Counterweight Trunnion Replacement

Lea Joyner Strauss Bascule Span
Presentation Objectives:

- Introduce Strauss Bascule Spans, Issues and Case Histories
- Demonstrate Information Exchange at Movable Bridge Forums in Practice
- Present the Lea Joyner Bascule Span Project
  - Detection of Counterweight Trunnion Issues
  - Jacking the Counterweight
  - Replacing the Counterweight Trunnions and Hanger Plates
Simple Trunnion with Fixed Counterweight

Advantages
- No channel obstruction (swing span)
- No visual impact (vertical lift)
- Trunnion on fixed axis
- Provides repeatable/reliable operation
- Span opens and closes same each time

Challenges
- Requires longer span, deeper pier compared to rolling lift or “remote” counterweight types
- Requires special cwt detailing to maximize angle of opening and avoid interference with trunnion supports
Simple Trunnion with Fixed Counterweight

- 1800s - increasing need for railroad and ship traffic to co-exist
- Prompted developments in movable bridge technology
Scherzer Rolling Lift Bascules

- Metropolitan West Side Elevated Company
- Needed 4 tracks across Chicago River (early 1890s) – between Jackson and Van Buren streets
- William Scherzer consulted
- Swing span too obstructive
- Trunnion bascule encroached on navigation width
- Scherzer Rolling Lift Patented in 1893 (Scherzer died at 35, 2 months after filing patent)
- Movable Bridge Tech Wars - Battleground: Chicago
Scherzer Rolling Lift Bascules

**Advantages**
- Provides large angle of openings
- Allows for shorter span lengths
- Allows for smaller counterweights, resulting in smaller piers

**Challenges**
- Tends to “walk” transversely during operation
- Reliability with repeatable operation due to span “walking”
- Requires special detailing at track/tread plates
- Initial alignment challenges – precision survey
- Requires additional machinery; i.e. tail locks
- Operating machinery mounted to the movable span
Simple Trunnion vs. Scherzer Rolling Lift Bascules

180’ C-C Trunnion

125’ Channel

150’ C-C Roll
**Strauss Bascules**

- Joseph B. Strauss – Early 1900s Patents for pinned “remote” counterweight
- Competing patented bascule bridge types – Strauss vs. Scherzer
- First Strauss constructed in 1904 (shown above)
- Strauss Engineering Corp. designed over 400 bascule bridges worldwide

Wheeling & Lake Erie Railroad
Single Leaf Heel Trunnion
Strauss Bascules

Under-Deck Articulated Counterweight

Vertical Overhead Counterweight

Heel Trunnion
### Strauss Heel Trunnion Bascule

**Heel Trunnion**

- Leaf center of gravity A rotates about main trunnion B1
- Overhead rotating counterweight frame
- Parallelogram B1–D–E–B2
- Forward center of gravity at A
- Center of gravity of counterweight at C
- B2-C parallel to A-B1 maintained by link D–E between the counterweight and trunnion tower
- Ratio of leaf dead load moment about B1 to counterweight moment about B2 remains constant
Advantages
- Small Substructure
- Allows for low profiles without cwt pit
- Pivot/Trunnion closer to navigation channel; providing same channel as simple trunnion with shorter leaf

Issues
- Stress reversals at rocking truss and counterweight link
- Overstressed pins and rocking truss
Strauss Heel Trunnion Bascule

- Rocking Truss
- Cwt Trunnion
- Link
- Pinion
- Operating Strut
- Main Trunnion
• Leaf center of gravity P rotates about main trunnion A
• Counterweight supported on posts which pivot on two counterweight trunnions (B)
Strauss Vertical Overhead Counterweight Bascule

**Advantages**
- Small Substructure
- Allows for low profiles without pit

**Issues**
- Inadequate counterweight tower on some versions
- 1928 Hackensack River Bridge Failure
- Dynamic Effects not considered

Saugus River Bridge Boston & Maine RR Vertical Overhead Counterweight
Strauss Under-Deck Articulated Counterweight Bascule

- Strauss moved rear center of gravity closer to main trunnion
- Leaf center of gravity A rotates about main trunnion B
- Line A-C intersects main trunnion axis B
- Counterweight hangs from two counterweight trunnions
- Parallelogram B–C–E–D maintained by link D–E between the counterweight and trunnion tower
The Strauss Bascule Bridge Company

- 1920s Strauss sales catalog
- Underscores the bascule bridge technological battleground
The Strauss Bascule Bridge Company

The Trunnion—The Keystone of Bascule Efficiency

The Strauss Bascule Bridge may truly be considered as built around the "trunnion." The trunnion is a short shaft upon which the leaf, so called, i.e., the movable section of the bridge, is mounted, and about which it rotates. It is the "element of movement," the vital element of every bascule, upon which the efficiency of the entire structure depends.

Self-evidently, the element of movement of a bascule bridge must be of unquestionable integrity. This is true of the trunnion because the stresses to which it is subjected can be definitely determined and provided for. The trunnion carries its load in surface bearing. It is only necessary, therefore, to fix a safe pressure per square inch in order to determine the extent of surface, i.e., the size of the trunnion required, which at once guarantees that it will carry the load imposed upon it without overstress. In
Group II. Underneath Counterweight Type

FIGURE 7, (a) and (b), illustrates the Underneath Counterweight Type, showing views closed and open of the Stutson Street Bridge over the Genesee River, at Rochester, New York, completed June, 1918. The counterbalancing principle in this type is the same as in the vertical overhead counterweight type described under Group I, and is shown diagrammatically in Fig. 8. As the name implies, however, the counterweight and link are located underneath the roadway, which arrangement is not less advantageous than when placed above the roadway, and is best adapted for use where clearance between water level and under side of bridge is not too limited.

In the design illustrated, the bascule span consists of two symmetrical leaves. Two deck trusses for each leaf are used, each mounted on a trunnion just below the roadway, supported in symmetrical bearings secured to a pair of structural steel columns, or trunnion posts. These posts are directly supported over the center line of the channel pier and are part of an adjacent trestle-like approach span which also serves to support the operating machinery and operator’s house, and transmits to the piers, the live load uplift at the extremity of the short arm of the leaf.

Each leaf is exactly balanced about the main trunnions, as in a single leaf design, but unlike the single leaf span, which is supported at both ends, there is no support at the ends of the leaves at the center of the span and, therefore, each must act as a cantilever span under live load. The live load on the long arm of the leaf will thus produce an uplift at the extremity of the short arm, referred to above as being transmitted to the piers through the agency of the adjacent approach span. This result is accomplished by providing the extremity of the short arm of each leaf truss with a bumping casting having an extended horizontal surface facing upward which comes into
The Strauss Bascule Bridge Company

- Strauss embraced trunnion design
- Scherzer primary competitor
- Catalog countered with disadvantages of rolling lift spans:
  1. Fixed dead load on foundations
  2. Reduction of pier depth
  3. Eliminate possibility opening under live load
  4. Machinery fixed on piers
  5. Critical machinery (trunnions) protected

Likewise, hand operation is more convenient and efficient.

5. The vital parts of movement, the trunnions, are securely housed in journal bearings lined with phosphor bronze bushings, well lubricated, reducing wear to a minimum, protected against influence of weather, lodgment of dirt, etc. Trunnions in their bearings give surface contact with pressure distributed over requisite area for safe unit load.

Figure 15: Double Leaf Underneath Counterweight Highway Bridge, Third Street over Christiana River, Wilmington, Delaware

Length span Bascule, 372 feet; approach spans, 110 feet 4 inches; width roadway, 37 feet; double track street railway; sidewalks, 8 feet. Completed, 1916
Issues

- Excessive friction in the counterweight linkage and trunnion bearings induces repetitive bending moment in the counterweight hangers – especially at small angle of openings
- By early 1930s counterweights were falling off
- Hangers failed in fatigue due to seized counterweight trunnion bearings resulting in collapse of leaves
Tayco St. Bridge Collapse

Collapse of Tayco St. Bridge over the US Canal, Menasha, WI

- Constructed in 1928
- Collapse of South Leaf in 1989
- West counterweight bearing seized at 10 degree opening
- Subsequent failure of hangers and counterweight links
## Strauss Bascules – History of Issues

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Strauss Bascules – History of Issues

Burnside Bridge Bascule Span, Portland, OR
1926 Strauss Under-Deck Articulated Counterweight
4 Million LB Leaf
2007 $5.5M Cwt Trunnion and Hanger Plate Replacement

Simpson Ave. Bridge, Hoquiam, WA
1928 Strauss Under-Deck Articulated Counterweight
2007 Cwt Trunnions and Hanger Plate Replacement

Salmon Bay Bridge, Burlington Northern Santa Fe (BNSF) Railway, Ballard, WA
1914 Strauss Heel Trunnion
5.5 Million LB Leaf
2010 $3.5M Cwt trunnion Replacement

Platt St Bridge, Tampa, FL
1926 Strauss Under-Deck Articulated Counterweight
2012 Cwt trunnion Replacement
• **Strauss Bascule - Under-Deck Articulated Counterweight**
• **Constructed in 1937 – one of last designed by Strauss**
• **160 ft main trunnion to main trunnion – 130 ft channel**
• **4 Lanes with 6.5 ft sidewalks**
• **3M LB Leaf/1.4M LB Cwt**
Lea Joyner Bridge Strauss Bascule Span

1937 Nashville Bridge Company Shop Drawing
Project Location

- US 80/LA 15 from Monroe to West Monroe
- Ouachita Parish, LADOTD District 05
- Boeuf River – Ouachita River System
Location – Looking South over the Boeuf River

- Desiard St Bridge (Swing Span)
- Lea Joyner Bridge

- Average Daily Traffic – 40,000
- Main Passageway for Commercial Barges
- 6 – 10 Required openings/week

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2010 - 2012 Project
- Deck Replacement
- Structural Steel Rehabilitation
- Operating Machinery – New Open Gears
- Rehabilitate Center Span Locks

Designer: LADOTD Bridge Design Section
Contractor: PCL Civil Constructors
Subcontractor: Electro Hydraulic Machinery
Subcontractor: JC Machine
Construction Specialty Engineer: H&H
Evidence of the Issue

October 2010 Initial Strain Gage Results:
• East Leaf: Friction – 40 kip-ft/Imbalance - 40 kip-ft
• West Leaf: Friction – 130 kip-ft/Imbalance - 40 kip-ft
Evidence of the Issue

2012 Temp. Operating Machinery Electric Winch System
- Double Sheave Block Line Pull – 4 tons
- Difficulty in Operating Span
- Noise emanates from west leaf trunnion cwt bearings
Evidence of the Issue
Movable Bridge Industry Forum in Practice

- Meeting at October 2012 Heavy Movable Structures (HMS) Symposium, Orlando, FL
- PCL, LADOTD, H&H
- Discussion of numerous past Strauss Cwt Trunnion Replacement Projects
- Strategy Developed for Lea Joyner Bascule Span

Burnside Bridge Counterweight Trunnion Replacement

Replacing the Counterweight Trunnion Bearings in a Strauss Bascule Bridge
Burnside Bridge Reconstruction Project – Multnomah County, Oregon
Jon Heinrich, P.E., Chuck Maggio, P.E., Ed Wortman, P.E., Tyr Aldana, P.E.

ABSTRACT

This paper will highlight the rehabilitation of a 1926 double leaf Strauss Bascule Bridge. The movable leaves span 252 ft (83.5 m) over the Willamette River connecting downtown Portland to the NE quadrant of the City. This is a major commuter route, carrying 5 lanes of vehicular traffic, as well as a high volume of pedestrian and bicycle commuters.

The bascule span is an under-deck articulated counterweight style bascule, and prior to the rehabilitation, had a history of operational issues. The link arms that were used to stabilize the counterweight during travel had a history of failures at the pinned connections, and evident misalignment problems. Additionally, the east leaf required more power than the west leaf, and rotated significantly slower.
Evolved into Emergency Repair Design-Build Project

- **Schedule**
  - Initiated in January 2013
  - Summer 2013 completion target
  - Inspection – address other potential problems, i.e. hangers, links
  - Weekly meetings – LADOTD/PCL/JC Machine/H&H
  - Plans production – critical to procure material
  - Fabrication – local machine shop
  - Bridge closings – No restrictions allowed for barge traffic

- **Cost**
  - $4M Estimate
  - Evolved into Design-Build Project
Lea Joyner Bridge Counterweight Trunnion Replacement

**EXISTING COUNTERWEIGHT TRUNNION BEARING ASSEMBLY**

- **Hanger Plate Assembly, Typ.**
- **27” dia. Housing “light driving fit” with girder webs**
- **8 ½” dia. Trunnion “light driving fit” with Sleeve, fixed to hanger plates**
- **20 ½” dia. Trunnion Sleeve rotates within bushed housing**
- **22 ½” dia. (20 ½” I.D.) bronze bushing “driving fit” with housing**
- **1 ½” dia. Rods**

Scale: 1 ½” = 1’-0”
Replace 4 assemblies
Quantities shown are per assembly

**Hardesty & Hanover**
engineering that moves you
Lea Joyner Bridge Counterweight Trunnion Replacement

- Concrete chipped away from hanger plate for in-depth inspection
- determined to splice new hanger plates
- Link arms showed no signed of distress
Counterweight Jacking

- Strauss design minimized bascule pier
- Pier shaped to counterweight fit

Counterweight in open position
Less than 1 ft to front pier wall
Few inches to trunnion tower platform

Notched Portion of counterweight
Fits around base of trunnion tower
Counterweight Jacking

Leaf angle at 35 degree optimal for jacking frame and barge traffic
Counterweight Jacking

Jacking Design
• 3” dia. All Thread 150 ksi Tension Rods
• Attached to bracket off girder heel
• Brackets positioned either side of cwt trunnion – transfers cwt load through intended design load path
• Maintains balance of leaf
• Relieves load at cwt trunnion
• Bracket weldments utilized existing rivet holes
• Rivets removed and replaced with high strength bolts

Brackets at girder heel
Counterweight Jacking

Web Bracket
- Shape of connection plate of web brackets derived from
  - Spacing of rivets
  - Minimum bolt spacing
  - Number of bolts necessary for jacking loads
- Closer to main trunnion
  - Designed to take double load compared to flange brackets

Flange Bracket
- Built up to clear back of counterweight
- Designed such that tension rods cleared the counterweight
- W36x256 connected to back of girder
- W14x159 attached to top flange
- Welded box attached to top flange of W14x159
Wind Load Bracing

- HSS 12x8 ½” (Hollow Structural Section)
- Pinned (2 ½” dia.) at trunnion tower and girder bottom flange
Counterweight Jacking

Cribbing System at bottom of counterweight – 1 per trunnion
- 2 stacks of 3 - W14x233
- 1 ½” Top & Bottom Plates
- 1 set per trunnion
- 4 – 400 Ton ½” stroke pancake jacks/assembly
- Tension rods passed thru both sets and secured against bottom-most plate
- 2 support points for each tension rod
- Jacks tension rods while compressing hangers, relieving dead load stress
- Bearings and spherical washers used at each support point to maintain rods plumb

Grillage System

Tension Rod Spherical Washers and Bearings
Counterweight Jacking

- Main Trunnion
- Wind Brace
- Cribbing System
- Tension Rods
- Cwt Trunnion
- Brackets at girder heel
Counterweight Jacking

Hanger Plate Monitoring:
- Rods in tension while hanger plate compressed to relieve counterweight load from cwt trunnions
- Actual cwt and forward leaf dead loads unknown
- Dial indicators welded to girder flange monitored vertical and horizontal displacement
- Estimates of cwt dead load made throughout the process – approx. 1.4M LB
- Uneven rod spacing varied load in tension rods
- Jacks were pressurized with separate manifolds in groups of 2 jacks
- Jacking performed incrementally
- Shims driven at designated grillage locations to remove load from jacks
Hanger Plates Cut
Trunnion Sleeve and Bushing Assemblies Removed

- **Bushing Removal**
- **Sleeve & Trunnion Pin Removal**

- Packed hardened grease from existing sleeve
Housing Inspection & Field Machining:

- Inspect ID of existing housings
  - Field machine or replaced
- Field line bore 1/8” larger
- Shop machine final OD of new bushing
- Schedule Decision - New housings ready for final machining
- All four existing housings were acceptable for field machining
- Saved time by eliminating line boring the girders for new housings - about 1 week/leaf

Housing Field Machining

Housing before and after Field Machining
New CWT Trunnion Assembly

New Counterweight Trunnion Assembly

Existing Counterweight Trunnion Assembly

EXISTING COUNTERWEIGHT TRUNNION BEARING ASSEMBLY
SCALE: 1/8” = 1’-0”
REPLACE 4 ASSEMBLIES
QUANTITIES SHOWN ARE PER ASSEMBLY
New Bushings Installed

New Bushings Packed in Dry Ice Installed in Housing
New Hanger Plates and Sleeves

Shop Assembled Hanger Plates, Sleeves, Pin

Shop Assembled Hanger Plates, Sleeves, Pin Sleeve - RC6 Fit with Bushing
New Hanger Plates and Sleeves

New Hanger Plate Spliced to Existing

Final New Counterweight Trunnion Assembly
Lea Joyner Cwt Trunnion Replacement Timeline

- October 2012 HMS Meeting
- Decision to Replace Counterweight Trunnion in January 2013
- February 2013 – Site visit for preliminary inspection and coordination
- February thru May: Jacking and trunnion replacement designs investigated
- Late May 2013 – Construction of jacking cribbing began
- June 1, 2013 – Bridge closed to vehicular traffic
- June 9, 2013 – West Leaf Counterweight jacked
- June 11-12, 2013 – Trunnion bushing removed and housing inspected.
- Late June 2013 – New hangers installed; counterweight load relieved from jacking system and returned to hangers.
- Bridge opened to traffic for July 4th Holiday
- Mid July – Initiate similar procedure at East Leaf
- Project Complete before estimated deadline of August 9, 2013
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