Understanding Movable Bridges and a Guide to Design and Preservation

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Movable Bridges

- Movable bridges are unique because they integrate conventional structural components with mechanical drives that are controlled with electrical systems ranging from original rudimentary systems to modern day computer systems.

Movable Bridges Cont.

- They are also different from most highway bridges in that they can support or facilitate access to many modes of transportation including vehicular, maritime vessels, trains, bicycles, and pedestrians.

Movable Bridges Cont.

- In some instances, these structures are historic, and it is required to implement a preservation approach that adheres to the Secretary of the Interior's Standards and does not significantly change the character defining features of the bridge and will not disqualify it from potential eligibility on the National Register.

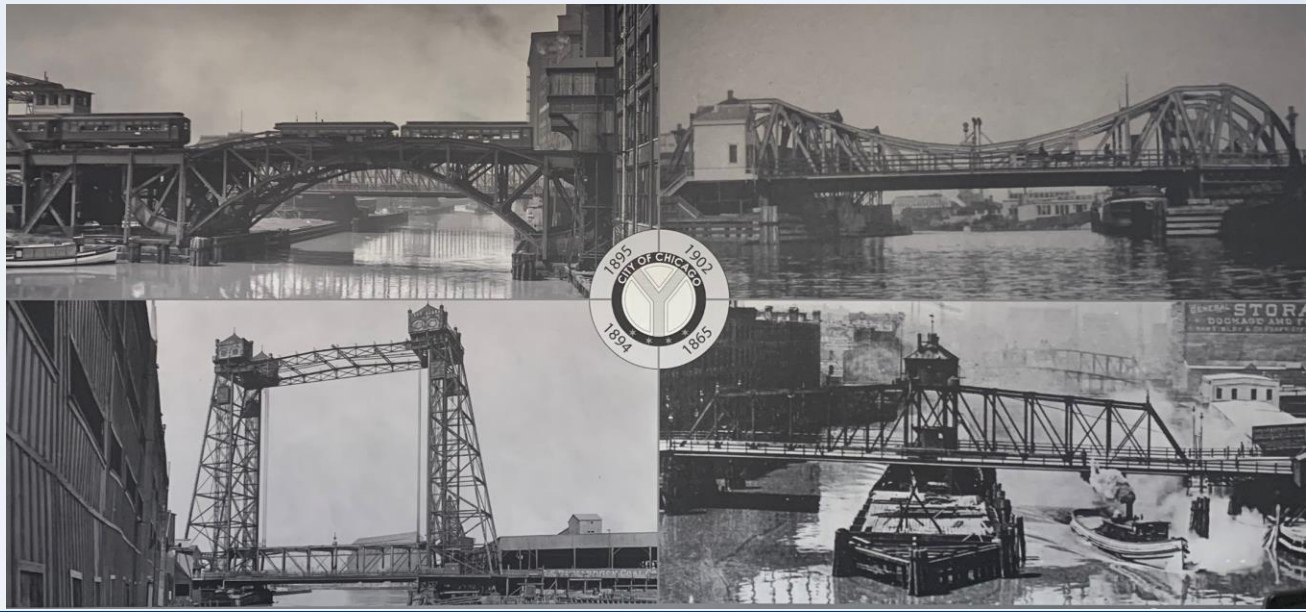
- Trunnion Bascule Bridge, also known as the Chicago Style of Bridge was developed in Chicago in the early 1900. It feature a movable span that rotates around a fixed trunnion, it was a remarkable innovation over the prevailing swing bridge and became a model for bridge builders worldwide.

Chicago Movable Bridges

The Chicago Movable Bridge Preservation Plan can be found at: https://www.chicago.gov/city/en/depts/cdot/provdrs/bridge/supp_info/cmbp.html

The bridges are listed in the order of the generation in which they were designed and/or constructed:

- First Generation: 1900 - 1910
- Second Generation: 1911 - 1930
- Third Generation: 1932 - 1949
- Fourth Generation: 1952 - 1967
- Fifth Generation: 1976 - 1984



Chicago Movable Bridges Cont.

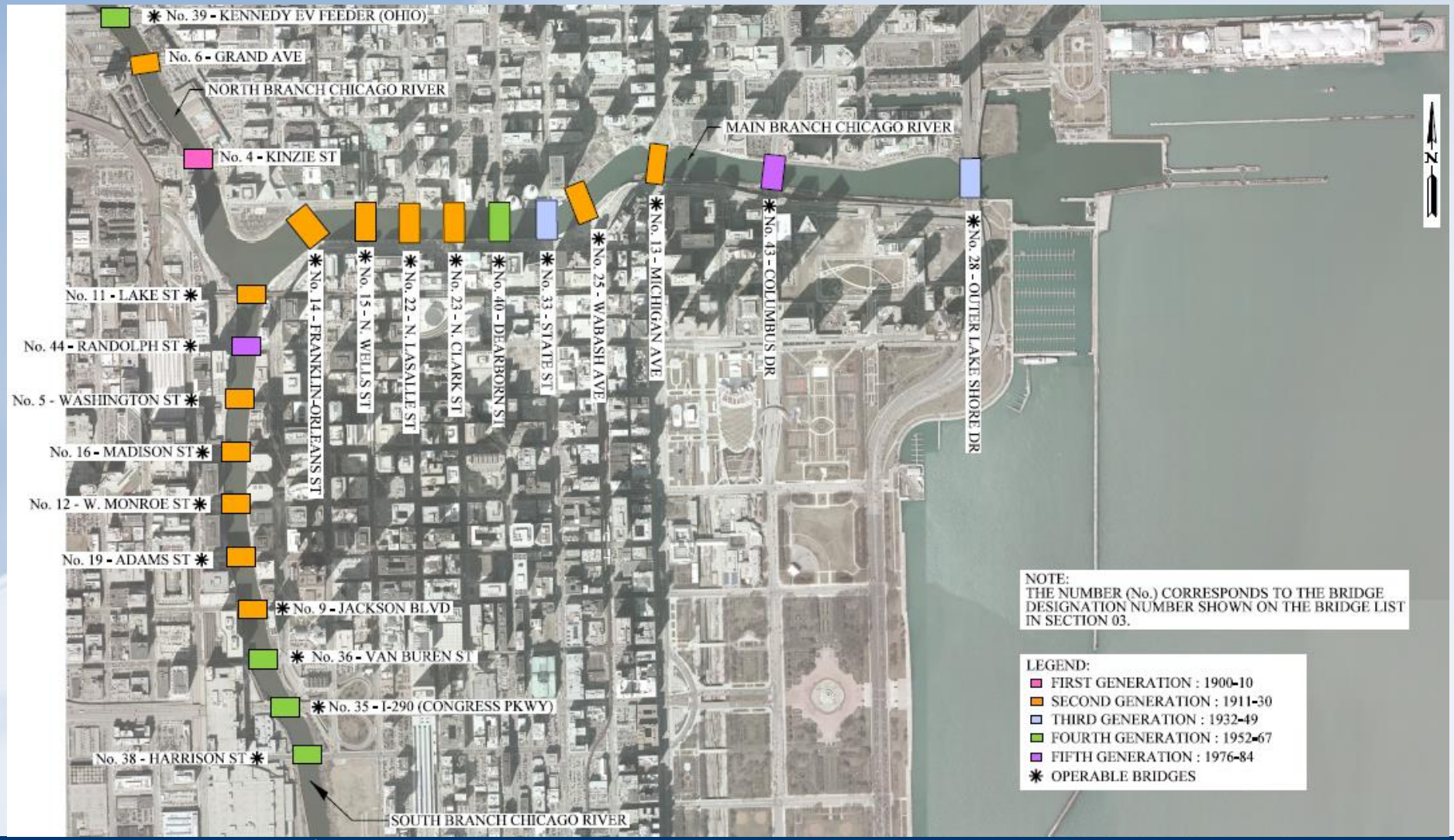
CDOT owns and maintains 42 Movable Bridges

- 40 CDOT Movable Bridges*
- 2 IDOT Movable Bridges
- Only 36 fully Operational

The majority of the movable bridges in the City are “Chicago Style” Bascule Bridges.

1925 Photo of South Branch, Looking North

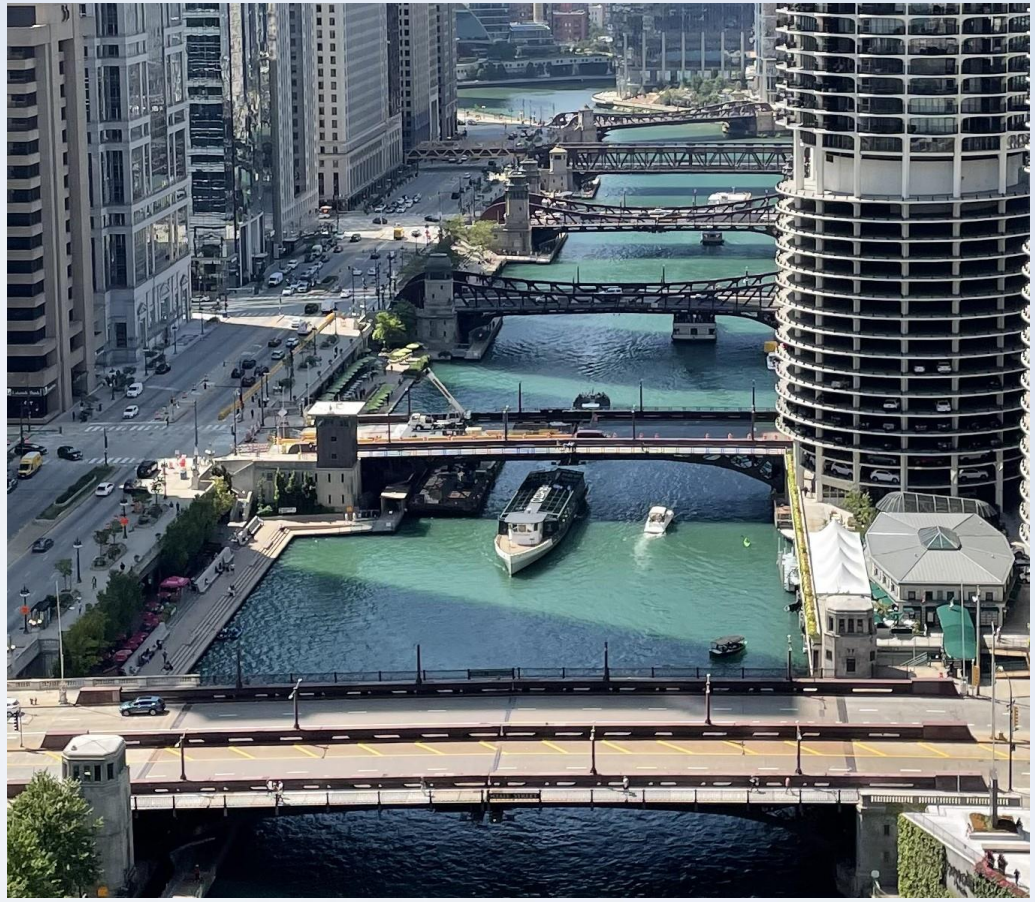
Chicago Loop Movable Bridges



Movable Bridges

While all movable bridges follow the same general design and operational principles, each bridge has a unique design, geometry for the time period, and operational demand.

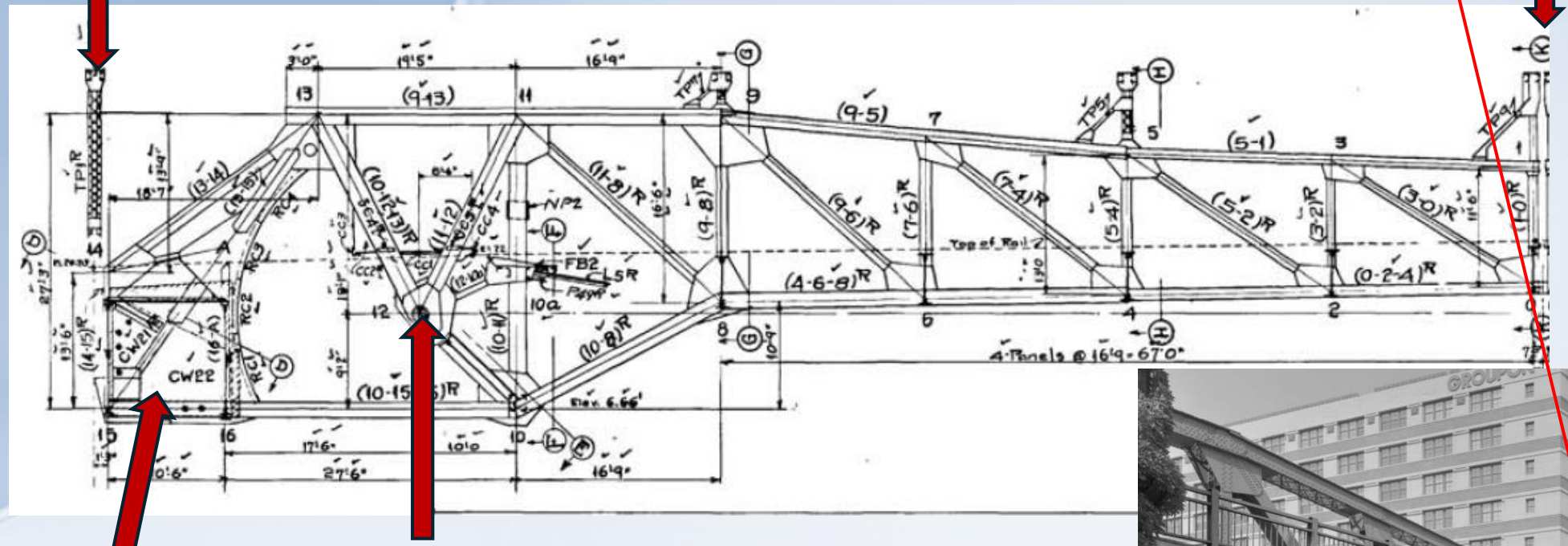
- No two Bascule Bridges are the same
- No two Bridge Tenders Operate the bridge exactly the same way
- Know the People Operating and Maintaining these Complex Structures



Single Leaf of a Bascule* Bridge

Rear Break

Center Break

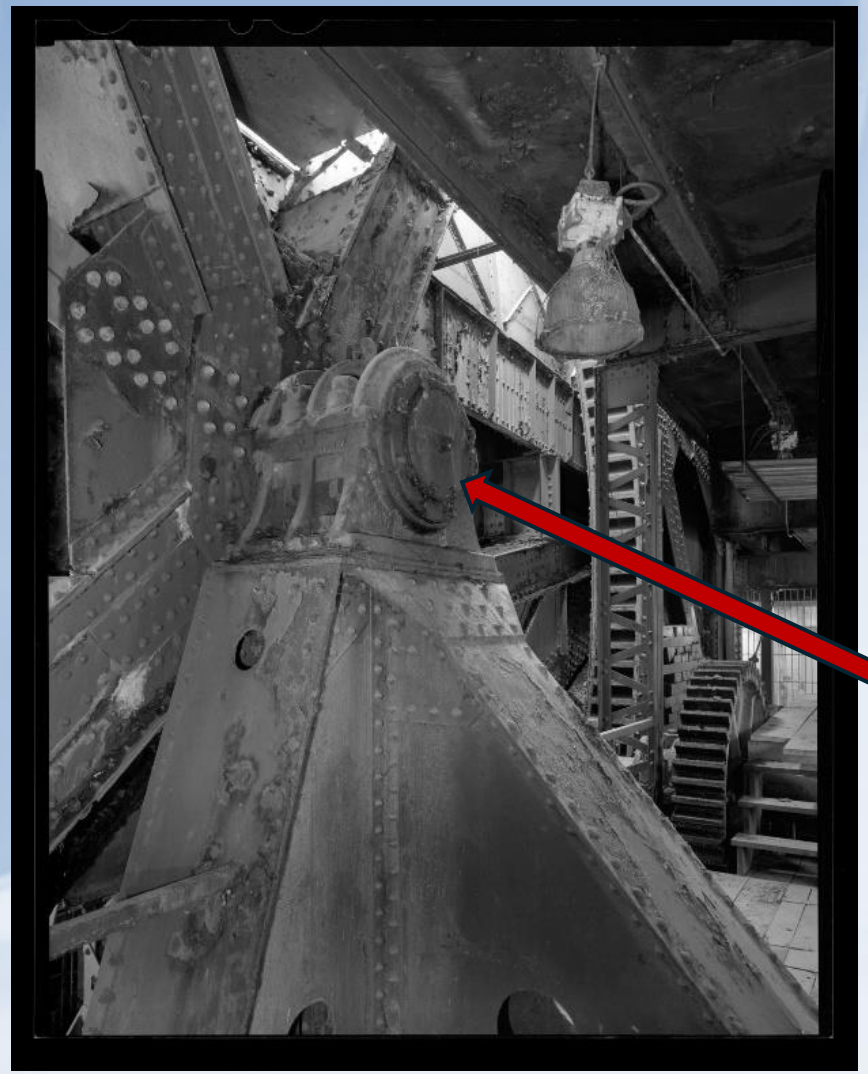


Trunnion

Counterweight

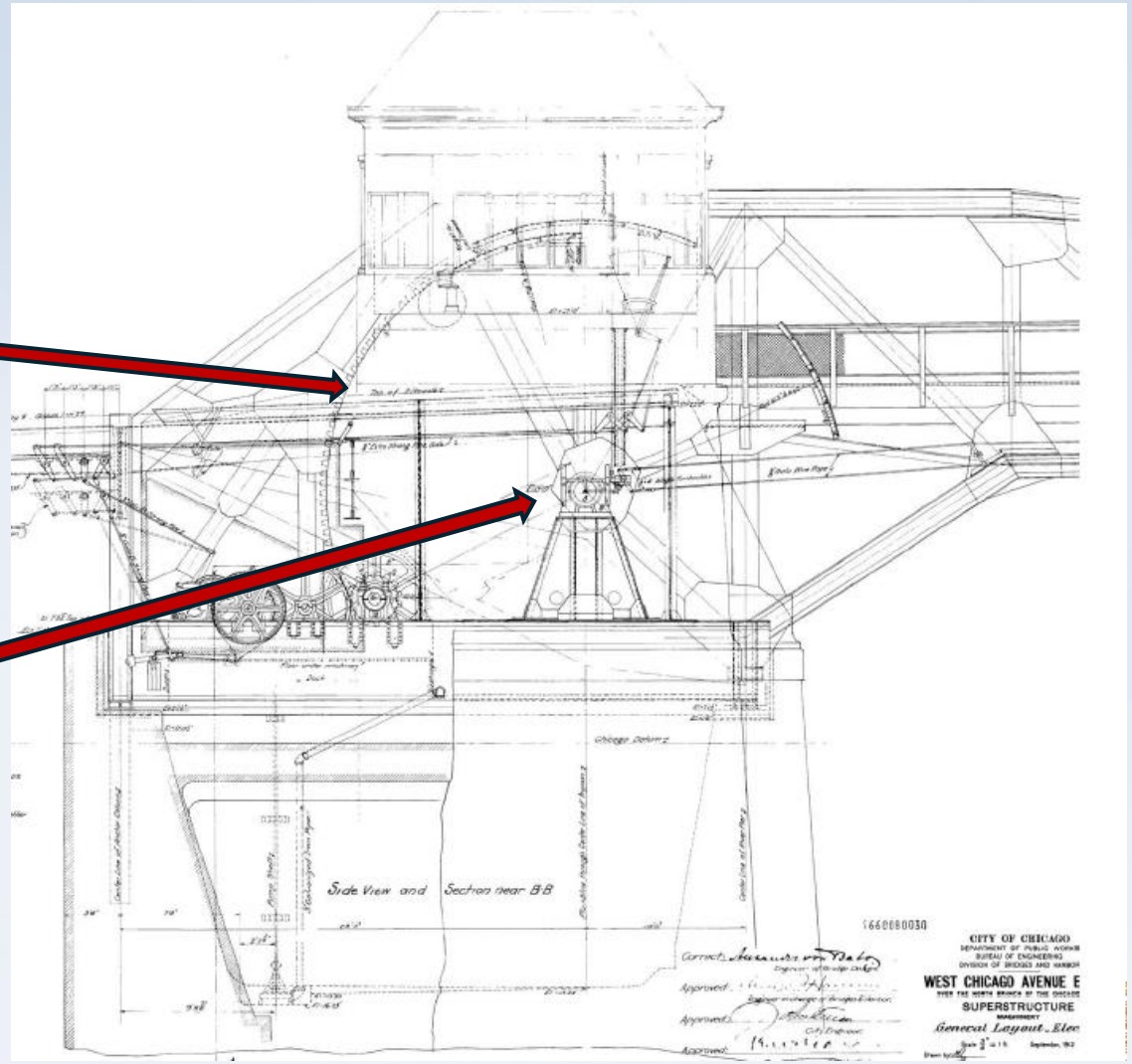
*Bascule - French for “Seesaw”

Bridge House and Gears Elevation

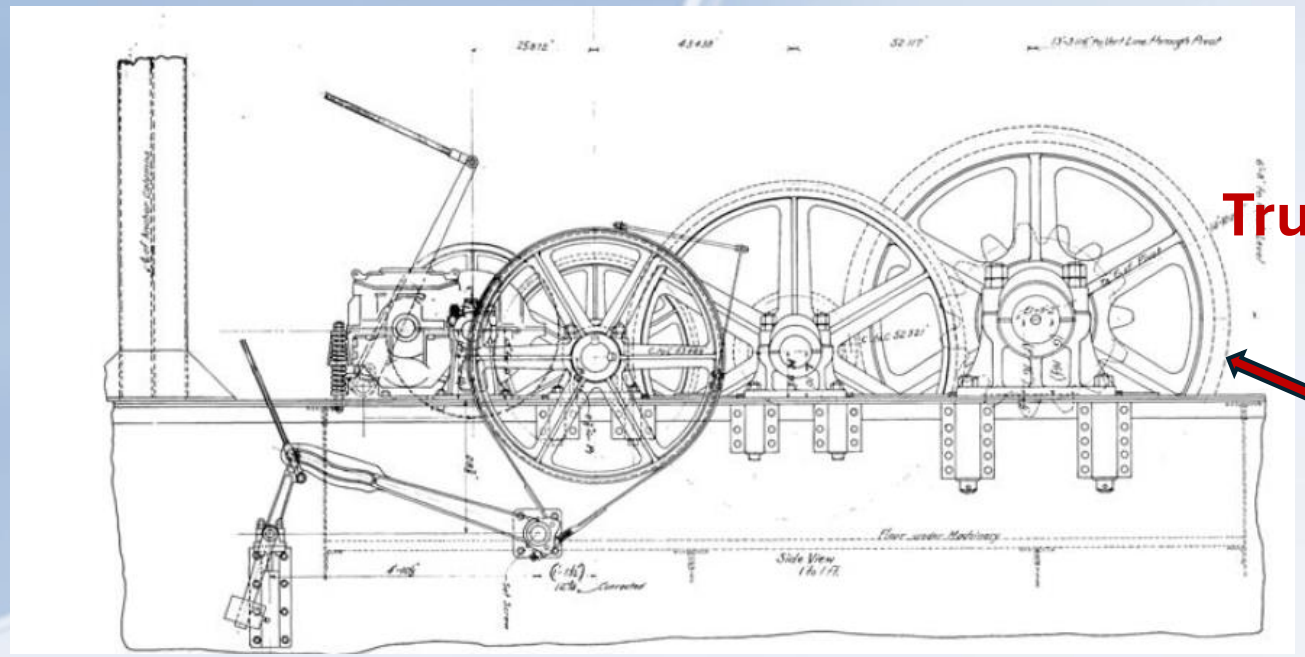


Rack

Trunnion



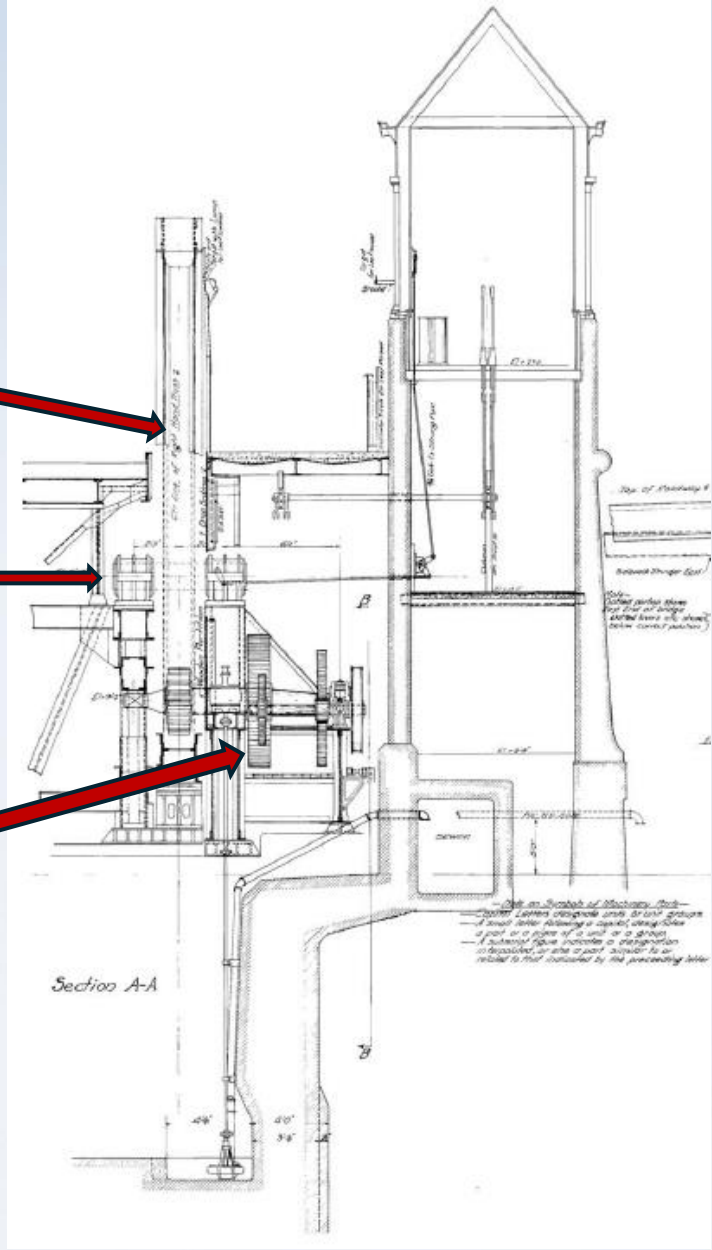
Bridge House and Gears Section



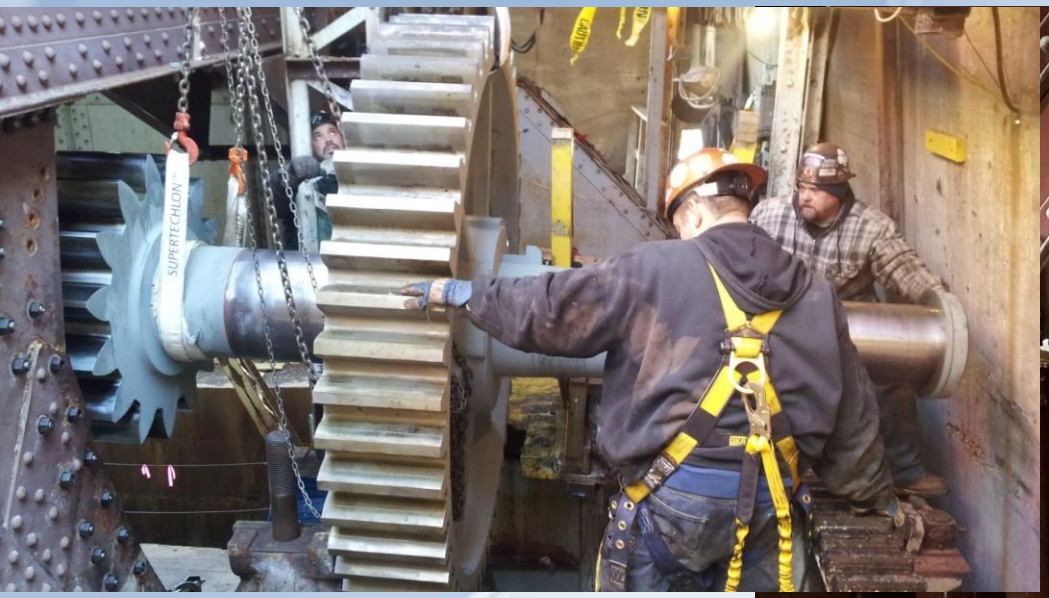
Rack

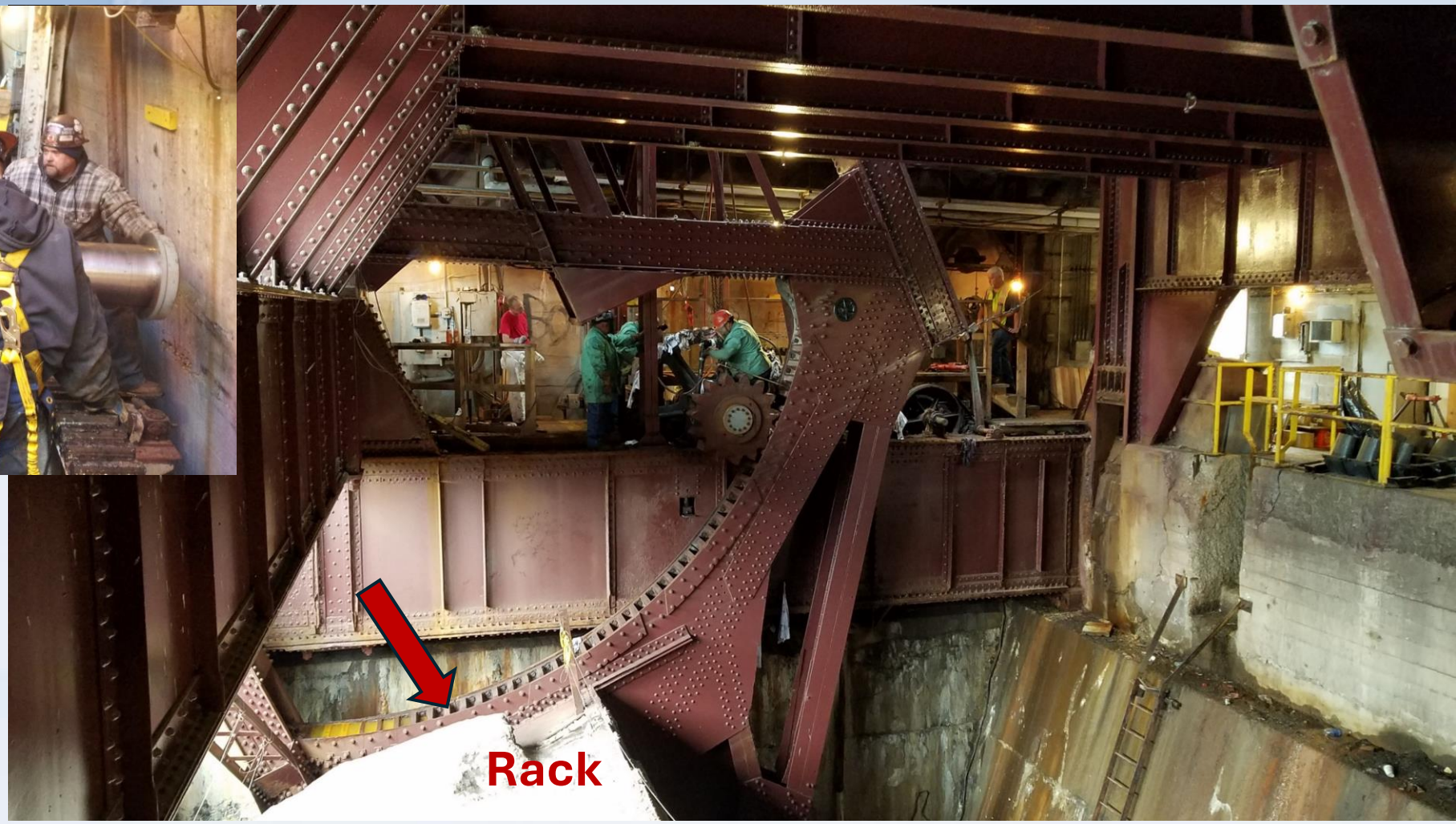
Trunnion

Gears

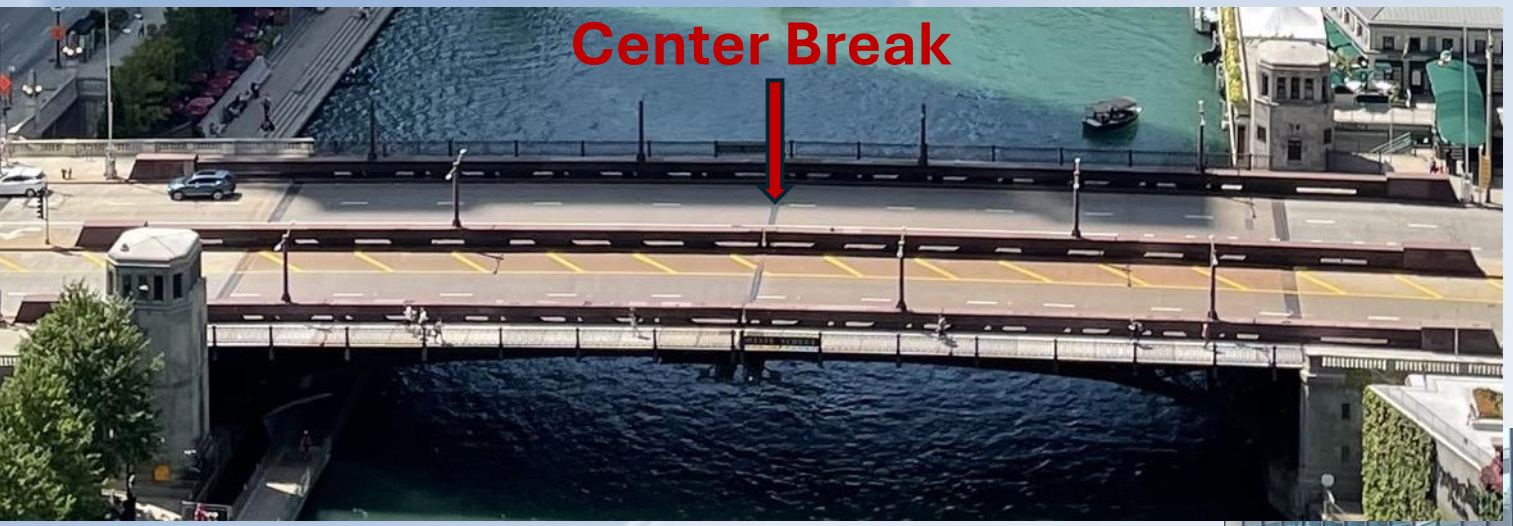


Pinion Gear

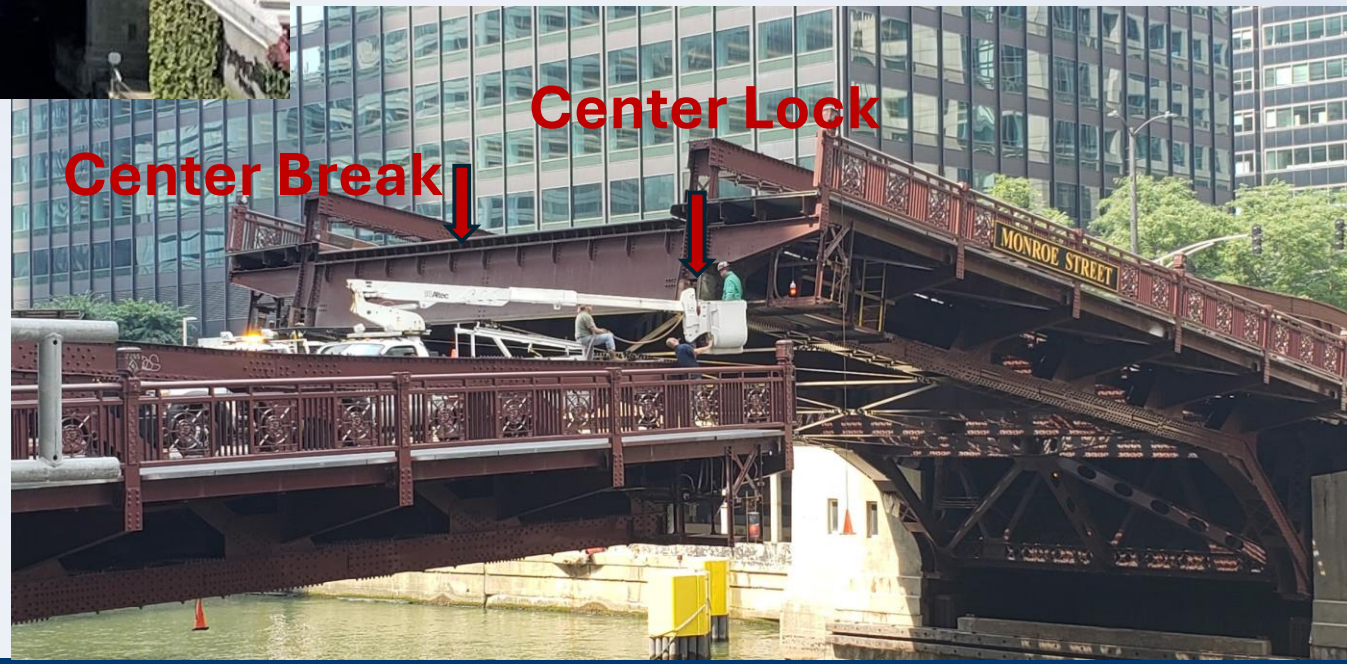




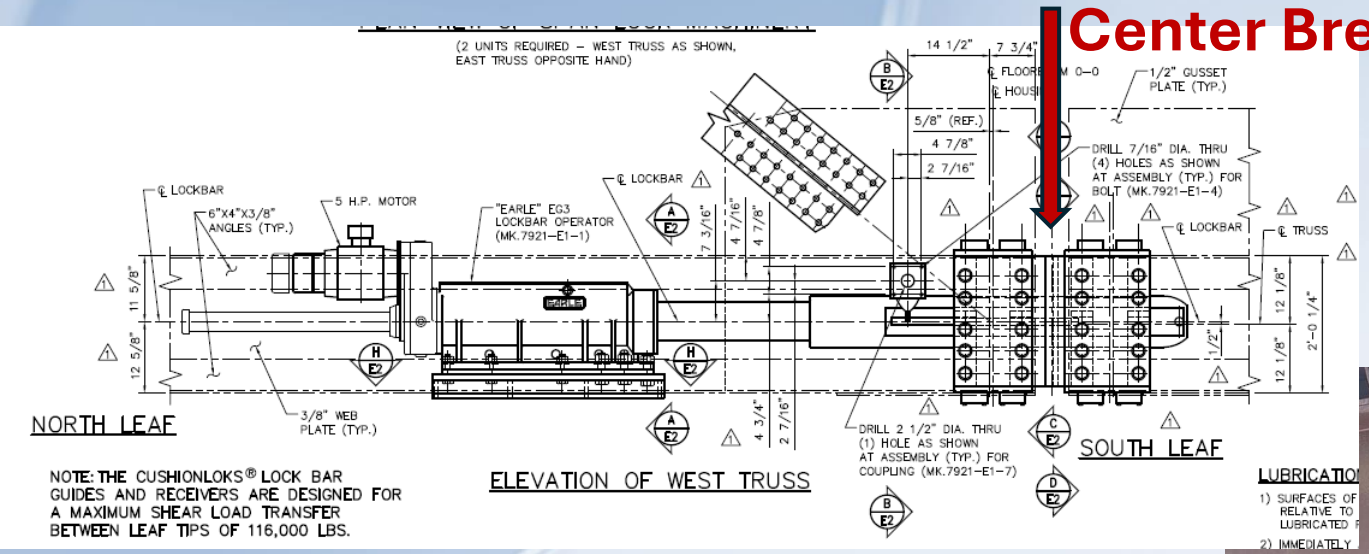
Center Lock



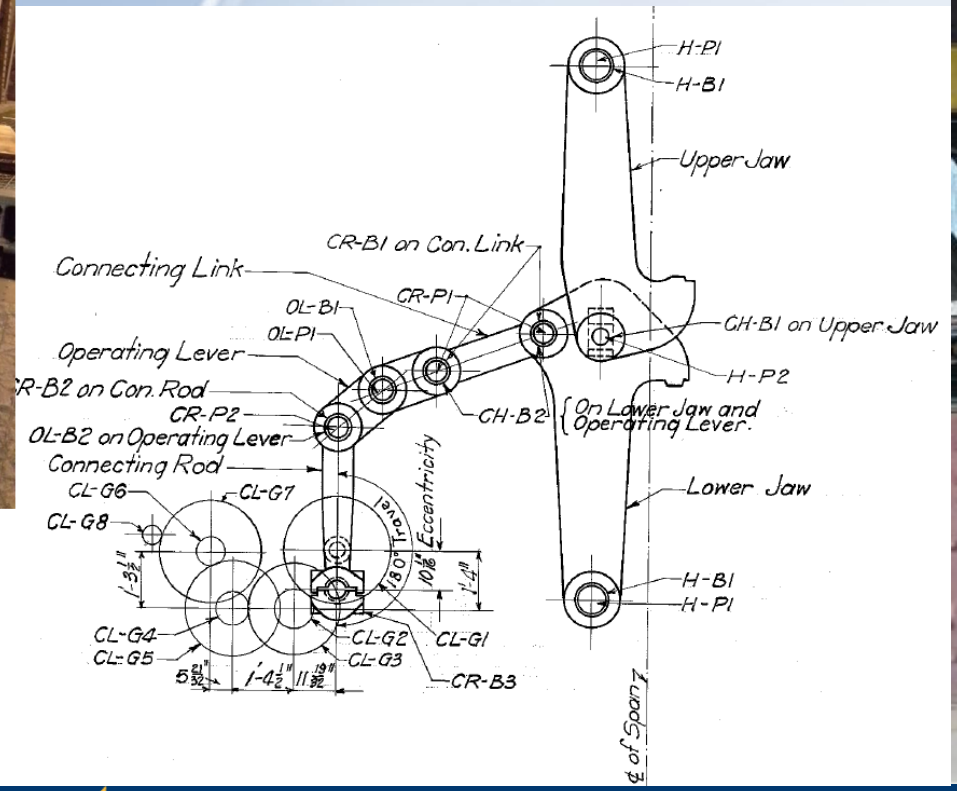
Center locks are installed so that loading on one leaf will force the other leaf to deflect an equal amount, thereby transferring forces and providing a smooth roadway for the traffic.



Center Lock Cont.

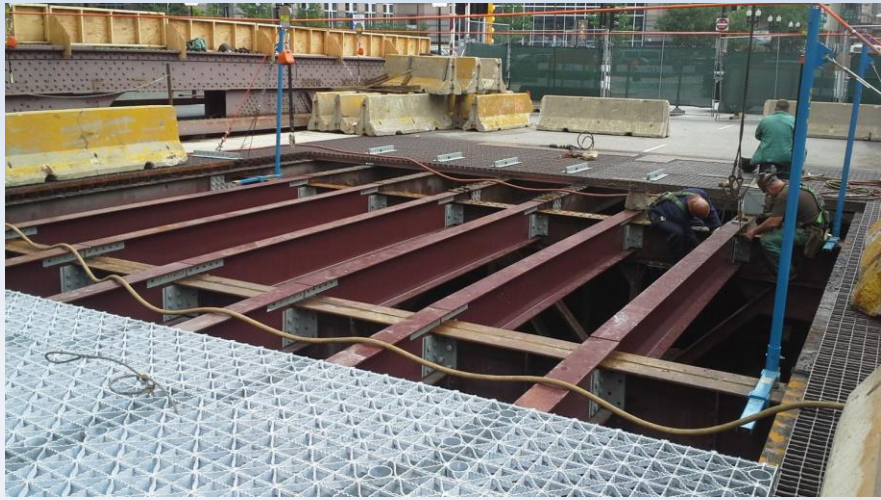


Center Lock- Scissor Locks



Deck and Framing System

- When re-decking existing bridges, the jack beams shall be eliminated by the use of deeper beams and/or by spacing stringers more closely.
- Whenever possible, a closed deck such as full or half depth concrete-filled shall be used. If a fully closed deck causes difficulty in balancing, then a closed deck shall extend from the rear break to at least the nearest floor beam. **The life of the bridge floor can be extended by covering as much of the framing as possible.**



Alignment

- Seasonal and daily temperature changes, affect the alignment and position of different components of the bridge. As the bridge materials expand or contract due to temperature changes, alignment of the mechanical components become affected. This leads to an increase in friction between moving parts. During bridge operation, significant changes in mechanical friction may be an indicator of a need for maintenance or adjustments in component alignment.
- For example, on a few occasions having the Fire Department hose down the bridge in the late afternoon during a boat run when the temperatures gets too high.

Alignment During Construction

- During a rehabilitation project don't replace all floorbeams at the same time:
  - Once these have been removed the bridge will twist/deflect because the existing loads are isometrical.
  - Old stressed that have been introduced into the system during repairs.
  - Or some connections have been loosened.
- Once this happen it will be extremely difficult to get the original shape, and you may end up additional residual stresses to the structure.

Properly Supported

- A typical bascule bridge has three supports: **Trunnion**, **Live Load Bearing,** and **Anchor Column**.
- The Bridge is consider to be properly position when, under **No Live Loads**, the **Live Load Shoe** is in contact with the **Live Load Bearing**, and a gap of up to **1/4”** at the **Anchor Column**.
- In other words, the anchor column is considered a redundant support, preventing the trunnion from being subjected to excess uplift under live loads.
- When the bridge is not properly positioned, there is contact at the anchor column and a gap at the live load bearing without live load.

Span Balance

- Span balance for bascule bridges should follow the AASHTO LRFD provisions except that the DOT preference.
- Remember no 2 Bascule Bridges are the Same, so talk to the user, and learn of the operational history of that structure.
- Balance and alignment are affected by rehabilitation, repairs, deterioration, and/or painting projects.
- Incorrect balance condition will lead to different support reactions, internal stresses, and a fundamentally different behavior.
- If properly balanced, the span should drift to close when held at the near half open positions. If the span drifts down too quickly or drifts down from the fully open position, it may be too span-heavy.

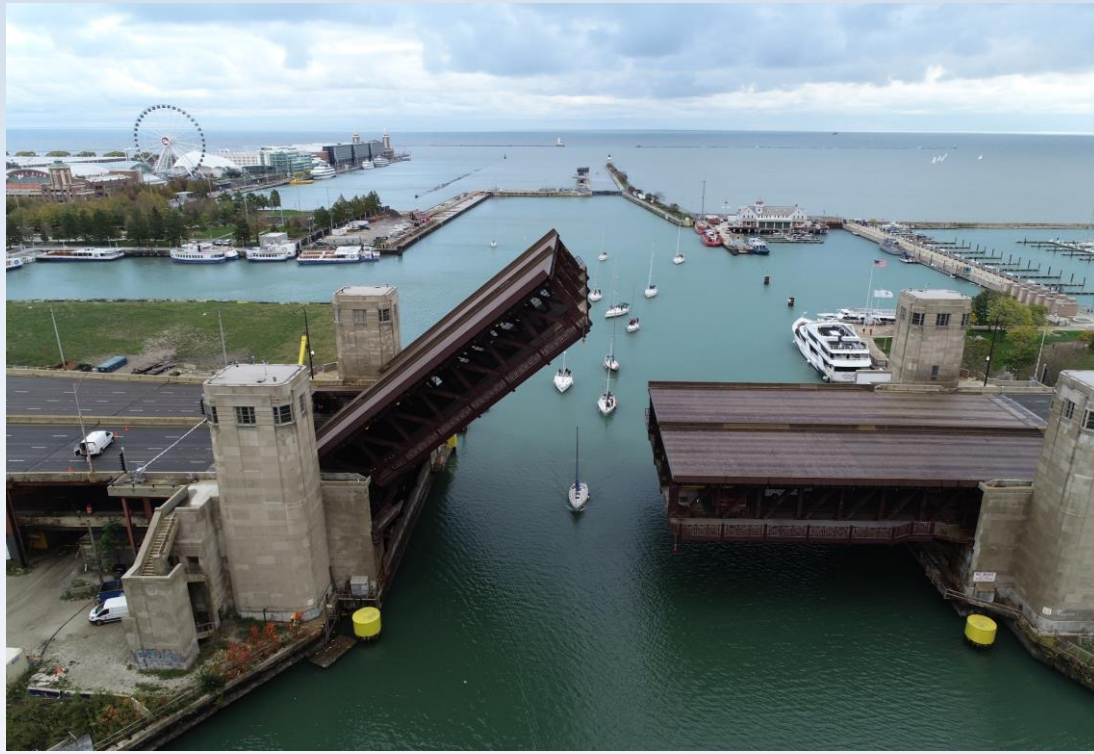
Balance Testing

There are three main ways to perform a balance test:

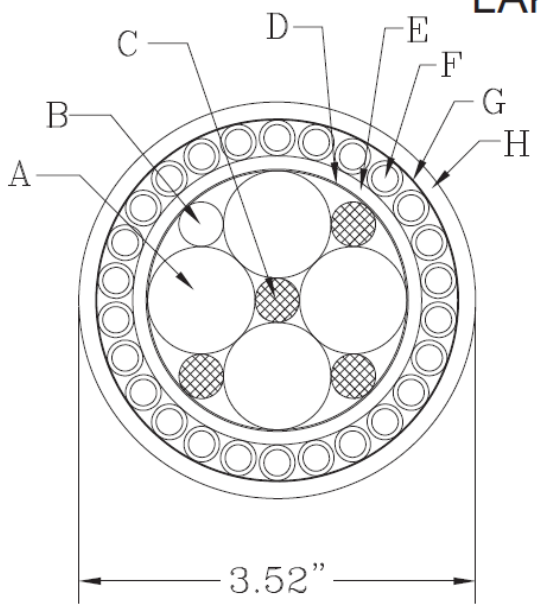
- Drift Test (typ. used by In-House Work Forces)
- Strain Gauge Testing (Used during Phase II & III)
- Motor Current Balance Testing (not typically used)

Drift Test

- Drift tests can be used to make correcting adjustments to the counterweight. To conduct a drift test, the span is raised to 10 degrees open and held. The brakes are then manually released. The spans should slowly drift to the closed position. The test is repeated at 10-degree intervals until the spans are fully open.
- If properly balanced, the span should drift to a nearly closed position when held at the near half open positions.



Submarine Cables



LAKEFRONT TRAIL / LAKE SHORE DR

SUBMARINE CABLE 030384 MOD

A – 4/c 500 KCMIL 37/w Uncoated Copper, Separator, .075” wall XLP Insulation – 2,000V Printed ”1–ONE, 2–TWO, etc.”

B – #1/0 AWG 19/w Uncoated Copper, Green Covered Jacket – Ground

C – Non–Hygroscopic Fillers, as necessary

D – .008” Rubber/Fabric Tape

E – .110” wall HDPE Inner Jacket

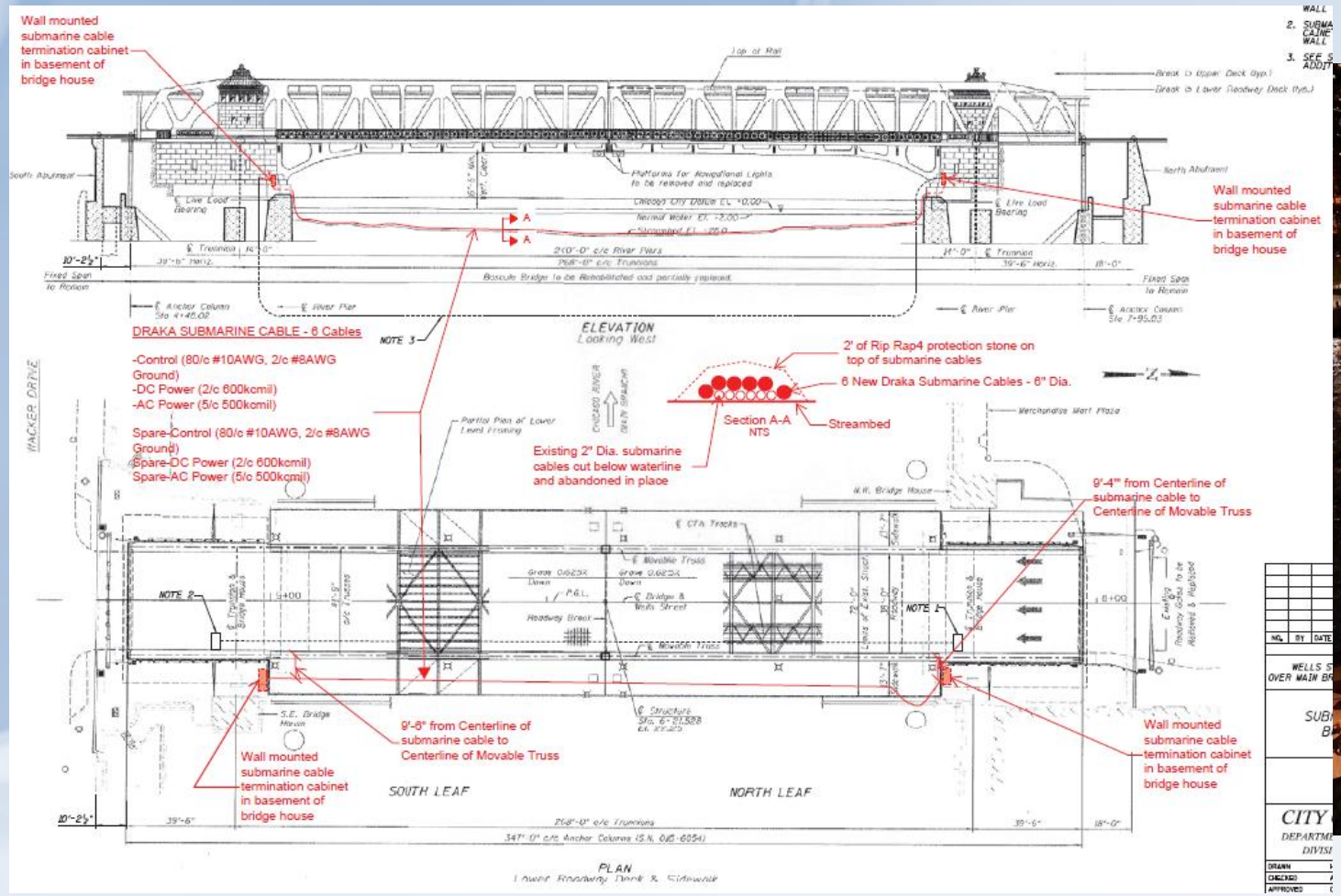
F – #4 BWG (.238”) Galvanized Steel Wires covered with HDPE

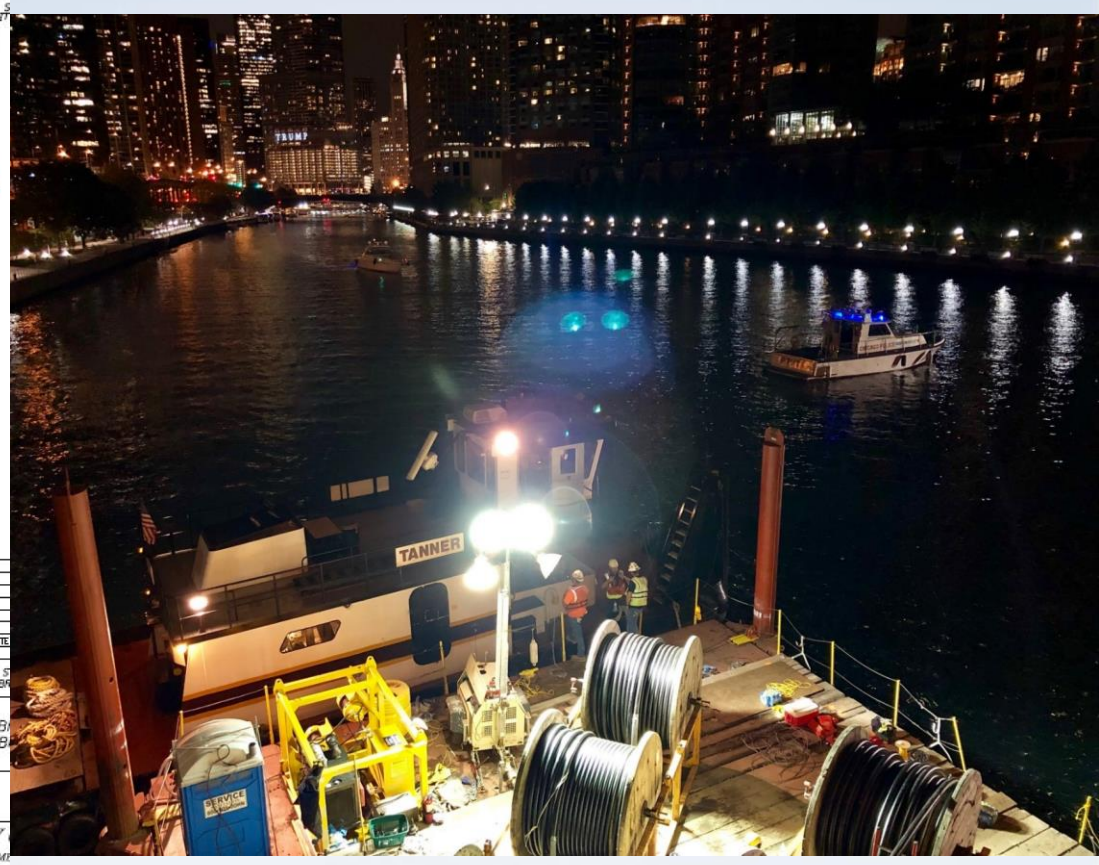
G – .002’ Corrugated Polyester Tape

H – .140” wall HDPE Outer Jacket

NOTE: Weight in air – 12.9 lbs/ft
Weight in water – 9.1 lbs/ft
Bend Radius – 22” min.
Voltage Rating – 2000V
Installation Load – 7,000 lbs max.
Cable in accordance with Lakefront Bicycle Trail #3 over the Chicago River CDOT Project NO.: E–6–650 Item 179 Submarine Cable Assembly

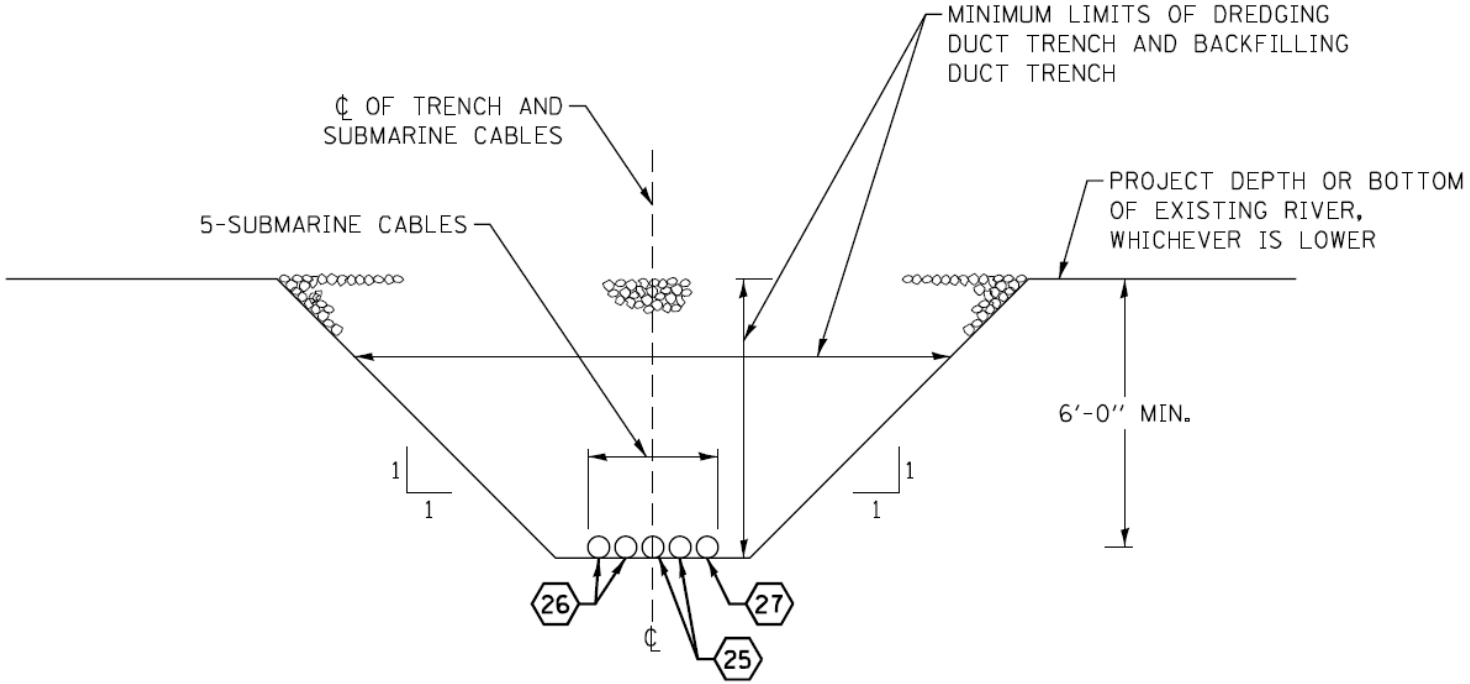
Submarine Cables Cont.





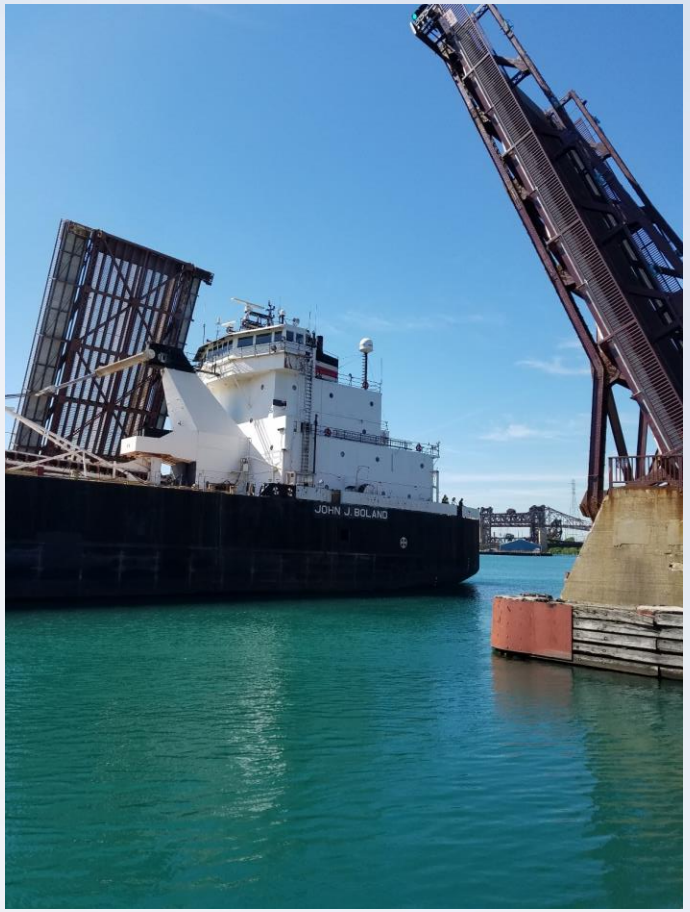
Submarine Cables Cont.

Submarine Cables - designers like to include the dredging option of submarine cables instead of self settling installation, but often forget the interruption to vessels.

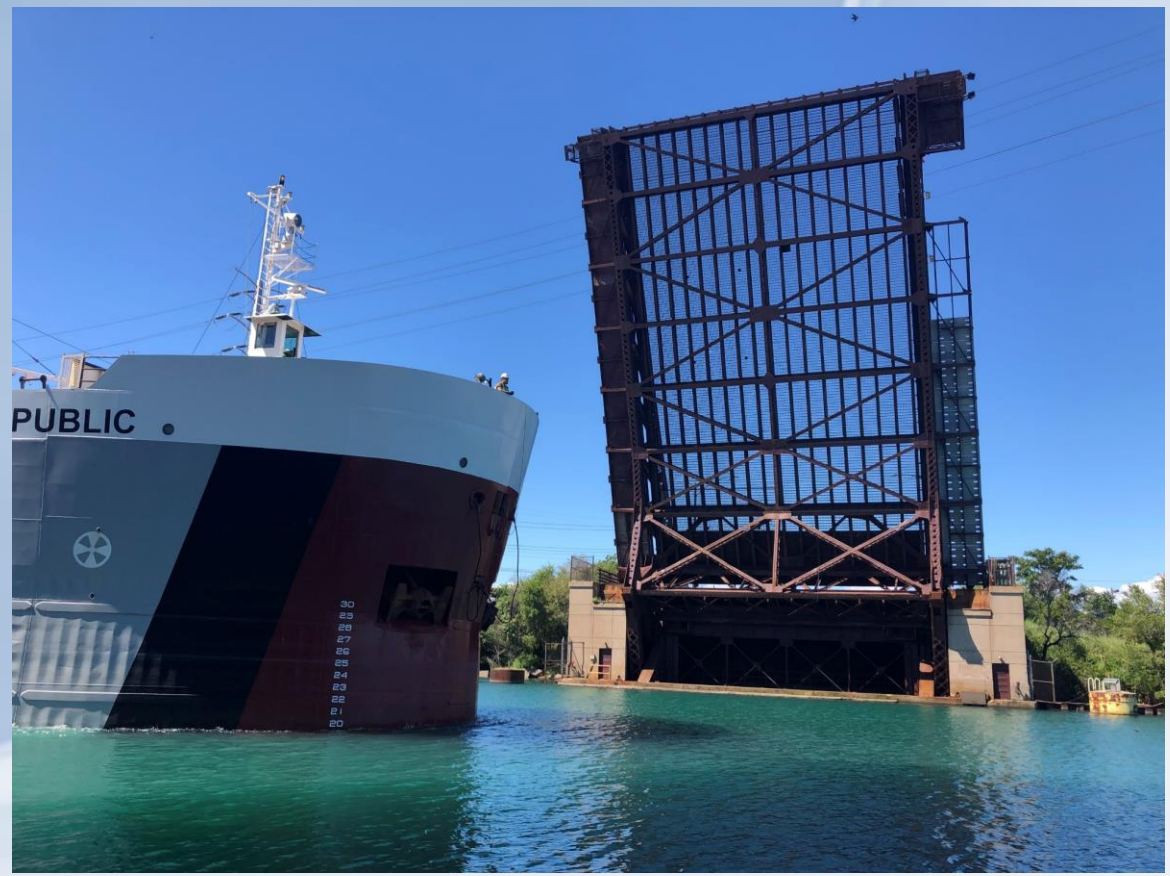


SECTION THROUGH SUBMARINE CABLE TRENCH

NOT TO SCALE



Submarine Cables Cont.

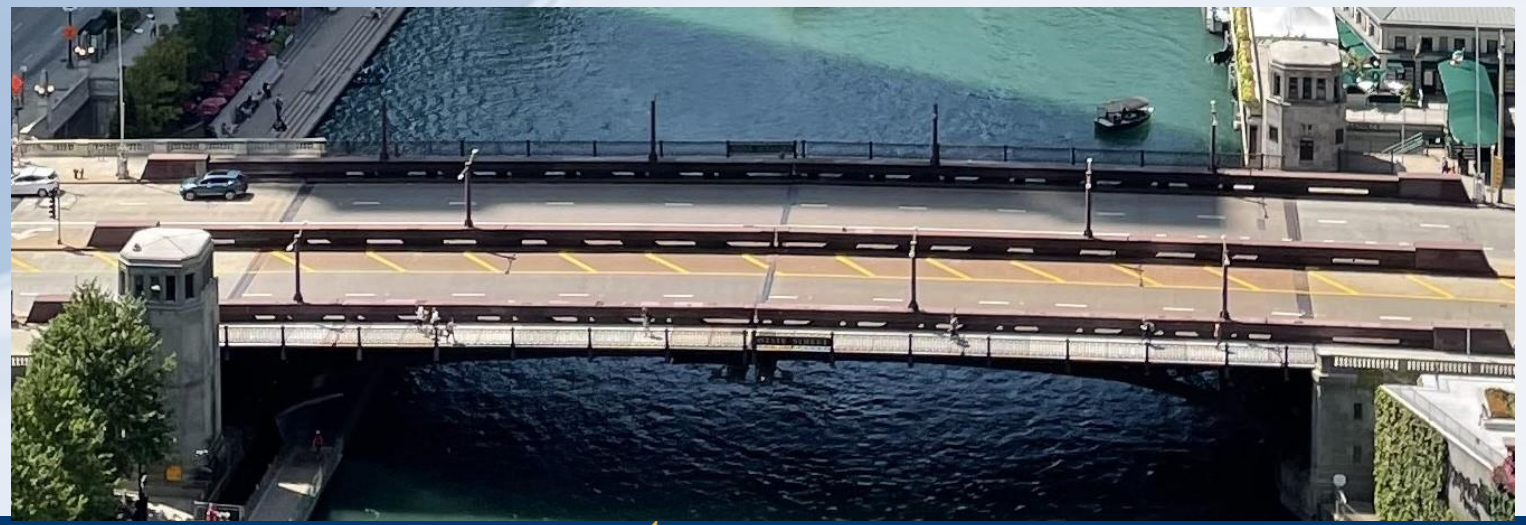


Background - Control Systems

- A.C. motors required a great deal of modification to minimize the pounding of the pinion gears in the rack teeth when one pinion would lag or lead the other. This pounding was even more drastic when the size of the motors required a separate regulator for each motor.
- D.C. proved to be a much smoother operation due to the fact that each of the two main motor armatures could be put in series, forcing both pinion gears to synchronize in the rack teeth.
- The primary function of a bridge electrical drive is to provide a smooth, controlled acceleration and deceleration in both raising and lowering bridge leaves.

Bridge Leaf Control

- Each leaf shall be capable of being operated independently from its respective Control Console when required for maintenance or emergency reasons (vessels collisions). In the event that control of either leaf is lost by the Control Console because of any failure, the submarine cable provides the operator the ability to transfer power and control to independently operate each leaf from either side.



Include in Capital/Repair/Maintenance Projects

- Greasing of geartrains, bearings, and other movable parts: often missed on specs for rehabilitation projects.
- Personnel Safety: Machinery and brake covers, painting repairing walkways, and safety rails.
- Cleaning Stringers and Floor Beams on Open Grid Decks
- Cleaning of the Counterweight Pits and Sump Pumps
- Painting of ALL structural components
- Reliability Testing: **shimming** of live load bearings, anchor columns, center lock, and heel locks.
- Operational Lighting and Gates

Rule of Thumb

- The size, type of structural members take in consideration the access for **future inspection and repairs**
- If possible, all parts of the bridge should be accessible for painting and repairs.
- The allowable stress of any part not accessible shall be taken as half.

Rule of Thumb Cont.

The following members shall be designed to allow for 1/16” cross-section loss due to corrosion at the surfaces where members are prone to accumulation of dirt, water, snow, deicing salts, etc.:

- Trunnion girders, longitudinal girders, and S-girders
- Truss member spanning between the counterweight box and live load support
- Anchor column and trunnion column
- Anchor bolts and trunnion bolts (min. 2” in diameter)
- Floor beams or columns immediately at the expansion joint
- Stringers and floor beams carrying open steel grid
- Gusset plates of main truss (min. thickness 3/4 inch)

Construction - Movable Bridge Coordinator

- **Construction** should be added to the contract documents: The Contractor to designate a Movable Bridge Coordinator who shall coordinate all aspects of the Bascule Bridge Rehabilitation. The Movable Bridge Coordinator coordinate the structural, architectural, mechanical, and electrical work to ensure proper implementation and operations.
- **Desing**, also known as the **PM**: This person needs to have a general understanding of Structural, Electrical, Mechanical, Civil, Architectural, and Computer Engineering to be a good Project Manger of a Movable Bridge Project.

  ✓Know your client, know the owner, and know the workforce operating these Bascule Bridges.

  ✓No two Bascule Bridge are the same, each bridge has a unique design, geometry time period, and operational demand.

Specifications Improvements

- Performance based specifications for Mechanical and Electrical work need to be minimized as much as possible, and include as many details as possible in the specs/drawings.

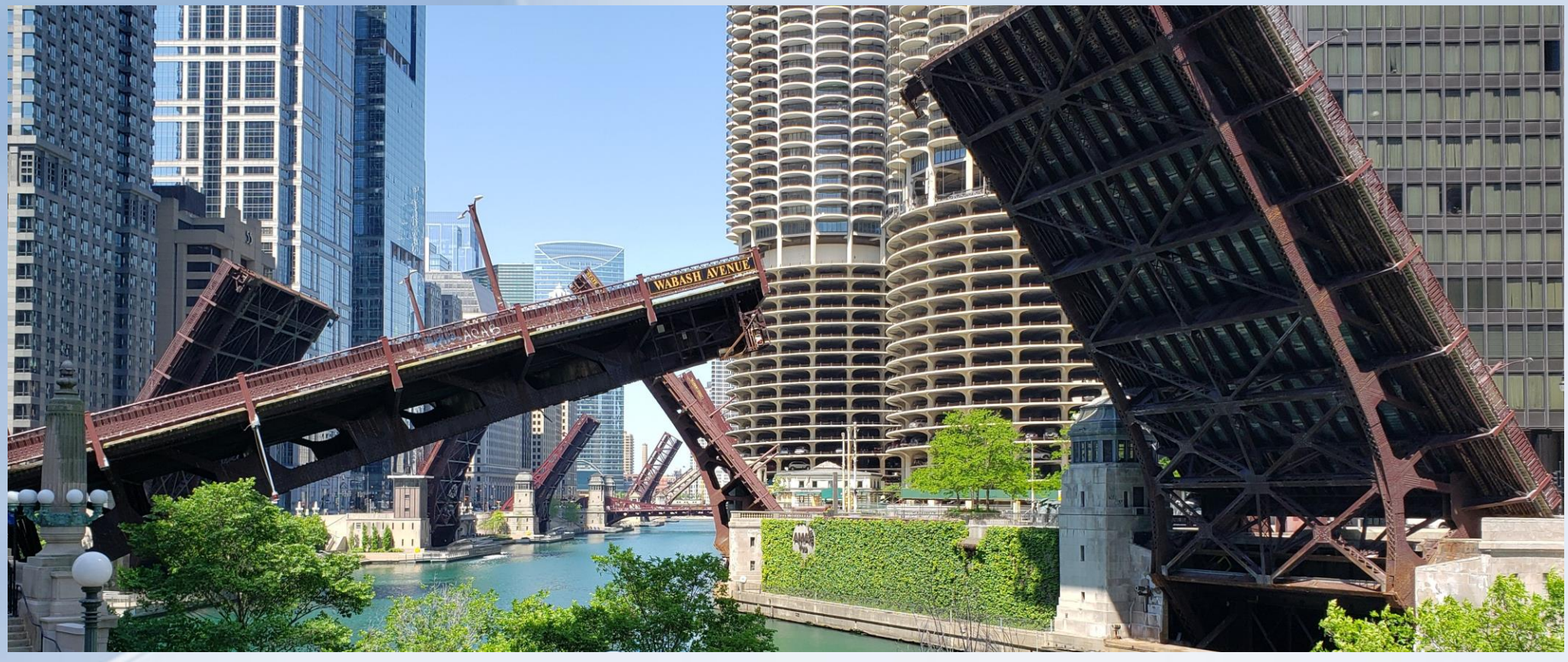
- For rehabilitation projects of 100-year Bascule Bridges, a good practice is to include both Electrical and Mechanical allowance of each. Unless you are doing a complete replacement.

- Avoid complex lump sum items that have potential for changes. Is hard to accommodate any changes in those items, and cause claims by the contractor.

Specifications Improvements Cont.

- These are old bridges and some of them may have asbestos in the mortar or in the interior building materials. Make sure this is properly detailed in the spec/drawings, because there are many instances that the remediation work will hold all work.

- The specifications should include a list of final acceptance criteria:
  - Should include stipulation for the minimum number of days to witness testing with DOT prior to final acceptance.
  - Should include stipulation for the minimum number of days for training DOT work forces prior to turnover.



Any Questions?

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