HEAVY MOVABLE STRUCTURES, INC.
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Haystack Bridge: Repurpose of a Bascule

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Project Background

The Sonoma Marin Rapid Transit (SMART) District was established by California State legislation in 2002, and with the voter approval in 2008 of Measure Q, a 0.25% sales tax, the district embarked upon construction of passenger rail service from Healdsburg to Larkspur in Northern California. Having already purchased the historic Northwestern Pacific right-of-way, which roughly parallels US Highway 101, SMART began evaluating the existing right of way for the design service life of the new passenger rail service. One of the oldest structures on the right of way was the existing Haystack swing bridge (built in 1904) over the Petaluma River.

During the initial condition assessment of the swing bridge, it was brought to SMART's attention that the Galveston Causeway bascule bridge in Texas was due for replacement. This existing rolling bascule bridge, built and installed in 1986, would be removed from service, replaced by a new vertical lift bridge that increases the channel width at the Galveston site. SMART undertook an initial evaluation and condition assessment of the bascule bridge and determined that for roughly the same cost to rehabilitate the existing swing bridge, SMART could purchase and install the bascule bridge.

Some of the major advantages of replacing the swing bridge are as follows:
1.) Increased lifespan of the structure;
2.) Higher allowable train speed for the newer bridge; and,
3.) Improved navigational experience with larger channel and reduced operation times for opening and closing the bridge.

Figure 1 – Removal from Galveston Causeway

Rolling Bascule Arrangement & Details

The new Haystack Bridge is a steel truss rolling bascule with a main span of 124'-5", which allows for a navigational channel of just under 90'-0" (see Figure 2). The bridge was disassembled, shipped to a California facility (nearby the Haystack Bridge) and then modified and refurbished prior to site installation. The seismic requirements for the project led to the majority of the modifications, such as a method for locking the structure in place in both the open and closed positions. A major challenge for the project was that both the rail and navigational channel had to remain operational during the construction of the bridge, and the contractor was limited to a very short one-time outage during which the rail service would be switched from the old swing bridge to the new bascule bridge.

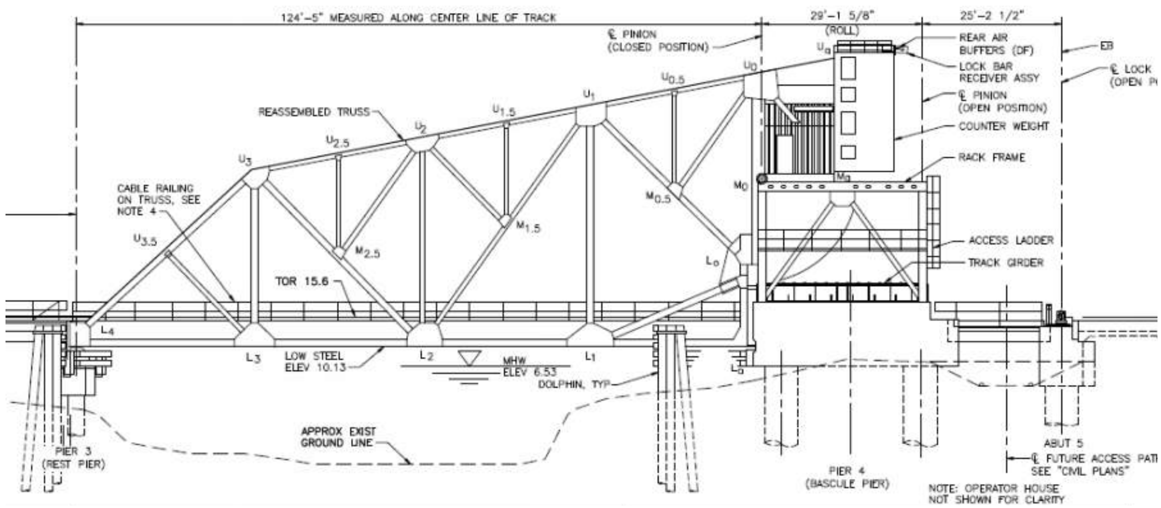

Figure 2 - General Arrangement

Rolling Bascule Mechanical and Electrical Systems

The bascule leaf support machinery consists of flat and curved tread plate assemblies. The existing flat tread plate assemblies were re-used and installed on new track girders and the existing curved tread plate assemblies were re-used and remained installed on the segmental girders and the connection bolts were re-used to the extent possible. Line bearing of segmental girder on track girder was checked only for the 100-year seismic load combination using 150% of the allowable stresses from AREMA 6.5.35.5 and without dead load impact.

The bascule leaf drive machinery was assembled partly from existing components and partly from new components. One new rack pinion shaft was provided because the original shaft was destroyed as part of the bridge removal process. The design included evaluating the existing rack pinion gears for use on the new shaft. The condition of all other machinery on the output side of the speed reducer and the speed reducer was evaluated and components were re-used to the extent possible. Any components that could not be re-used were replaced in kind.

The machinery is operated by two (2) new duty motors that are arranged to operate simultaneously during normal operation. In the event of a single motor failure or standby generator operation, the bridge is configured for single motor operation at reduced speed using either motor. New span drive machinery brakes were provided and a new support was provided for the new span drive motors and brakes and was designed to fit up with the existing structure. All new components were designed and detailed to meet AREMA requirements.

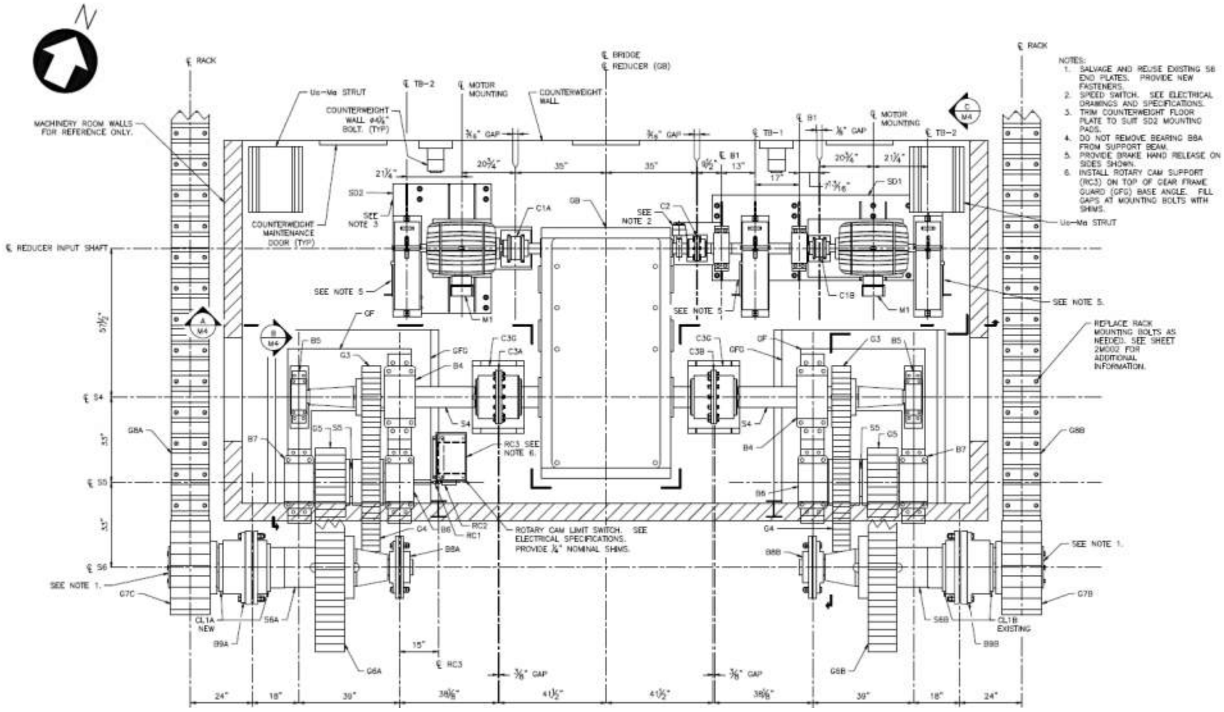

Figure 3 – Span Drive Machinery Layout

There are two air buffers mounted at the toe end of the bascule span that are used when closing the bridge and two air buffers mounted on the counterweight that are used when opening the bridge to the fully open position. The existing air buffers were installed on the bascule span and counterweight after being disassembled at a shop, rehabilitated as needed and tested in accordance with AREMA requirements to ensure reliable operation.

The existing live load supports and centering devices were evaluated, rehabilitated as required and installed in the proper location to support the toe end of the structure and to properly align the structure in the fully closed position.

New span lock systems were designed for each truss to hold the span in the normally open position. The open position span lock system was sized for winds loads in accordance with AREMA requirements. For the closed position, the existing span lock system was refurbished and installed at the toe of the bascule span. Once engaged both the open and closed position span lock systems participate in the overall seismic resistance. Under the 100 year serviceability event, minor repairable damage is expected. Under the 500 year and 2400 year event, the span lock systems could suffer significant damage and plastic deformation due to post-yield behavior.

Capacity of both span locks for the Level II seismic forces was checked using the ultimate strength of the lock bar material. Extensive damage to engaged span locks is expected to occur under 2400 year event forces but failure is not expected. This is permissible under the defined project design criteria.

The bridge electrical system was developed in accordance with the defined operating criteria, AREMA requirements and to satisfy the constraints of the proposed mechanical operating system. The bridge electrical system was based on controlling accurately both operating speed and torque smoothly under all operating configurations and loading conditions. Conventional interfaces and safety interlocks were provided between the bridge operating system and the railroad train control/signal system to assure safe railroad and bridge operations.

The bridge control system was based on distributed Programmable Logic Control (PLC) with PLC's located in the MCC and also housed in the operator's control console. Fiber optic communications were utilized for communications between the PLC's, the standby generator, telephone, intrusion alarm, fire alarm, CCTV, etc. associated with the bridge. The PLC and communications are arranged to allow remote surveillance and control of the bridge from SMART control and railroad dispatching center.

Apart from remote control the bridge is capable of being locally controlled from a control console strategically located in the operator's control house to optimize, in conjunction with CCTV, vision of the approaching railroad and navigable channel for ease and safe bridge operation.

As part of the mechanical and electrical design the requirements for testing and commissioning were defined and specified. This consisted of both factory/shop testing and inspection as well as complete testing and commissioning of the installed mechanical and electrical systems. The mechanical shop testing and inspection definition and specification included meeting the testing and inspection requirements as defined by SMART as well as by AREMA 6.8 and assuring the accuracy and quality of the work prior to the mechanical components being released to the field for erection.

The electrical testing that was specified included factory electrical testing of each major item of electrical equipment followed by functional testing of the integrated power and control system.

Mechanical and electrical field testing and commissioning was performed in phases during and following erection of the mechanical plant and the installation of the electrical systems. During the design phase, the requirements for this testing and commissioning were specified and included necessary acceptance criteria in accordance with the SMART Contract and approvals to be met prior to the bridge being handed over and placed into service.

Field Survey of Machinery Components

Personnel from Stafford Bandlow Engineering were on site at the Napa storage yard in January 2014 to conduct a field survey of the existing machinery components for the Haystack Bridge. Shimmick Construction Company (the Contractor) personnel provided assistance throughout the inspection. The survey was generally visual in nature with limited disassembly and cleaning of components to provide a preliminary assessment of the condition to determine requirements for repair, rehabilitation, or replacement as part of the ongoing mechanical design.

The following photographs depict significant conditions found during the inspection.

Figure 4 - Gear coupling teeth severely damaged due to corrosion.

Figure 5 - Gear hub fit with the shaft with excessive clearance.

Figure 6 - Gear teeth with isolated damage.

Figure 7 – Bearing journal with moderate scoring and corrosive pitting in the fillet at the shoulder.

Figure 8 – Open gear frame with a crack the full height of the web.

Figure 9 – Different open gear frame with a crack 2/3 the height of the web.

Figure 10 – Air buffer piston rod damaged due to corrosion.

Figure 11 – Span lock operators were found in poor condition and were replaced.

Figure 12 – Both span lock front guides were badly damaged and were replaced. Shoes were salvaged.

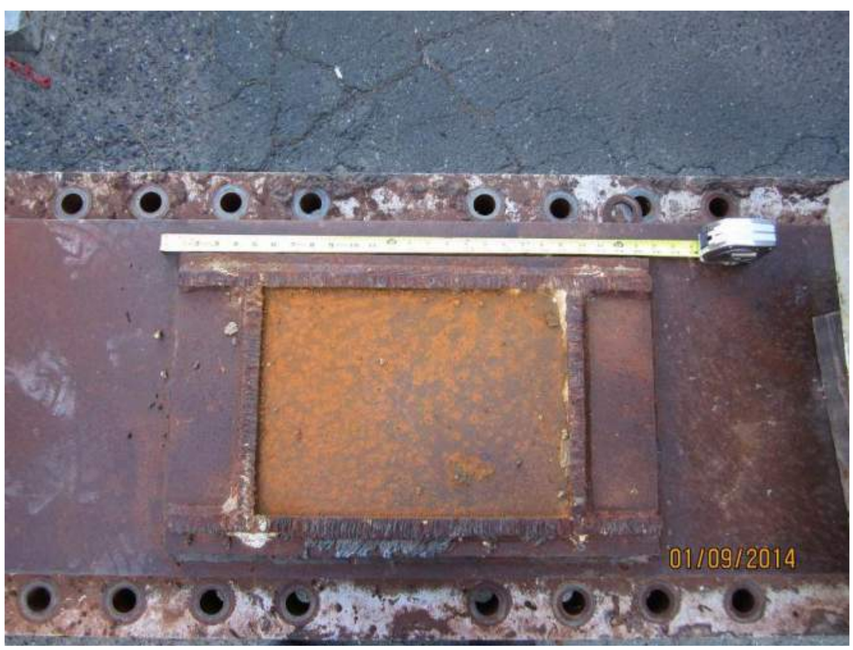

Figure 13 – There is plate welded to the rolling surface of the flat tread that was removed and the surface was repaired.

Figure 14 –A few curved tread mounting bolts were found to be damaged or missing and required replacement.

Figure 15 –Live load supports were corroded and were machined to restore a flat surface.

Erection Analysis and Scheme

The Contractor chose to erect the bridge in the vertical "open" position, to remain clear of the navigational channel, as well as to allow the existing swing bridge to remain operational allowing freight service on the line which could not be interrupted. The Contractor also wanted to erect the bridge counterweight by supporting it on the existing foundations, and avoid the need for any additional piles in an environmentally sensitive habitat. COWI's scope was to develop and validate erecting the bridge in the open position, design the temporary works required to support the counterweight and segmental girder during erection. The interim stages were modeled and validated using SAP2000, and other than some local stiffening to the counterweight box, the structure showed to be quite robust and more than adequate for the open erection scheme.

Counterweight Assembly

The counterweight assembly was probably the most complex structural component of the bridge, made up of numerous wall plates, steel counterweight and tie rods.

There were two complications with erecting the bridge in the open position.

1.) Supporting the counterweight assembly (Approximately 600 Tons) on the existing foundations.
2.) Providing a method to allow for both vertical and longitudinal adjustment of the box for bolt-up to the segmental girders.

The general scheme for supporting the counterweight is shown in Figure 16, and consists of a steel grillage supported at Abutment 5, and the main bascule pier. The foundation turned out to have more than adequate capacity to support the counterweight, as the bascule pier supports the entire bridge during opening/ closing, and Abutment 5 is designed for very large loads when the bridge is in the open positioned and then locked to Abutment 5 for the seismic loading.

The beam seat on the main bascule pier is designed for a much smaller load than it would be subjected to when supporting the counterweight assembly for the construction scheme. The Contractor engaged COWI early on in the process of developing the erection scheme, and as such, COWI was able to detail some additional local reinforcement in the beam seat region to increase the capacity of the seat for the temporary construction loading. This ensured that there was minimal impact to the construction of the main bascule pier, and had no effect on the project schedule.

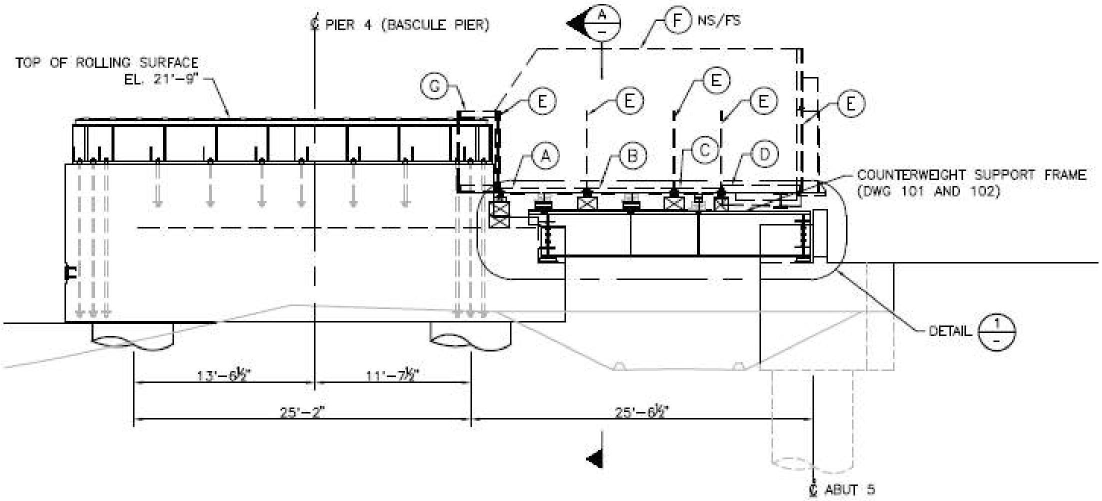

Figure 16 - Counterweight Assembly Scheme

The segmental girders were placed on the rolling girders and then the segmental girders were rolled up to bolt to the counterweight. The counterweight was assembled very close to the final position, and the system was designed to allow for +/- 1-inch vertical adjustment and +/- 2-inch longitudinal adjustment. The adjustment system design incorporated hydraulic jacks on a steel sliding plate with a Teflon sliding surface. This allowed the fine adjustment of the counterweight box for bolt-up with the segmental girders. The photo in Figure 17 shows one of the hydraulic jacks on a sliding plate.

Figure 17 - Counterweight Support Frame

The segmental girders required support once rolled to the open position, until the remainder of the counterweight assembly could be completed and provide support. COWI was able to develop a simple support mechanism that keyed into the rolling girder, and temporarily tied into a steel splice connection above. With the segmental girder supported, the counterweight frame position could be adjusted so that the segmental girder could be bolted to the counterweight assembly. After the remainder of the counterweight box was assembled, the segmental girder temporary support posts were removed.

Refer to Figure 18 for a drawing of the procedure and Figure 19 for a photo of a temporary support post.

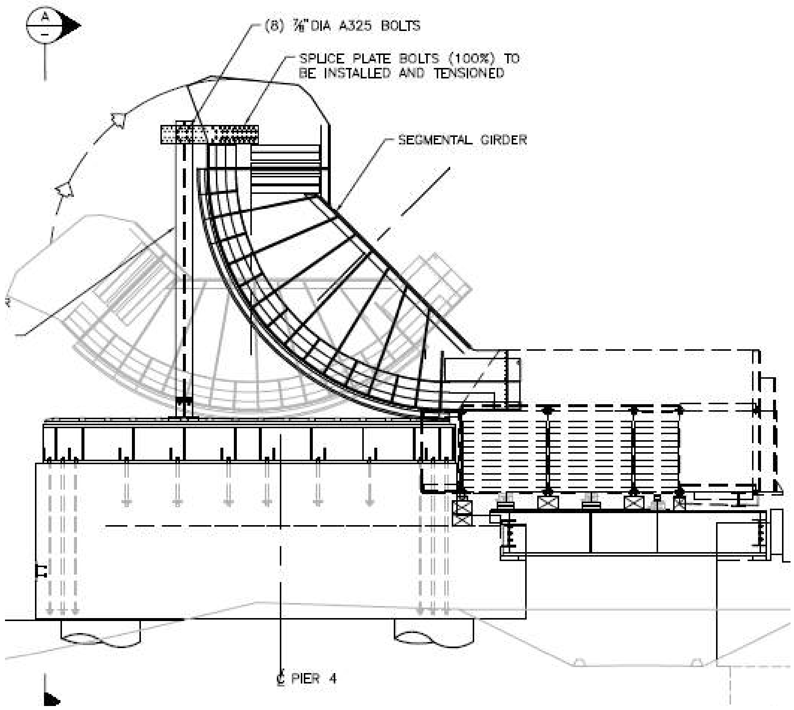

Figure 18 - Segmental Support Post

Figure 19 - Photo of Support Post

Truss Assembly

The bascule structure was dissembled into sub-assemblies in Galveston using a methodical manner resulting in units as large as possible for shipment. These sub-assemblies were never broken down with the original bolts remaining in place in order to preserve as much of the original bridge geometry as possible. The erection of the truss above counterweight level was straight-forward.

A simple tie down utilizing existing anchor bolts on Abutment 5 stabilized the structure in the interim condition. Refer to Figure 20.

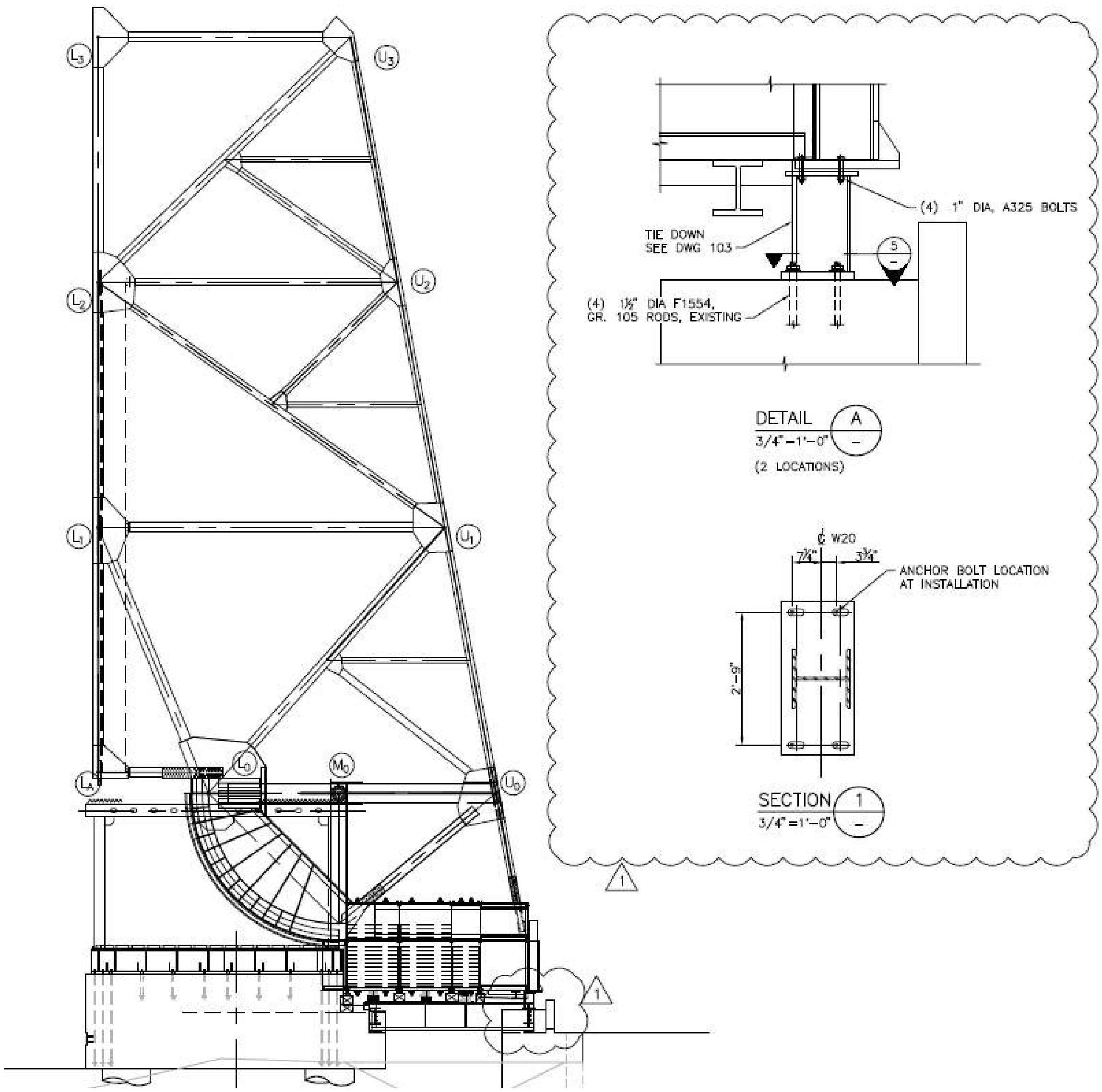

Figure 20 - Stability Tie Down for Truss Erection

Balancing Scheme

It was not practical to install the timber ties and train rails when the bridge was in the open position, so COWI was tasked with creating a scheme so the bridge would remain counterweight heavy through the entire 90 degree rotation to close the bridge. The allowable construction imbalance allowed by the owner was small, so temporary counterweight was employed on the leaf to account for the weight of the missing ties and rail to meet the imbalance requirements With the small construction counterweight heavy imbalance, only a small load was required at the tip of the bridge to pull it down to the closed position. Refer to Figure 21 for a general arrangement of the pull down scheme.

The mechanical brakes were used as a failsafe for potential unexpected events during the initial closing. Additionally, the temporary tie down (shown in Figure 20 above) was detailed with slotted holes so that the tie could remain engaged during the first 8-inches of the pull down, allowing for a preliminary assessment of the bascule balance, before the tie down was disengaged. The plan was to then to install the timber ties, rail, and any other miscellaneous items, while at the same time removing the additional counterweight installed on the bridge. Stafford Bandlow Engineering performed balance testing via the dynamic strain gage method once the bridge was operational via the span drive machinery. The data gathered during the initial pull down was used to assist in developing the final balance of the bascule. With the new bridge operational, the existing swing bridge was dismantled and the rail line re- routed to the new bridge and service restored.

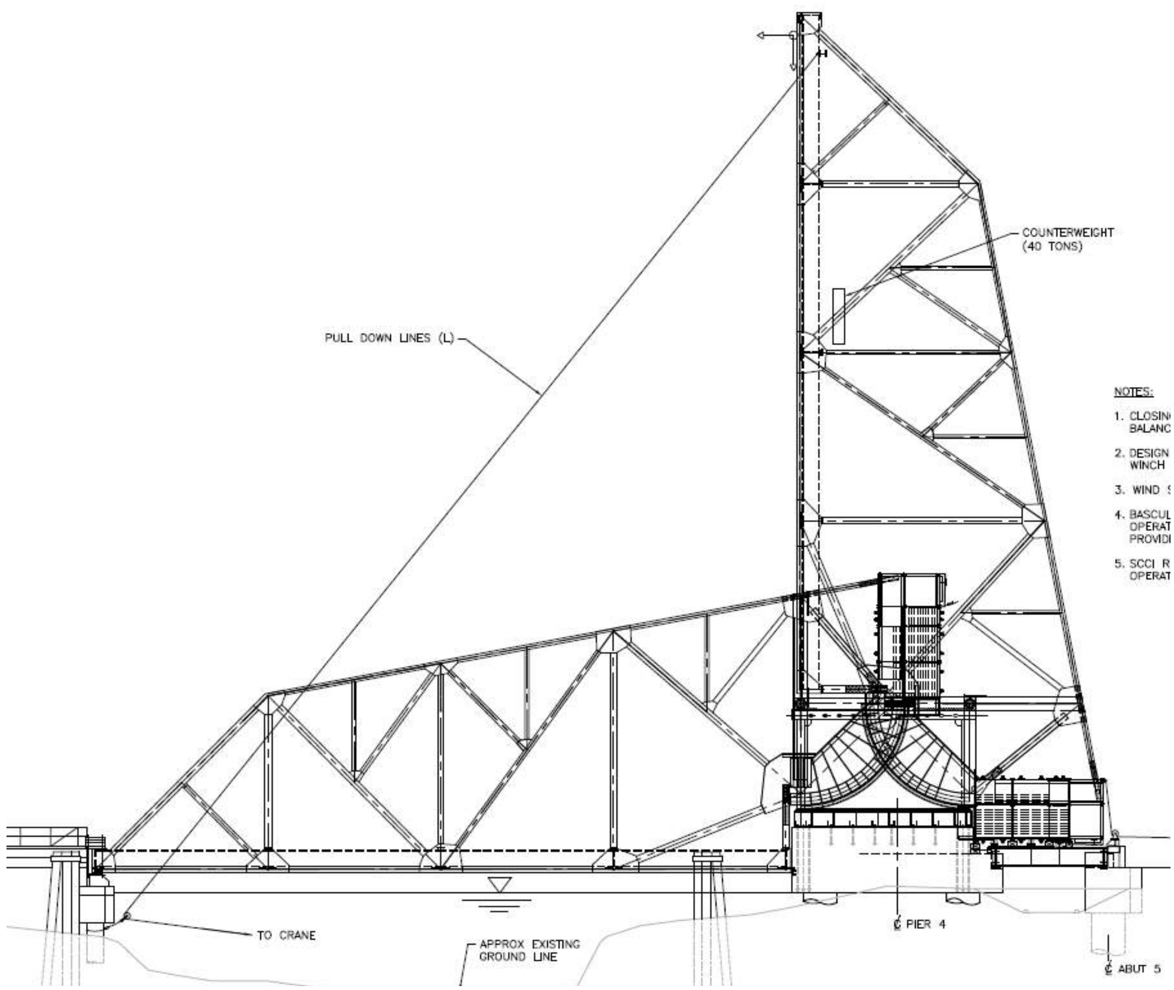

Figure 21 - Pull Down Scheme

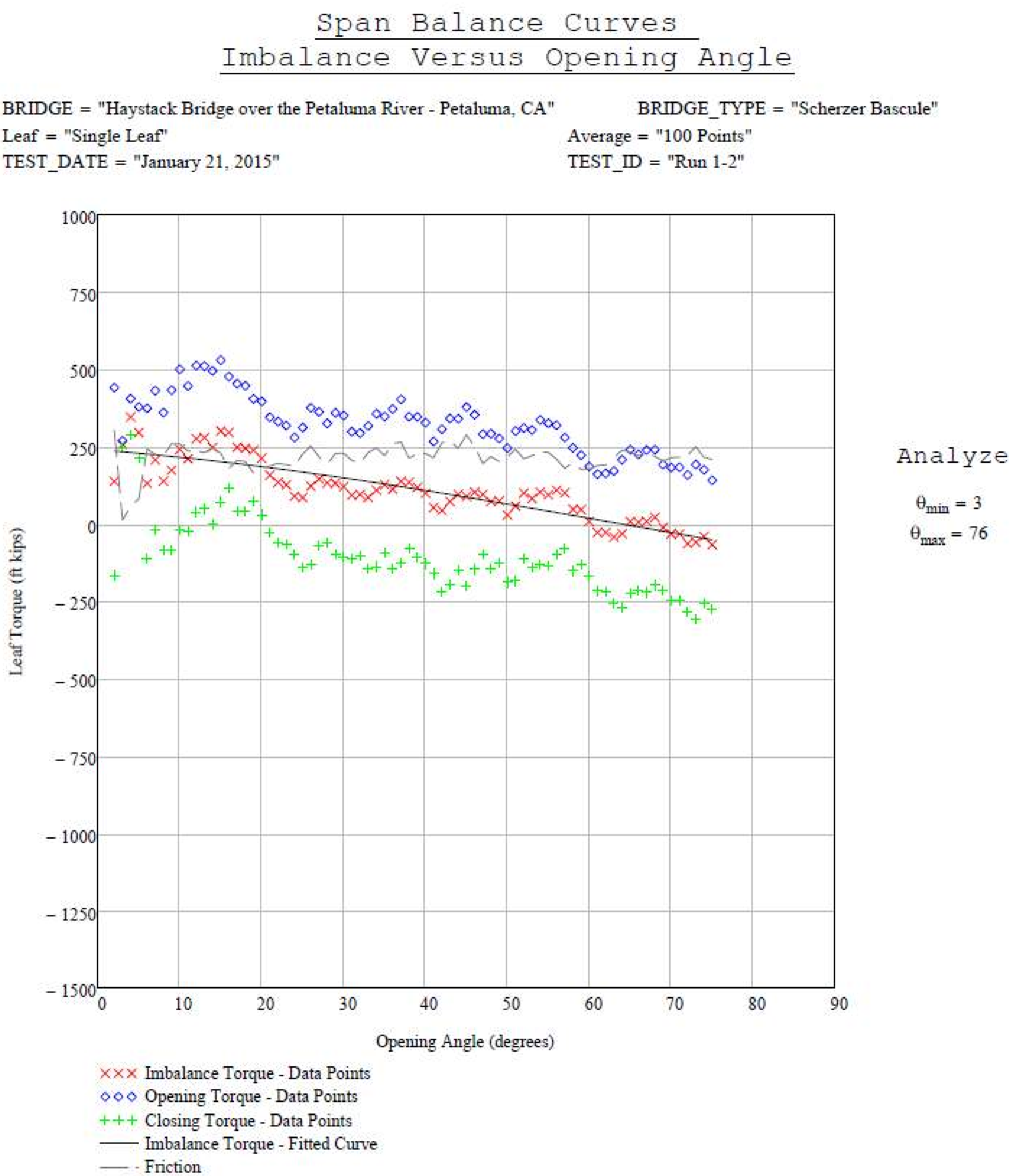

Figure 22 – Strain Gage Balance Testing Graphical Results

Summary

The first train successfully crossed the Haystack Bridge in October 2015. SMART expects to begin their passenger service sometime in late 2016. The project site and requirements presented some unique challenges but a dedicated effort by all parties brought the project to a successful conclusion. SMART chose a non-conventional replacement of the Haystack bridge and now have a more robust, functional, and better bridge for both rail operation and water navigation.

Figure 23 - New Haystack Bridge Span Drive Machinery

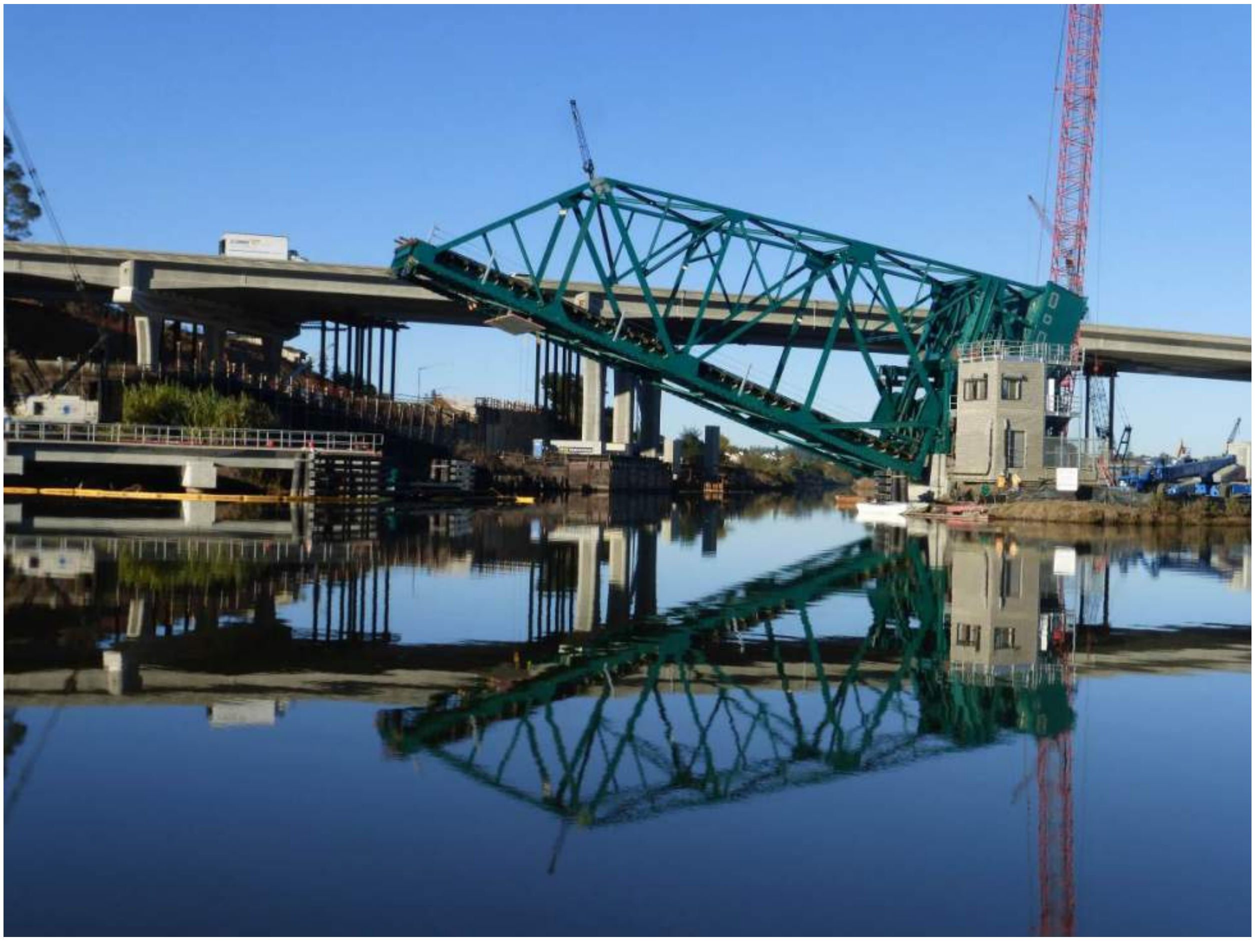

Figure 24 - Initial Closure of New Haystack Bridge

Figure 25 - First Train Crossing of New Haystack Bridge

Acknowledgements:

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