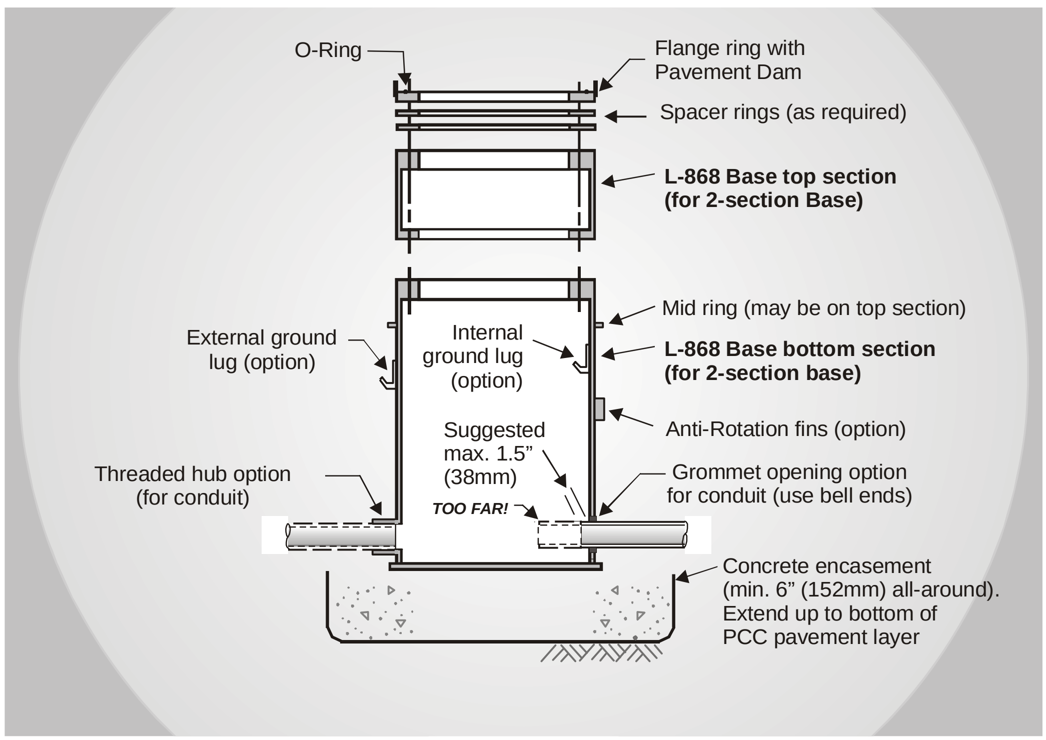


Figure A.3 - Elements of L-868 Light Base, Class IA or IB.

The tolerance information for light base locations is provided in FAA AC 150/5340-30. **Table A.1** provides a summary of light location tolerances contained in the Advisory Circular. The reader should refer to the current edition of the AC, including changes that may include revisions.

Table A.1 - Light Location Tolerances Allowed by FAA AC 150/5340-30.

LIGHTING SYSTEM	ALLOWABLE TOLERANCES
Runway Edge Lights	• 2 ft. (0.6M) to 10 ft. (3M) from defined R/W edge. • Lateral from line of edge lights: None[1]. Recommend ± 2 in. (51mm) • Longitudinal spacing: None[1]. Recommend ± 2 ft. (0.6M)
Runway Centerline Lights	• 2 ft. (0.6M) from R/W centerline (clear between centerline and edge of light base). • Lateral from line of lights: ± 1 in. (25mm) • Longitudinal spacing: ± 2 ft. (0.6M) • RW threshold to first light: 75 ft. (22.9M) , +12.5 ft. (3.8M), -25 ft. (7.6M)
Touchdown Zone Lights	• First TDZ row from R/W threshold: 100 ft. (30.5M), ± 25 ft. (7.6M) • TDZ row spacing: 100 ft. (30.5M), ± 2 ft. (0.6M) • RW centerline to inboard light in light bar: 36 ft. (11M), ± 6 in. (152mm) • Between lights in 3-light bar: 5 ft. (1.5M), ± ¼ in. (6mm)
Taxiway Edge Lights *(these usually are not in PCC pavement)*	• 2 ft. (0.6M) to 10 ft. (3M) from defined T/W edge. • Lateral from line of lights: None[1]. Recommend ± 2 in. (51mm) • Longitudinal spacing[2] (within equally spaced segments): ± 10%, 2 ft. (0.6M)
Taxiway Centerline Lights	• Up to 2 ft. (0.6M) from T/W centerline (clear between centerline and light base). • Lateral from line of lights: None[1]. Recommend ± ½ in. (13mm) • Longitudinal spacing: ± 10%; for 12.5 ft. (3.8M) spacing, ± 2 ft. (0.6M)
In-Pavement Runway Guard Lights	• Hold marking to center of light: 2 ft. (0.6M), ± 2 in. (51mm) • Lateral from transverse line of lights: ± 2 in. (51mm) • Lateral spacing, Method 1 (preferred): 9 ft. 8 in. (2.9M), ± 1 ft. (0.3M) • Lateral spacing, Method 2: Uniformly as possible, min. 8 ft. (2.4M), max. 13 ft. (4M) between lights. • Lateral spacing between lights: ± 2 in. (51mm) (see AC for spacing alternatives)

LIGHTING SYSTEM	ALLOWABLE TOLERANCES
In-Pavement Stop Bar Lights	• Hold marking to center of light: 2 ft. (0.6M), ± 2 in. (51mm) • Lateral from transverse line of lights: ± 2 in. (51mm) • Lateral spacing, Method 1 (preferred): 9 ft. 8 in. (2.9M), ± 1 ft. (0.3M) • Lateral spacing, Method 2: Uniformly as possible, min. 8 ft. (2.4M), max. 13 ft. (4M) between lights. • Lateral spacing between lights: ± 2 in. (51mm) (see AC for spacing alternatives).
Taxiway Clearance Bar Lights	• Center Light: In line with T/W centerline lights, and min. 2 ft. (0.6M) from nearest T/W centerline lights. • Outboard Light spacing (transverse to T/W centerline: 5 ft. (1.5M) ± 1 ft. (0.3M) • Lateral to transverse line of lights: ± 2 in. (51mm) • At Low Visibility Hold Point: 2 ft. (0.6M) ± 2 in. (51mm) from TW/TW hold marking.
[1] "None" means that allowable tolerance is not provided in FAA AC 150/5340-30, and the engineer should apply judgment to define tolerance for the contractor. [2] Longitudinal tolerances are applied to individual lights (or row of lights for TDZ lights), and are not intended to displace the next light (or row of TDZ lights) in a system from their normal location.	

A.2 CONDUIT/DUCT

Conduit under pavement is typically 2 inches (51mm) although larger diameter conduit is used to connect a Size B light base (3 inches (76mm) for hub connections and 4 inches (102mm) for grommet connections. Conduit placed in saw kerfs range from ¾ through 2 inches (19-51mm) depending on cable.

The conduit material is usually PVC Schedule 40 pipe conforming to Federal Specification W-C-1094 and UL 651. A heavy duty PVC Schedule 80 can be used but it is usually not required when conduit is concrete encased. Rigid galvanized steel conduit, conforming to UL Standards 6, 514 and 1242, is also used and is often found in older installations. Rigid steel conduit is more expensive and in some cases be subject to corrosion. Some airports prefer rigid steel conduit where conduit is installed in shallow saw kerfs.

Flexible galvanized liquid tight conduit, UL approved, is sometimes used for the final connection to a light base. This allows correction for slight misalignments, particularly where hubs are used for conduit entry to the light base.

Conduit installed using directional drilling under the pavement section may be rigid galvanized steel or high strength plastic pipe such as SD-11. The plastic conduit is lower cost and easier to pull, and requires fewer connections or couplings than rigid steel conduit.

Fittings and couplings must be compatible with the type of conduit installed. This includes couplings, elbows, expansion joints, and other components from the manufacturer of the conduit or approved by the manufacturer for the intended function. Special items are also available such as split duct, is used where existing direct buried cable needs to be protected. Split duct is available as PVC Schedule 40, and should be concrete encased when installed.

Conduit enters the light base using a conduit hub or grommet hole. It is always better to order the light bases with hubs or grommet openings instead of having to field cut openings after a light base is installed, although sometimes field cutting is necessary, such as when connecting new conduit to existing light base. Whether to use hubs or grommet openings is a preference, and opinions vary. The merits of each are summarized as follows:

Conduit Hubs. With hubs, the conduit will not penetrate the base interior. Hubs, however, are fixed and may require a flexible connection to establish final alignment with the base and conduit. Typically liquid-tight metallic tubing is used through the concrete encasement portion to provide final alignment and connection. Care must be used during concrete encasement of the base so as not to distort the section of the flexible tubing, which could inhibit pulling cable.

Grommet Holes. With grommet holes, conduit is pushed into the light base. The alignment of the base and conduit does not have to be perfect, since the neoprene grommet will allow some adjustment from normal to the base. However, a common mistake is to push the conduit too far into the light base, resulting in more difficulty pulling cable and organizing components inside the light base. Conduit installed too deeply into the light base is difficult to correct. Bell fittings should be used inside the base to lessen the chance for cable damage.

1. Rings. Rings can be used for height adjustment or azimuth and level correction.

2. Selection of Light Base. The type of light base used is dependent upon the type of installation, paving techniques and ambient conditions. For corrosion resistance, the available options include powder paint coating on a traditional galvanized steel base or stainless steel. With powder paint coating it customary to include stainless steel threaded inserts at the bolt holes. The non-metal (high strength plastic) load-bearing base has a bottom section that is installed and cut off to proper height. A top section is set on using anchors and a metal load-bearing ring treated for corrosion resistance.

3. Conduit Connection to Light Base. Conduit connects to the light base either high, low or through the bottom. For a new pavement that incorporates a deep base the conduit is typically concrete-encased polyvinyl chloride (PVC) installed in the pavement subbase. On retrofit situations the conduit is normally installed in a pavement saw kerf entering high on the light base.

Conduit attaches to the light base using a conduit hub or grommet hole. It is always better to order the light bases with provisions for conduit rather than field cutting openings after a light base is installed. However, some situations require field cutting.

Conduit installed below the pavement is less likely to be disturbed by movement of the pavement structure and drain water to the light base. For retrofit installation placing conduit under the pavement requires removing the pavement full depth which results in increased cost. Directional boring the conduit under the pavement may be an option.

Conduit installed in a saw kerf on the pavement surface is directly subject to changes in ambient conditions. Changes in the surface temperatures results in differential movement of pavement and kerf backfill. Seasonal changes in temperature result in pavement movement at joints. Joints at saw kerfs are a maintenance problem. Conduits at near surface offer a greater potential for water draining through conduits and into the light base.

4. Setting Jig. A jig is used to hold the base level, in proper alignment, and at the correct height for placing the concrete anchor. Jigs are available from the base manufacturer or custom built by experienced contractors. An acceptable jig must:

- Securely hold the light base and reinforcement in place until the concrete encasement is placed and hardened.
- Allow adjustment of the base before placing the anchor.
- Allow for aiming the light base (orientation of bolt holes will determine fixture aiming).

Figure A.4 illustrates the use of a jig in preparation for placing the concrete anchor.

Figure A.4 - Setting the Light Base Using a Jig.

A.3 RINGS AVAILABLE FOR THE L-868 LIGHT BASE

Several types of rings are available. **Table A.2** lists rings and their function with respect to their use with L-868 light base. The reader is advised to consult the current FAA certified products list on the use of rings for special applications (see FAA AC 150/5345-53).

Table A.2 - Rings for L-868 Light Bases.

Type	Function
Flange Ring, with O-ring and pavement dam	Recommended at the top for seating the light fixture and preventing the sealant in the annular space around the top of the base from bonding to the fixture, thereby inhibiting fixture removal for maintenance. Rings are available from ¼-inch (6mm) to ¾-inch (19mm) thick, with the pavement dam extending approximately 5/8 inches (16mm) high up on the light fixture edge (fixture edge is typically ¾-inch (19mm) high). Pavement dams 1-1/8 inches (29mm) high are used with fixtures that are 1-1/4 inches (32mm) thick. The pavement dam is not a precision component in the manufacture of the ring, and is not recommended to be used as a reference for leveling when installing a light base. Some installers mount the light base with the flange ring on the setting jig so that the pavement dam is in contact with the jig; leveling the base by leveling the jig is therefore dependent on the precision of the pavement dam.
Spacer Ring	Used to achieve proper fixture height for the standard Class 1 base, these are available in various thicknesses, from as small as 1/16-inch (1.6mm). Spacer rings are not required with adjustable (screw) type bases.
Azimuth Ring	Used to correct aiming if a base is incorrectly oriented relative to centerline or proper aiming direction.
Bevel Ring	Used to correct leveling on a faulty base installation. Sufficient space is required above the light base to accommodate the bevel ring. The smallest thickness is ¼ inch (6mm), and the maximum difference in thickness is ½ inch (13mm) in order to maintain bolt hole alignments.
Snow Plow Ring	Provides extra protection for the light fixture from snow plow blades, and can replace the flange ring with pavement dam.
Adaptor Ring	Used for adapting a fixture to a light base with a different bolt circle diameter.
Multi-hole Ring	These can make it easier to correct defective threads in bolt holes. With 24 bolt holes, the ring can be turned to provide 6 good holes for securing the light fixture.

APPENDIX B. INSTALLATION AND IMPACT ON LIGHT PHOTOMETRICS

Light photometrics are the characteristics of the light output from a fixture. The quality of the light output is a function of the lamp, lens design and filter (determined by the fixture manufacturer), the height and orientation of the fixture relative to the pavement surface, and cleanliness of the lens filter. Electrical performance of the lighting circuit can also be a factor.

There are different photometric requirements for different lights. A runway centerline light has different requirements than a touchdown zone light and each which will be different from a runway edge light, and so on. The requirements are specified by isocandela curves. They define the intensity (candelas) in a main beam area and a secondary larger beam area relative to proper aiming of the fixture. An example is shown by **Figure B.1**. This light has a requirement for minimum average 5,000 candelas in the main beam area (yellow portion), and 10% of that value for the outer "10%" ellipse. The portion under the horizon is ignored.

Runway light fixtures curves are concentric ellipses. Taxiway lights have beam coverage represented by rectangles. The isocandela curve shown in **Figure B.1** is for an L-850B touchdown zone light, indicating a "toe-in" of 4 degrees. The toe-in is achieved either by the fixture characteristics or the orientation of the light base as installed. It is important that the engineer indicates to the contractor how the toe-in will be achieved.

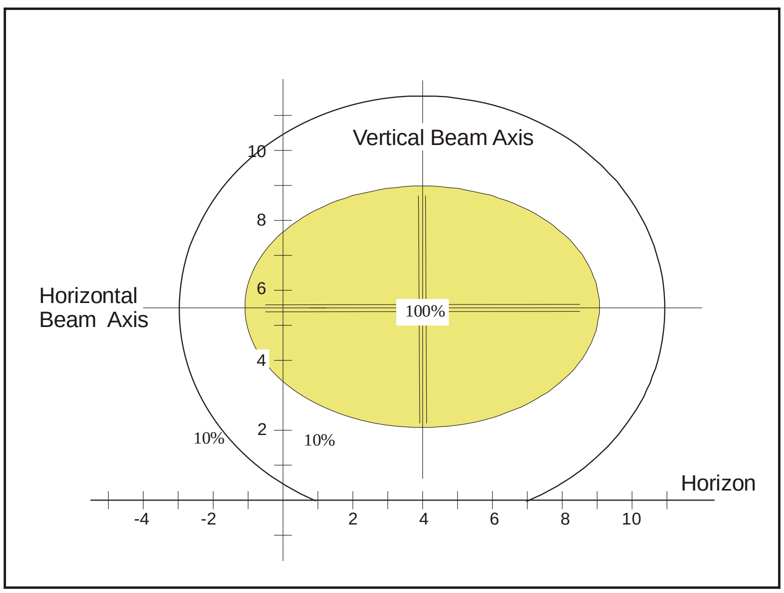


Figure B.1 - Light Fixture Photometric Curve.

Tolerances for the installation are important for achieving proper photometric performance. Key parameters are: (1) fixture height relative to pavement surface, (2) levelness of the fixture (relative to horizon, not pavement slope), and (3) azimuth, or aiming. Understanding these tolerances and field checking for compliance are critical for proper installation.

1. Fixture height. The edge of an in-pavement fixture is required to be even with the adjacent pavement, measured on the low side of a sloping surface, +0 inch -1/16 inch (+0mm -1.6mm). A fixture set too low will have too much of the beam blocked by the pavement. If too high, it is subject to damage from snow plows (in colder areas) or may affect "rideability" of the surface.

   A frequent error is to measure height from the top of the pavement dam on the flange ring instead of the edge of the light fixture. The pavement dam is intended to be about 1/8 inch (3mm) lower than the fixture edge but is not manufactured with precision (height may vary more than 1/16 inch (1.6mm) from one side to the other side of the ring). Establishing height using the pavement dam may therefore result in the fixture being high relative to the pavement.

2. Level. The fixture is required to be level (with the horizon) but tolerance is not provided by the FAA AC. A tolerance of ± ½ degree is recommended. A fixture that is out of level can impact the visual signal to pilots, whether by tilting the main beam axis as seen by the pilot, or lowering the vertical spread of the beam by tilting the fixture forward in the beam direction. Tilting the fixture forward in the beam direction may also result in the pavement partially blocking the beam.

3. Azimuth: The azimuth, or aim, of the light is particularly important for runway lighting where aircraft are at speed and need to acquire the lights at some distance (compared with taxiway lighting). The standard tolerance is ± ½ degree. Note that not all lights are aimed in the direction of traffic. Touchdown zone lights and runway edge lights are "toed-in" 4 degrees, and unidirectional taxiway centerline lights are aimed "into the curve" towards the 4th fixture ahead. The toe-in must be accommodated by the light fixture optics, or by the orientation of the light base when installed.

APPENDIX C. CORROSIVE CONDITIONS

C.1 GENERAL

Corrosive environments can have a deteriorating impact on certain materials, including the galvanized steel on the commonly used Class IA light base. Local conditions (soil type, proximity to shorelines, etc.), deicers commonly used on pavements, or other causes may contribute to the corrosive environment. Corrosion on light bases can be a maintenance problem for an airport and may require repair or replacement of the light base. Repair or replacement of the light base will typically require repair of the surrounding pavement or replacement of a portion of the pavement, depending on the severity of the corrosion and the selected repair procedure.

Deicing materials in use today for pavements, such as potassium acetate, sodium acetate, potassium formate, have significant benefit over earlier deicing materials but are corrosive to galvanized steel, resulting in a higher incidence of corrosion on light bases at airports. The extent of the problem will be different for each airport.

Certain lighting systems may be more susceptible to corrosion from deicing fluids than others. For example, deicing fluid run-off may impact edge lights more than centerline lights which are typically positioned on the pavement crown, or a lighting system with provisions for drainage may have less exposure to corrosive fluids.

> The extent that corrosion is a problem for galvanized light bases has not been quantified, but will certainly vary from airport to airport. It may also vary from location to location within an airport.

C.2 SELECTION OF LIGHT BASE MATERIAL

The use of non-corrosive materials for light bases has increased in recent years with the availability of approved alternatives to the galvanized steel light base and the desire of airports to reduce or eliminate this type of problem. Light bases fabricated of materials other than galvanized steel (e.g., stainless steel) or with special coatings over the galvanized steel light base (e.g., epoxy coating or black powder paint) have been installed at several airports to address the issue of early corrosion, but these special materials come at a price.

> RECOMMENDATION: The extent that corrosion is an issue for an airport should be a factor in determining if, and the extent to which, more expensive non-corrosive light bases (Type IB or IIB) should be selected.

It may be more economical for an airport with low incidence of corrosion to select Class IA galvanized steel light bases instead of the more costly Class IB or IIB light base for a project.

Factors for selection should include the risk of occurrence as well as impact on cost and airport operations if additional maintenance or early replacement is anticipated.

C.3 DRAINAGE

Good drainage of the light base and conduit system can minimize the time that in-pavement lighting components are exposed to corrosive conditions from sources such as deicing fluids. The extent that drainage provisions can reduce the potential for corrosion on light bases is unknown, but it is reasonable to expect that any measure that limits the exposure of materials such as galvanized steel to corrosive conditions will be helpful.

While provisions for drainage of light base and conduit systems may be included in the design for a variety of reasons, for some airports it may be a cost effective alternative to installing more expensive light bases.

NOTE: The benefit of providing drainage for light base/conduit systems as an alternative to selecting more costly Class IB or IIB light bases in order to address potential for corrosive damage is difficult to determine. Drainage provisions may be installed for other reasons, depending on an airport's experience and needs.