Evaluation of In-Pavement Light Fixture Designs and Performance

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By: Joseph Breen

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Background

- **In-Pavement Light Fixture Assemblies Utilize a Circle of Six (6) Bolts and Two-Part Locking Washers to Secure The Light Fixtures to the Light Bases or Light Base Extensions.**
- **Incidents Have Occurred at Certain Airports Where In-Pavement Light Fixture Bolted Connections Have Failed Resulting in Light Fixtures Completely Separating from the Light Bases or Light Base Extensions.**
- **Possible Root Causes of the Bolted Connection Failures Include Inadequate Bolt Clamping Forces for Resisting Impact Forces Generated by Modern Commercial Aircraft and Improper Installation/Maintenance of Bolted Connections.**

Light Assembly Bolt Clamping Force Requirements and Limitations

- **FAA Criteria Currently Requires Combined Clamping Force of Bolt Circles be Capable of Resisting a 3,000 Pound Horizontal Shear Force, Simulating a Braking Aircraft Tire.**
- **Bolt Clamping Forces Must Also Be Adequate to Prevent Significant Fluctuation in Bolt Tension When Subjected to Aircraft Tire Loading.**
- **Significant Fluctuation in Bolt Tension Can Result in Fatigue Failure of the Bolts.**

Light Assembly Bolt Clamping Force Requirements and Limitations (Continued)

- **Light Fixtures Use Six (6) 3/8 Inch Diameter Bolts (Stainless or Coated Carbon Steel) Typically Installed into Threaded Holes in the Light Bases or Light Base Extensions, with Two-Part Lock Washers, and a Maximum of 3 Spacer Rings.**
- **Alternatively, Adapter Rings are Installed Between the Light Fixtures and Light Bases or Light Base Extensions.**
- **Clamping Forces are Limited Based on Strength of Overall Light Fixture Assemblies including Light Fixtures, Adapter Rings (If Applicable), Internal Threads in Light Base or Base Extension Flanges, Spacer Rings, Bolts, and Two-Part Lock Washers.**

Bolt Torque-Tension Relationships

- **Bolt are Installed Utilizing Calibrated Torque Wrenches to Achieve Required Clamping Forces.**
- **Bolt Torque and Axial Clamping Force (Bolt Tension) are Related Mathematically by the Following Formula:**

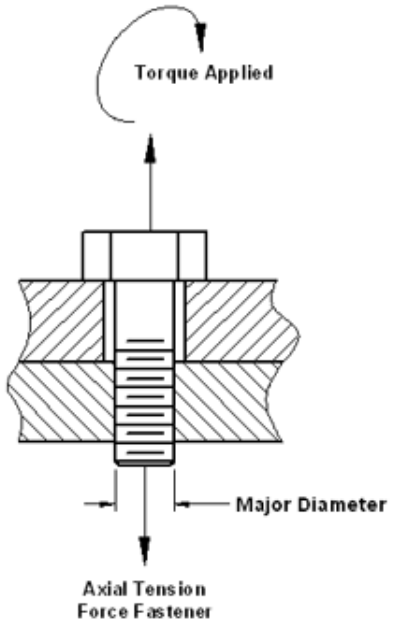
T = K x D x Fp

Where: T = Bolt Torque in Inch-Pounds

K = Friction Coefficient

D = Nominal Bolt Diameter (Inches)

Fp = Axial Clamping Force



Torque-Tension Relationships of Bolted Connections

- **Bolt and Lubricant Manufacturers Publish Friction Coefficients (K Values) as Guidance for Determining Required Installation Torques for General Bolted Connections.**
- **These Friction Coefficients are Derived from Test Procedures Conducted with Through Bolted Connections Using Carbon or Alloy Steel Bolts, Nuts, and Hardened Steel Washers to Develop Torque-Tension Properties.**
- **Light Fixture Assemblies Currently Utilize Tapped Hole Connections Consisting of Bolts made of 18-8 Stainless Steel and Coated SAE J429 Grade 2 Carbon Steel, and Light Base Flanges made of ASTM A36 Steel and Stainless Steel.**
- **Using Published Friction Coefficients (K Values) for Selecting Installation Torques Can Result in Unintended Bolt Tensions.**

Torque-Tension Relationships of Bolted Connections (Continued)

- **Developing Torque-Tension Relationships for Various Bolt and Tapped Hole Combinations for Light Fixture Installations will be Accomplished Utilizing a Skidmore-Wilhelm Bolt Tension Calibrator.**
- **Testing of Each Combination of Bolt and Light Base or Light Base Extension with Lubricants Applied to Uncoated Bolts Will Be Accomplished to Determine Accurate Torque-Tension Relationship and Resulting Friction Factor (K).**

In-Pavement Light Fixture Assembly Materials

- **Bolts are either SAE J429 Grade 2 (Coated) or Stainless Steel Alloy 18-8. Testing will also Include SAE J429 Grade 5 (Coated) and ASTM F593P Grade 410 (Black Oxide Coated) Bolts.**
- **Two Piece Lock Washers are Required by the FAA to be Stainless Steel.**
- **Light Bases and Light Base Extensions are made of Galvanized Mild Carbon Steel (ASTM A36) and Stainless Steel (Type 304).**
- **Light Fixture Housings are Made of Aluminum Alloys Specified by the Manufacturers that Satisfy Requirements in FAA AC 150/5345-46.**
- **Adapter Rings, Utilized in Some Designs for Connecting Light Fixture Housings with Light Bases or Light Base Extensions, are made of Ductile Cast Iron.**

Strategy for Evaluation

- **Project Phase I: Laboratory Testing**

  - Determine Strength Limitations of Light Fixture Assemblies for Resisting Increased Bolt Clamping Forces.

  - Evaluate Performance of Light Fixture Assemblies using Bolts Prescribed in FAA EB 83 and Bolts Having Greater Strengths and Larger Diameters.

  - Evaluate Light Fixtures over a Range of Commercially Available Strengths.

  - Evaluate Corrosive Properties of Coated Carbon Steel Bolts and Black Oxide Coated Stainless Steel Bolts.

Strategy for Evaluation (Continued)

- **Project Phase II: Field Testing**

- Instrument and Install In-Pavement Light Fixtures in the FAA National Airport Pavement Test Facility (NAPTF) and on ACY Runway and/or Taxiway.

- Evaluate Performance of Installed Light Fixture Assemblies under Controlled Aircraft Wheel Loading/Tire Pressure Conditions.

- Controlled Wheel Loading with Test Vehicle in the FAA NAPTF and Instrumented FAA Aircraft (B727 and Smaller Size Aircraft) at ACY.

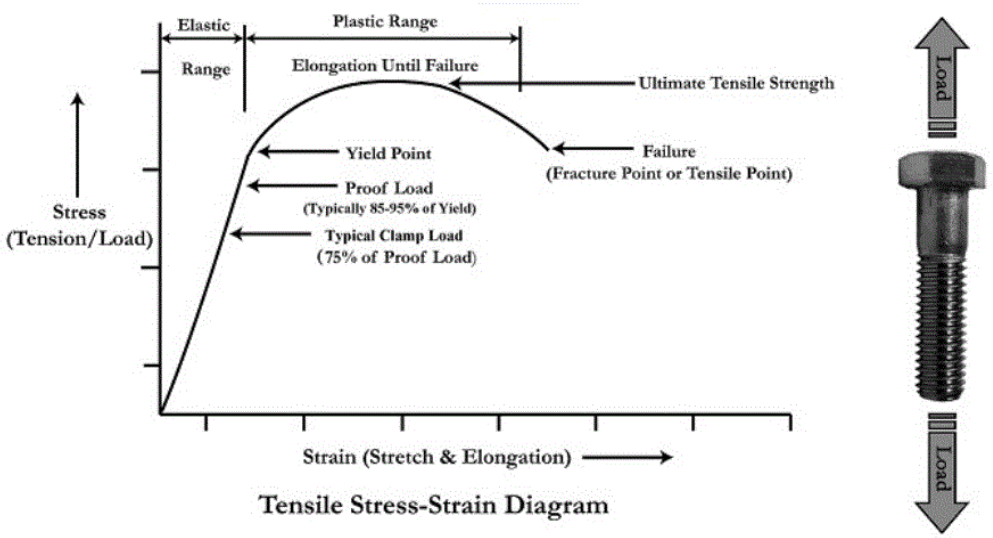
- In-Pavement Light Fixtures will be Installed and Evaluated in Both Asphalt and Portland Cement Concrete (PCC) Pavement.

Laboratory Testing Objectives

- **Evaluate Clamping Force Limitations of Various Combinations of Light Fixtures with and without Adapter Rings, Threaded Holes of Light Base Extensions, Bolts, Two Part Locking Washers, and Spacer Rings.**
- **Testing will Evaluate Light Fixtures Representing the Range of Light Fixture Strengths.**
- **Testing will evaluate current bolt sizes and types and bolts of higher strength and increased diameter.**
- **Bolt Hole Threaded Inserts will also be Evaluated with Larger Diameter Bolts.**
- **Torque-Tension Relationships for Various Bolt and Tapped Hole Combinations.**
- **Bolts will be Torqued to Failure of Individual Light Fixture Assemblies Identifying Weakest Component.**
- **75% of Failure Torque Will be Used as a Basis for Shear Force, Compressive Load, and Vibration Testing of Bolted Connections for all Light Fixture Assembly Combinations.**

Bolt Grades, Sizes, and Mechanical Properties

- **SAE J429 Grade 2 – 3/8 inch Dia.**
- **SAE J429 Grade 5 – 3/8 and 7/16 inch Dia.**
- **ASTM F593C (Type 304) – 3/8 inch Dia.**
- **ASTM F593P (Type 410) – 3/8 and 7/16 inch Dia.**
- **Torque-Tension Relationships to be Developed Based on Tensioning Carbon Steel Bolts to 75% of Proof Load and Stainless Steel Bolts to 75% of Yield Point.**



Tensile Stress-Strain Diagram

Bolt Grades, Sizes, and Mechanical Properties (Continued)

- **SAE J429 Grade 2**
  - **Min. Proof Strength – 55,000 psi**
  - **3/8” Dia. Bolt Preload (75% Proof) – 3,197 lb.**
- **SAE J429 Grade 5**
- **- Min. Proof Strength – 85,000 psi**
  - **3/8” Dia. Bolt Preload (75% Proof) - 4,941 lb.**
  - **7/16” Dia. Bolt Preload (75% Proof) – 6,758 lb.**

Bolt Grades, Sizes, and Mechanical Properties (Continued)

- **ASTM F593C (Type 304)**
  - **Min. Yield Strength – 65,000 psi**
  - **3/8” Dia. Bolt Preload (75% Yield) – 3,778 lb.**
- **ASTM F593P (Type 410)**
  - **Min. Yield Strength – 90,000 psi**
  - **3/8” Dia. Bolt Preload (75% Yield) – 5,231 lb.**
  - **7/16” Dia. Bolt Preload (75% Yield) - 7,155 lb.**

Two-Part Lock Washers and Threaded Inserts

- **Two-Part Lock Washers (3/8” and 7/16” Bolt Size) Made of Stainless Steel.**
- **Two-Part Lock Washers Selected for Compatibility with Strengths of Associated Bolts.**

- **Threaded Inserts Used with 7/16” Dia. Bolts Installed into 17/32” Dia. Pilot Holes in Flanges.**

Light Base Extensions and Spacer Rings

- **L-868B Class 1A Extensions - 3/8” and 7/16” Dia. Threaded Holes**
- **L-868B Class 1B SS Extensions – 3/8” and 7/16” Dia. Threaded Holes**
- **L-868B Class 1A Extensions – 17/32” Dia. Through Holes**
- **L-868B Class 1B SS Extensions – 17/32” Dia. Through Holes**

- **Spacer Rings with 3 Thicknesses (1/16”, 1/2”, and 1”) Made of Carbon and Stainless Steel Matching Mating Light Base Extensions**

Torque-Tension Testing

- **Testing of Each Combination of Bolt and Light Base Extension with Lubricants Applied to Uncoated Bolts Will Be Accomplished using a Skidmore-Wilhelm Model J Bolt Tension Calibrator.**
- **Accurate Torque-Tension Relationships and Resulting Friction Factors (Ks) will be Determined.**

Failure Torque Testing

- **Torque Bolts of Fully Assembled Light Fixture Assemblies in 5 ft-lb Increments to Failure Torque.**
- **Failure Torque Defined as Peak Torque or Point at Which Bolt No Longer Able to Generate Additional Installation Torque.**
- **Peak Forces Determined Based on Friction Coefficients Determined from Torque-Tension Testing.**
- **Testing to be Accomplished with no Spacer Rings and with 3 Combinations of Spacer Rings (1/16”, 1/2”, and 1” Thick Spacers).**
- **Testing with 7/16” Diameter Bolts will be Accomplished with Threaded Inserts Installed Into Flange Pilot Holes 17/32” Diameter.**

Horizontal Shear Force Testing

- **Testing per FAA AC 150/5345-46 Simulates Shear Loading Applied to Top of In-Pavement Light Fixtures by Braking Aircraft Tires.**
- **AC Prescribes that Horizontal Shear Load be Applied to Light Fixture Through a Bar Attached (Welded) to the Top of the Fixture.**
- **A Shear Load of 3,000 pounds is applied and released 20 times to each end of bar by a Press Monitoring any Indication of Failure (Slippage).**
- **Shear loading will then be increased in 1,000 pound increments until Failure (slippage) Occurs at the Joint.**
- **Testing Conducted with Bolts Torqued to 75% of Failure Torque.**

Compressive Load Testing

- **Testing per FAA AC 150/5345-42 Applying a Pressure of 450 Psi (51,000 Pound Approximate Equivalent Load) Uniformly Through a Rubber Block Into Light Fixture Assembly.**
- **Compressive Load Applied and Released 3 Times at Each Incremental Load.**
- **Incrementally Increase Compressive Load Until Loss of Bolt Preload or Fixture Damage.**
- **Bolt Preload Determined by Torque Verification Between Loadings.**
- **Testing Conducted with Bolts Torqued to 75% of Failure Torque.**

Vibration Testing

- **Testing per FAA AC 150/5345-46 Subjecting Light Fixture Assemblies to Sinusoidal Vibration Along 3 Perpendicular Axes.**
- **Testing Conducted without Spacer Rings and with 3 Spacer Rings.**
- **Mechanical Failure of any Component or Loosening of any Part or Fastener is Cause for Rejection.**
- **Testing Conducted with Bolts Torqued to 75% of Failure Torque.**

Corrosion Testing

- **Conduct Bolt Corrosion Tests of Stainless Steel Bolt Grades (with and without Black Oxide Coating) and Coated Carbon Steel Bolts Including Potassium Acetate Test and Salt Fog Test per MIL-STD-810F.**
- **Bolts will be Evaluated based on Evidence of Damage, Rust, Pitting, or Corrosion.**

Testing of Installed In-Pavement Light Fixture Assemblies

- **Testing in NAPTF**

- Install Instrumented Light Fixture Assemblies Into Both Portland Cement Concrete (PCC) and Asphalt Pavement Test Sections.

- Strain Gauges will be Installed on Assembly Bolts and other Load Bearing Components.

- Apply Cyclic Wheel Loading on and in Proximity to Light Fixture Assemblies Using the Test Vehicle.

- Measure and Record Forces Generated in Light Fixture Assemblies Including Fluctuation in Bolt Clamping Forces.

The National Airport Pavement Test Vehicle

Testing of Installed In-Pavement Light Fixture Assemblies (Continued)

- **Testing at ACY**

  - Install Instrumented Light Fixture Assemblies at ACY on Runway and/or Taxiway

  - Apply Controlled Wheel Loading on and in Proximity to Light Fixture Assemblies Using Instrumented FAA Aircraft (B727 and Other Aircraft) with Known Wheel Loads and Tire Pressures

  - Testing Shall Include Application of Aircraft Wheel Braking

  - Measure and Record Forces Generated in Light Fixture Assemblies.

End Product

- **Identify Torque-Tension Relationships of Various Bolt-Light Base Flange Tapped Hole Combinations.**
- **Identify Limiting Bolt Clamping Forces that Can Be Safely Applied to Light Fixture Assemblies.**
- **Evaluate Performances of Various Light Fixture Assemblies based on both Laboratory and Field Testing.**
- **Identify Changes for Incorporation into FAA Engineering Brief No. 83 "In-Pavement Light Fixture Bolts" Regarding Selection, Installation, and Maintenance of Bolts.**

Project Status

- **Laboratory Testing will be Conducted under an FAA Contract with Intertek of Cortland, NY (FAA Accepted Third Party Certification Body in Accordance with FAA AC 150/5345-53).**
- **FAA Laboratory Testing Contract was Awarded 9/19/2016 with a Duration of 9 Months.**
- **FAA Contract for Testing of Installed In-Pavement Light Fixtures is Planned for Award in Early 2017.**

QUESTIONS?