# Evaluation of In-Pavement Light Fixture Designs and Performance


Presented to: IES ALC Spring 2016 Meeting

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Date: April 7, 2016

# Background

- **In-Pavement Light Fixture Assemblies Utilize a Circle of Six (6) Bolts and Two Part Clamping 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 Forces Generated by Modern Commercial Aircraft and Improper Installation/Maintenance of Bolted Connections.**

# Planned FAA Research

- **Determine Maximum Bolt Clamping Forces that Can be Safely Developed in Securing In-Pavement Light Fixtures to Light Bases or Light Base Extensions.**
- **Evaluate Performance of Light Fixture Assemblies Based on Increased Bolt Clamping Forces.**
- **Instrument In-Pavement Light Fixtures to Determine the Loading that is Transmitted from Aircraft Tires Into the Light Fixtures.**
- **Determine What Bolt Clamping Forces are Necessary to Adequately Resist the Loading Generated by the Largest Modern Commercial Aircraft.**

# Research Strategy

- **Project Phase I: Laboratory Testing**
  - **Determine Strength Limitations of Light Fixture Assemblies for Resisting Increased Bolt Clamping Forces**
  - **Conduct Shear Force, Compressive Load, and Vibration Testing to Evaluate Performance of Light Fixture Assemblies Based on Increased Bolt Clamping Forces**

# Research Strategy (Continued)

- **Project Phase II: Field Testing**
  - **Instrument and Install In-Pavement Light Fixtures in the NAPTF and on ACY Runway and/or Taxiway to Evaluate Performance of Light Fixture Assemblies under Controlled Aircraft Wheel Loading Conditions**
  - **Utilize Instrumented B727 Aircraft and Smaller Size Aircraft at ACY to Evaluate Light Fixture Assemblies Under Varying Wheel Load/Tire Pressure Conditions**

# Light Assembly Bolt Clamping Force Requirements and Limitations

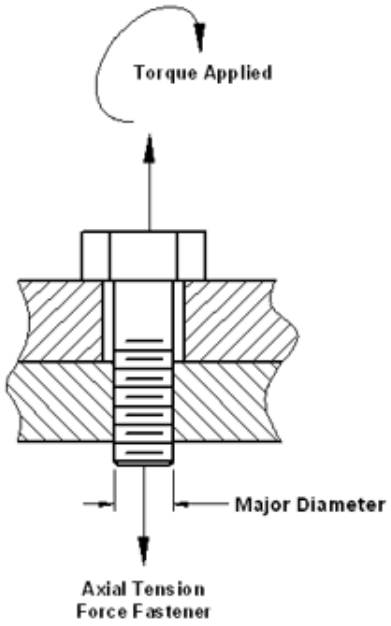
- **FAA Criteria Currently Requires Combined Clamping Force of Bolt Circles be Capable of Resisting a 3,000 Pound Horizontal Shear Force Simulating a Braking Aircraft Tire.**
- **Bolt Clamping Forces Must Also Be Adequate to Prevent Significant Fluctuation in Bolt Tension When Subjected to Aircraft Tire Loading.**
- **Significant Fluctuation in Bolt Tension Will 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) Installed into Threaded Holes in the Light Bases or Light Base Extensions, with Two Part Clamping Lock Washers, and a Maximum of 3 Spacer Rings.**
- **Bolt Clamping Forces are Limited Based on Strength of Overall Light Fixture Assemblies including Light Fixtures, Internal Threads in Light Base or Base Extension Flanges, Spacer Rings, Bolts, and Two Part Clamping Lock Washers.**

# Bolt Torque-Tension Relationships

- **Bolts 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)**

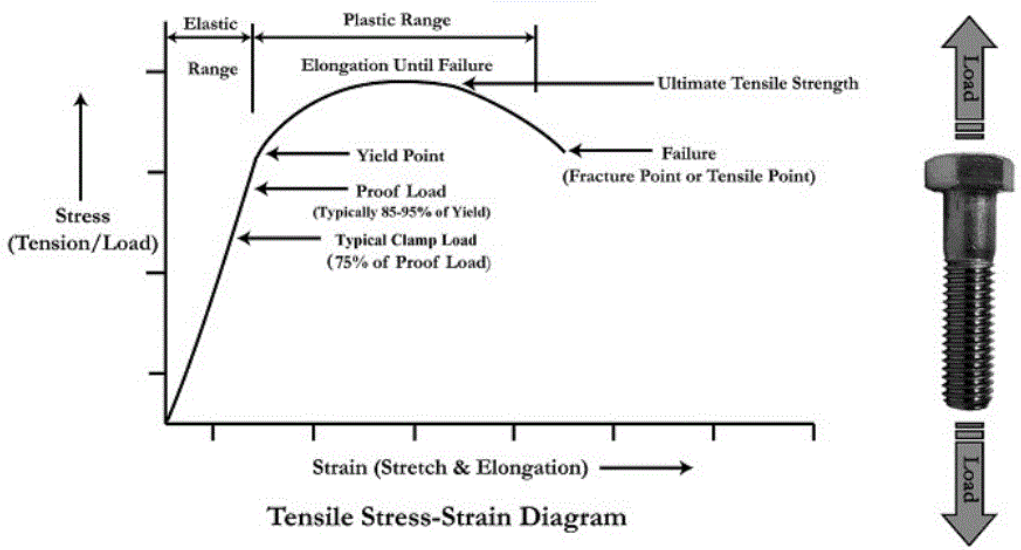
**Fp = Axial Clamping Force**

# 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.**
- **Friction Coefficients are Derived from Test Procedures Conducted with Conventional Carbon or Alloy Steel Bolts, Nuts, and Hardened Washers to Develop Torque-Tension Properties.**
- **Bolts are 18-8 Stainless Steel and Coated SAE J429 Grade 2 Carbon Steel, and Light Base Flanges are 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 Requires Testing Utilizing a Skidmore-Wilhelm Bolt Tension Calibrator or Equivalent Bolt Instrumentation.**
- **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 Coefficients (K's).**
- **Bolts will be Tensioned Incrementally up to 75% of Proof Load or Yield Strength Plotting Torque vs. Tension and Determining the Resulting Friction Coefficient (K).**



Tensile Stress-Strain Diagram

# In-Pavement Light Fixture Assembly Materials

- **SAE J429 Grade 2 (Coated) and Stainless Steel Alloy 18-8 Bolts are Currently Prescribed for In-Pavement Light Fixtures. Testing will also include SAE J429 Grade 5 (Coated) Bolts and ASTM F593P Grade 410 Black Oxide Coated Bolts.**
- **Two Part Clamping Lock Washers are Carbon Steel and Stainless Steel (Manufacturer's Standard).**
- **Bolt Hole Inserts are Hardened Steel and Stainless Steel (Manufacturer's Standard).**

# In-Pavement Light Fixture Assembly Materials (Continued)

- **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 Alloys Specified by the Manufacturers that Satisfy Requirements in FAA AC 150/5345-46.**

# Laboratory Testing Objectives

- **Evaluate Clamping Force Limitations of Various Combinations of Light Fixtures, Threaded Holes of Light Bases or Light Base Extensions, Bolts, Two Part Clamping Lock Washers, and Spacer Rings.**
- **Testing will evaluate current bolt sizes and types and bolts of higher strength and increased diameter.**
- **Bolt Hole Inserts will also be Evaluated with Larger Diameter Bolts.**
- **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 Connection Combinations.**

# Laboratory Testing Details

- **Horizontal Shear Force Testing will be Conducted Using a Tinius Olsen Machine with loads increased incrementally to the point of light fixture slippage or bolt failure.**
- **Compressive Load Testing will be conducted on Light Fixture Assemblies with loads increased incrementally to the point of loss of bolt torque.**
- **Vibration Testing will be Conducted over a Frequency Range of 20 to 500 Hz with a maximum acceleration of 10 G's Followed by a Frequency Range of 500 to 2,000 Hz with a maximum acceleration of 15 G's. Mechanical Failure of any component will be cause for rejection.**

# Laboratory Testing Details (Continued)

- **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**
- **Bolts will be Evaluated based on Evidence of Damage, Rust, Pitting, or Corrosion.**

# Testing of Installed In-Pavement Light Fixture Assemblies

- **Testing in National Airport Pavement Test Facility (NAPTF)**

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

**- Utilize Test Vehicle to Simulate Aircraft Wheel Load Traffic on Construction Cycle Test Sections and Instrumented Light Fixtures.**

**- 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**

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

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

  **- Testing Will Include Application of Aircraft Wheel Braking**

  **- Forces Generated in Light Fixture Assemblies, Including Fluctuation in Bolt Clamping Forces, will be Measured and Recorded.**

# 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

- **Statement of Work Has Been Developed for Laboratory Testing.**
- **Laboratory Testing will be Conducted by an FAA Accepted Third Party Certification Body in Accordance with FAA AC 150/5345-53C, “Airport Lighting Equipment Certification Program”.**

# QUESTIONS?