Precision Survey of Movable Bridges
A Presentation to the LTC
February 29, 2016, Baton Rouge, LA
Precision Survey of Movable Bridges

- Background of Tolerances
- Traditional Methods
- Digital Methods
- 4th Street Survey
- Other Project Examples
Typical Tolerance Requirements

- **Running Clearance**
  - Shafts in bearings / Lockbars in guides
  - Roughly 0.001” clearance per inch of shaft diameter

- **Locational Clearance**
  - Turned bolts & Stationary parts
  - 0.001” to 0.004” clearance

- **Interference Fit / Shrink Fit**
  - Shafts in gears or hubs / Keys
  - 0.002” to 0.015” interference

Introduction

Other Examples

Digital Methods

Traditional Methods

4th St Survey
Typical Tolerance Requirements

- **Turned Bolts**
  - 0.001” to 0.004” clearance with hole
  - Reamed at assembly
  - Holding alignment

- **Shims**
  - Adjustable in 0.003” increments
  - Fine adjustment of alignment

- **Flexible Couplings**
  - 0.002” parallel offset
  - 1/8 Degree Angular
Traditional Alignment Methods

- Optical Survey
  - 0.010” resolution
  - Machinery layout and alignment

- Machinist Level
  - 0.005” / 12”
  - ~0.02°
### Traditional Methods

- **Dial Indicators**
  - 0.001” resolution
  - Multiple alignment uses

- **Taper / Feeler Gauges**
  - 0.001” resolution
  - Gear & bearing alignment

- **Piano Wire**
  - Approx. 1/64” resolution
  - Trunnion alignment
Digital Methods

- **Laser Tracker**
  - Over 300 ft measuring distance
  - Less than 0.001” accuracy
  - Measurements environmentally sensitive
  - Bridge conditions can expect 0.005” accuracy at about 50 ft

- **Measuring Arm**
  - Less than 0.001” accuracy
  - Less sensitive to environment
  - Does not require line of sight
  - 6 ft measuring distance
Hydraulic Double Leaf Rolling Bascule Bridge

- Owned/Operated by LADOTD
- Structural/Mechanical/Electrical Rehabilitation – under contract by CEC
- Replace hydraulic span drive machinery
- Replace electrical power and control systems
- Replace deck, structural repairs, blast, clean, and recoat structure
Rolling Track/Tread Plate Replacement

- Periodic problems with existing track plates
- Wear at pintles and pockets
- Difficulty driving/retracting center locks
- Built up weld material on pintles and pockets to retain span alignment
New Track/Tread Plates

- Split design
- Replace lower portions first with span raised
- Lower portion dictates span alignment when seated
- Requires precise installation of lower portion
- Trunnion replacement includes line boring holes, possibility of relocating centers slightly
4th Street Survey
New Track/Tread Plates

- Curved treads must fit accurately to the curved girder
- Existing dimension shown as fraction
- Precise radius of existing curved girder not known
- AASHTO design code says to make curved tread plate “slightly smaller” than curved girder
4th Street Survey

- Service Technology out of Florida
  - Provided operators and data acquisition equipment.
  - Summarized Data for Contractor and Submitted to Engineer for Review

- Equipment “Mobile”, with Specialized Packaging
Faro Arm
Base Setup
- Solid, Clean, Stable
- Tripod or magnetic/clamp stands
Targets
- PunchMarks to Repeat at Different Bridge Positions
Faro Arm (cont.)

- Used to “Shoot” tread rolling surface and pocket geometry
- Trunnion Center and Girder Plane
- Interchangeable tips
Rolling Tread to Bascule Girder Flange Interface
- Radius
- Rotation/Translation Plane

Track
- Level
- Bolt Locations
- Parallelism with Adjacent Track
Laser Tracker

Base Setup
- Solid, Clean, Stable
- Tripod

Targets - Sphere
- Glued Pucks with Spherical Seats
- Masonry Nails with Spherical Head Recess
  - Anchored in Pier Walls to Relate all Set Ups
Laser Tracker (Cont.)

- 3 Setups per Leaf
- Related all 6 Setups and to Faro Points
- Relied on Line of Sight
- Measured trunnion center, cylinder rod axis, track and tread surfaces
4th Street Survey

- Centerline of Trunnion
  - OD of Shaft ends
  - Hydraulic Cylinder Rod Axis
Precision Survey Results

- Variation from Mean -0.015” to +0.011”
- Good Trend about a Mean Radius
- Primarily Faro Arm Data
- Tracker Target not small enough for Track and Tread Surfaces
- Tracker Confirmed Leaf Tracking Via Cylinder Rod Axis

4th Street Survey

Introduction | Traditional Methods | Digital Methods | 4th St Survey | Other Examples
4th Street Survey

Precision Survey Results (cont.)

- Good Grouping of Data Points at Each Tread Pocket
- Close to Expected 59 ½” Radius
### 4th Street Survey

#### Precision Survey Results (cont.)

- **West Leaf Both Corners within 0.048” of Nominal**
- **East Leaf 3/8” under Nominal**

<table>
<thead>
<tr>
<th>Location</th>
<th>Radius</th>
<th>X (in)</th>
<th>Y (in)</th>
<th>Error (in)</th>
<th>Notes</th>
<th>Best fit radius corrected for probe Ø</th>
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</thead>
<tbody>
<tr>
<td>North East</td>
<td>59.559</td>
<td>0.022</td>
<td>0.138</td>
<td>0.060</td>
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<td>North West</td>
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<td>-0.078</td>
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<td>Best fit radius and center, without #17</td>
<td>59.452</td>
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4th Street Survey

- Additional Checks with Jig
- Could not See Undersize at East Corners
- Not Certain Measurement Tolerance was Enough
  - Awkward Access for Side-by-Side Comparison in place
- Performed Additional Precision Survey
Precision Survey Results (cont.)

- Recheck of West Leaf Repeated
- Recheck of East Leaf Repeated in 1 of 2 Corners
- Concerned 1 East Corner has Anomalies
- Precision Check of Jig Geometry

### 4th Street Survey

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<tbody>
<tr>
<td>North West</td>
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<td>-0.016</td>
<td>-0.069</td>
<td>0.035</td>
<td>Best fit radius and center</td>
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Summary of Application

- Not good application for Traditional Methods
- System Validated Itself
- Took us a New Direction
- Machining After Removal
Loose Pros and Cons Summary

Digital Methods
- Integral reference line
- Finer tolerance
- Faro Arm less sensitive to line of sight
- Complex shapes, quantifies distance
- Susceptible to temperature and other environmental factors
- Need to compile and crunch data
- Tech is usually separate sub from installer

Traditional Methods
- Must make reference line
- Need line of sight.
- Offsets, not distances, simple geometry
- Very little temperature limitation
- More common qualifications of a millwright
- Tech is same as installer

4th Street Survey
Spit Bridge – Single Leaf Trunnion Bascule

Sydney, Australia

- Single Leaf Trunnion Bascule
- Full Electrical/Mechanical Rehabilitation
- Over-Engagement of Rack and Pinion Noted During Inspection
- Investigate Rack and Pinion Alignment for Entire Opening Angle
Spit Bridge – Single Leaf Trunnion Bascule
Sydney, Australia
Spit Bridge – Single Leaf Trunnion Bascule

Sydney, Australia

- Laser Tracker Survey
- Surveyed Inboard Ends of Trunnions
- Surveyed Static Position of Rack and Pinion Teeth
- Dynamic Tracking of Bascule Girder and Pinion During Operation
Spit Bridge – Single Leaf Trunnion Bascule
Sydney, Australia

- Surveyed Inboard Ends of Trunnions
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Florence Bridge – Span Drive Vertical Lift
Pike/Scott Counties, Illinois

- Strauss Span Drive Vertical Lift Bridge
- Emergency Inspection, Evaluation
- Emergency Rehab Design to Replace the Counterweight and Span Support Machinery
Florence Bridge – Span Drive Vertical Lift
Pike/Scott Counties, Illinois

- Replaced all Counterweight Sheave and Trunnion Assemblies
- Also Replaced Counterweight Ropes & Trunnion Bearings
- Work Done with Span Raised
Florence Bridge – Span Drive Vertical Lift
Pike/Scott Counties, Illinois

- Counterweight was supported at deck level
- Lift span was supported by temporary columns on rest piers and braced back to main towers.
- A majority of the tower dead load deflection was temporarily relieved.
Florence Bridge – Span Drive Vertical Lift
Pike/Scott Counties, Illinois

- Laser Tracker Survey to Determine Relative Differences in Tower Deflection
- Measured Trunnion Locations Before and After Jacking
- Helped Determine New Bearing Elevations
- Verified parallelism and linearity between trunnions
I-5 – Span Drive Vertical Lift
Portland, Oregon

- Twin Span Drive Vertical Lift Bridges
- In-Depth Inspection/Alignment Check and Balancing Project
- Rehabilitation Scoping and Sketch Plans
Laser Tracker Survey
Determine Operating Machinery Alignment
Determine Operating Rope Fleet Angle

I-5 – Span Drive Vertical Lift
Portland, Oregon
I-5 – Span Drive Vertical Lift
Portland, Oregon

- Span Drive Machinery Room
- Laser Tracker Positioned Centrally
- Targets placed on Shafts/Couplings

Tracker Head
Aux Drive Test
I-5 – Span Drive Vertical Lift
Portland, Oregon

- Laser Tracker Between Operating Drums
- Targets placed on Shafts/Gears/Ropes
Thank You!

Questions?