HEAVY MOVABLE STRUCTURES, INC.
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MOVABLE BRIDGE SOLUTIONS WITH ACROW PANEL BRIDGE SYSTEMS

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Basic Panel Bridge Components

Truss System

The basis of the steel panel bridge system utilized for all major elements of the Acrow Movable Bridge Systems, is an extension of the WWII Bailey Bridge technology developed in Great Britain to support the Allied invasion of Europe with the fundamental criteria being a pre-engineered, modular system capable of being erected by troops with or without heavy machinery in theatre. The current technology of the 10 foot long Acrow 700XS truss panel shown in Figure 1 utilizes high strength (65 ksi) steel members fabricated in Acrow's manufacturing facility in Milton, PA with critical dimensional controls, and extensive robotic assembly and welding systems necessary for repeatable modular components that comprise the Acrow panel bridge system. The 700XS bridge system utilizes 3 types of panels with varying degrees of shear capacity to resist varying shear demand within a structure. High strength reinforcing chords are utilized in the trusses to increase Ix/Sx of the truss system as shown in Figure 2. Three sizes of chords are available to provide increased capacity as warranted by moment or deflection requirements of the structure.

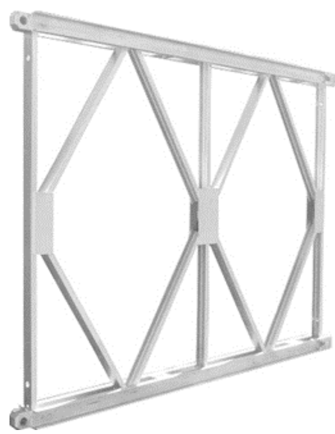

FIGURE 1: Truss Panel

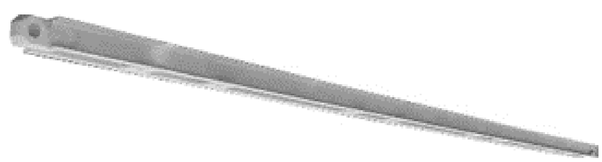

FIGURE 2: Reinforcing Chord

The truss panels and reinforcing chords utilize high-capacity pinned connections to form beam elements to satisfy load demands. Based on extensive modeling and testing, the truss panel components have demonstrated capacities of individual members to allow the truss system to be treated as simple beams for analysis and design. As a result, the trusses and reinforcing chords are configured with varying configurations to match shear, moment, and deflection requirements for the specific application. Examples of the range of the truss bundle configurations are depicted in Figures 3 – 5 depicting the simplest example of a SS truss bundle with single, unreinforced truss panels of single story, up to the extreme configuration of QDR4SH utilizing 4 truss lines stacked to achieve a double story bundle and utilizing the heaviest "super heavy" reinforcing chords.

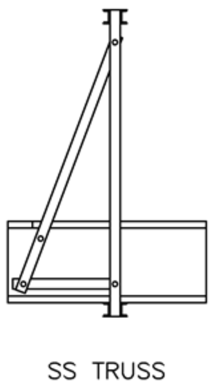

FIGURE 3

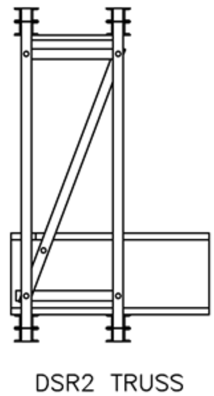

FIGURE 4

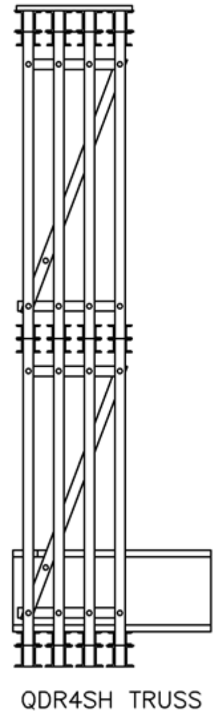

FIGURE 5

Transom/Floor Beams & Deck

The panel bridge technology utilizes transoms or floorbeams spaced at 10-foot intervals to support the modular deck system. The transoms are sized to accommodate the required road width and live load demand and supported directly on the panel pin connections of the truss bundles. Transom widths typically vary from single lane 12 foot deck up to 42 foot 3-lane conditions. Transom beams are sized to accommodate project specifications for flexural stresses and deflection limitations and utilize A790 Grade 50 rolled beams.

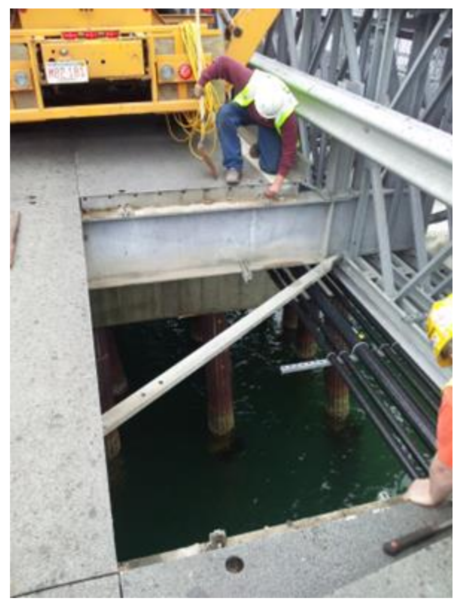

FIGURE 6: Deck Detail

The standard deck system utilizes orthotropic steel deck panels spanning the 10 feet between transoms. Two versions of the steel deck panels can be utilized based on live load demands. The deck panels consist of steel stringers and typically plain steel deck plate utilizing custom deck bolts for the connections to the transoms (Figure 6). Acrow deck panels have been laboratory tested to accommodate over 10 million cycles of AASHTO wheel loads. The deck panels can be supplied with a factory-applied epoxy aggregate riding surface or asphalt overlay to provide cross slope or crowned cross section as dictated by project design requirements. Typically, the epoxy aggregate surface is utilized to reduce the span DL for movable bridge installations.

Multiple guardrail Options are available to provide impact resistance and truss protection ranging from TL-2 or TL-3 MASH criteria. The post and rail system is typically utilized with the posts mounted directly on the transoms at 10-foot intervals.

The basic Acrow 700XS panel bridge system can be configured for numerous applications and site conditions. Examples of typical applications are provided below.

Vehicular Bridge Applications

The most common application of the panel bridge system is for vehicular roadways as temporary detours to support bridge reconstruction, or for permanent bridge installations in the International market. Span configurations, roadway width and riding surface, and live load conditions dictate the selection of the panel bridge components including the truss system, deck system, and transoms. Depending on roadway width and LL criteria, simple spans can range up to 230 feet, and multi-span applications can utilize a continuous span arrangement or "broken span" configuration to achieve breaks in the roadway profile as dictated by site conditions.

The Acrow panel bridge system also provides options for pedestrians and bike path requirements utilizing cantilevered footwalk systems outbound of the truss system. The typical footwalk system is depicted in Figures 7 and 8 with standard railing and chain link fencing, as well as a picket style railing system.

FIGURE 7: Footwalk with Fence

FIGURE 8: Picket Rail

In addition to conventional vehicular bridge applications, the Acrow panel bridge system can be utilized as construction access bridges to accommodate a wide range of construction vehicles, including off-road heavy haul trucks and permit vehicles. Extreme load conditions may also dictate the use of a timber deck system due to excessive wheel loads as depicted in Figure 9.

FIGURE 9: Heavy Haul timber deck

Pedestrian Bridge Applications

Pedestrian bridge applications can utilize two basic bridge configurations based on site and design criteria for span and width of the path. A common solution is the Acrow Box Pedestrian Bridge utilizing Acrow truss panels for support trusses and support of a floor system (Figure 10). Widths can be 5ft or 8 ft and spans can range up to 150ft depending on site specific criteria for LL and design code.

FIGURE 10: Box Pedestrian Bridge

For wider or longer spans, the conventional transom beam configuration can be utilized with varying walkway construction details and surfaces as depicted in Figure 11. Longer spans and multi-span arrangements can be accommodated to satisfy AASHTO pedestrian bridge code requirements.

FIGURE 11: Transom Pedestrian Bridge

Rail Bridge Applications

The basic Acrow panel bridge system has been re-purposed for rail bridges following the stringent AREMA design code, including LL effects from E80 criteria. Due to excessive axle loads from the E80 Alternate load configuration, rails must be supported to span the 10-foot transom spacing using stringer packs for each rail as depicted in Figure 12. The extreme vertical, longitudinal, and transverse load conditions mandated by the AREMA code dictate the need for special bracing and bearing components unique to the Acrow rail bridge installations.

FIGURE 12: Rail bridge installation

Military/Floating Bridge Applications

Acrow has provided bridge systems to several militaries throughout the world. The basic Acrow panel bridge system has been designed to satisfy US Army conditions for Military Load Classes up to MLC110 Track and MLC150 Wheeled in accordance with the Trilateral Code (LOCB). The military bridge solutions have included fixed (Dry Gap) bridging for simple or multiple span site conditions. As a unique application of the panel bridge system, Acrow has also developed and provided a floating (Wet Gap) bridging system to accommodate the extreme loading conditions from military tracked and wheeled vehicles depicted in Figure 13. The conventional panel bridge and deck system has been utilized in conjunction with floating piers consisting of segmental barges and custom pier interface components to transfer bridge loads into the floating piers for unlimited length of water crossing applications.

FIGURE 13: Military Floating Bridge

Utility Support Applications

The Acrow panel bridge and truss system has been utilized strictly for utility support applications for both piped and conduit utilities. Depending on the utility details and span conditions, a variety of solutions have been successfully implemented. A common application is a simple hangar system from a vehicular or pedestrian bridge installation supported by an element of the truss and/or transom system, or footwalk brackets as depicted in Figure 14. The Acrow box bridge has been adapted for utility support along with a worker access walkway shown in Figure 15.

FIGURE 14: Footwalk Bracket Supports

FIGURE 15: Special hangars from Pedestrian Bridge

Unique site conditions may warrant a limited width of support for staged construction applications, and a single Acrow truss bundle can provide a clear span support for a variety of utilities as depicted in Figure 16. Custom pipe trestles have also been cost-effective permanent solutions as depicted in Figure 17.

FIGURE 16: Truss bundle Support

FIGURE 17: Custom Pipe Trestle

MOVABLE BRIDGE SYSTEMS

Movable Bridge Design Criteria

Structural/Service Conditions

All Acrow movable bridge installations have been designed in accordance with the applicable AASHTO Movable Bridge Code. Historically, the Code utilized was the 1988 ASD Code, with more recent installations utilizing the LRFD Code for both structural and mechanical elements. The movable span and any approach spans utilizing the Acrow panel bridge system are designed with the applicable AASHTO Bridge Design Specifications to establish load demand and component/system capacities. The resulting span configuration is integrated into the full movable bridge installation as necessitated for the remaining systems in the installation. The span design is based on AASHTO criteria for both structural considerations as well as service and fatigue requirements. The movable span design is developed for each element including roadway deck, transoms, truss system, bearings, and footwalk elements as warranted by project and site conditions.

Other structural elements in a movable bridge system follow the same structural design process, typically based on environmental and service load demands dictated by the Movable Bridge Code. As an example, the towers on a Vertical Lift Span are deigned for gravity loads and lateral loads in combinations dictated by the Movable Bridge Code with allowable stress levels and factoring established per Code. Typically, there are no load demand or allowable stress adjustments regardless of the expected life of the installation.

Mechanical/Drive Systems

All drive system and mechanical elements in an Acrow movable bridge installation are designed in accordance with the applicable Movable Bridge Code, either ASD or LRFD. For domestic movable bridge machinery and rope systems, it is typically accepted by owners and the engineer of record to allow a 25% increase in allowable stresses if the bridge is temporary in nature. Similarly, a reduction in sheave diameter and increase in allowable rope stresses is considered acceptable in temporary bridge installations. This code relaxation results in manageable rope and drive systems along with related cost savings to the project.

Vertical Lift Bridges

Basic Configuration & Systems

Vertical lift bridge installations utilizing the Acrow panel bridge system resemble many aspects of conventional vertical lift bridges. Figure 18 depicts the following major elements of an Acrow Vertical Lift Bridge installation:

- Lift span/bearings
- Towers/crossheads
- Gantry and drive system
- Counterweight system
- Operating rope system (UH/DH)
- Control cabin/control system

Each system and element is described in more detail in subsequent sections.

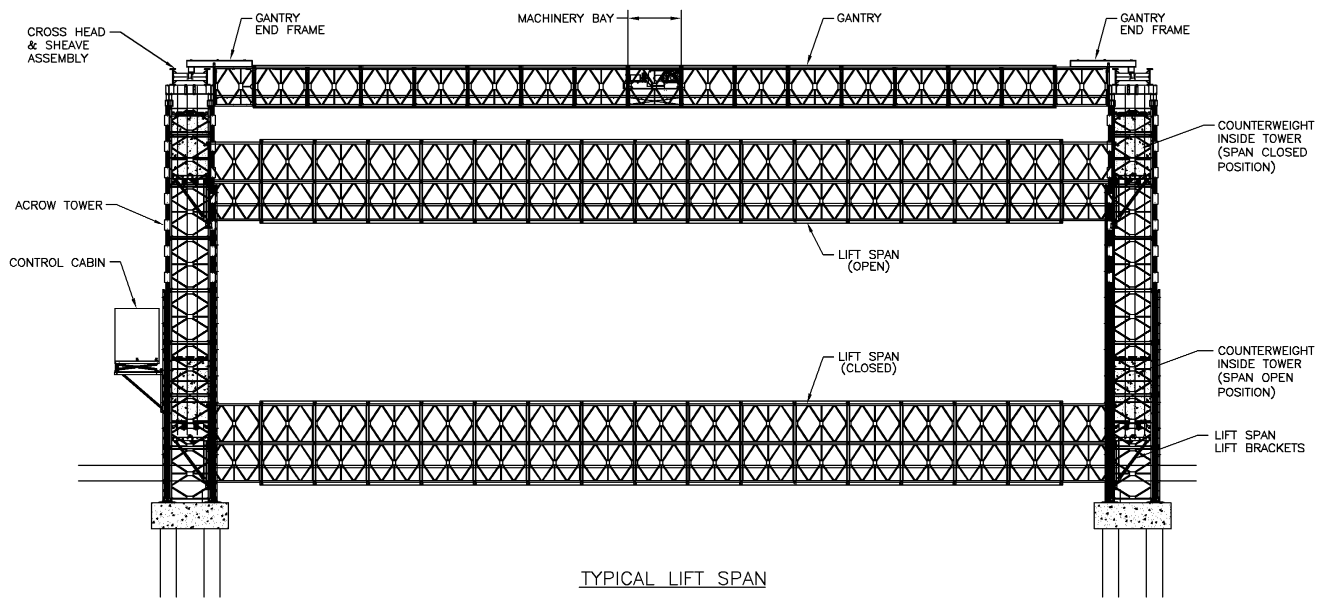

FIGURE 18: Vertical Lift Span

Lift Span and Bearings

As in all vertical lift span projects, the lift span length is dictated by the required channel width and fender system configuration and width. With the minimum span length established, the foundation system for the lift span bearings is then developed in collaboration with the contractor and foundation engineer with the objective of minimizing the lift span length and resulting weight. Recognizing that the final span length dictates the truss selection, span weight, and resulting drive system requirements, any effort to optimize the lift span length has obvious ripple effect and cost benefits to the owner.

The Acrow lift span consists of the side trusses, transoms/floorbeams, orthotropic deck panels with epoxy aggregate riding surface, cantilevered footwalk(s) as required, and lifting frames for attachment of the counterweight ropes and uphaul/downhaul operating ropes (Figure 19). The lift span utilizes guide rollers riding on the outside surface of the towers as their guideway to control the span position and resist wind forces throughout the span raising and lowering process.

FIGURE 19: Lifting Frame

The lift span bearings are typically positioned at the extreme ends of the truss lines, and special bearings depicted in Figure 20 are utilized to allow potential truss rotation in the transverse axis and assure uniform loading of each truss line in the bundle. The resulting bearing location, combined with the foundation design requirements dictate the final span length and location of the towers adjacent to the lift span.

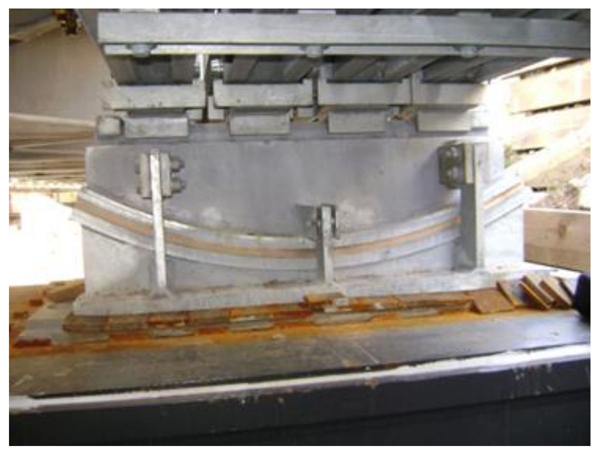

FIGURE 20: Lift Span Bearing

Support Towers & Crossheads

Support towers in the Acrow Lift Span system are critical and multipurpose. The primary purpose is to support the crossheads over each end of the span, which in turn support the gantry housing the mechanical drive pallet at midspan of the gantry as shown in Figure 21. The secondary and critical purpose of the towers is to house the concrete counterweights to achieve the required net lift span weight used for designing the span operating system.

FIGURE 21: Mechanical Pallet on Gantry

Support towers in the Acrow vertical lift span installation utilize standard Acrow 4-panel tower configurations with standard truss panels for each side of the tower, providing support for both vertical and horizontal loading conditions. The vertical lift towers also provide internal guides for the concrete counterweights in each tower during vertical travel, as well as runways for the lift span guide systems to limit longitudinal and transverse span movements from wind and dynamic forces during operation as shown in Figure 22. Tower heights are established by the specified vertical channel clearance and allowance for the gantry depth and crosshead dimensions. The Acrow towers can be reinforced similar to span trusses, by adding reinforcing chords as required to resist the combined vertical and horizontal loading conditions dictated by Code.

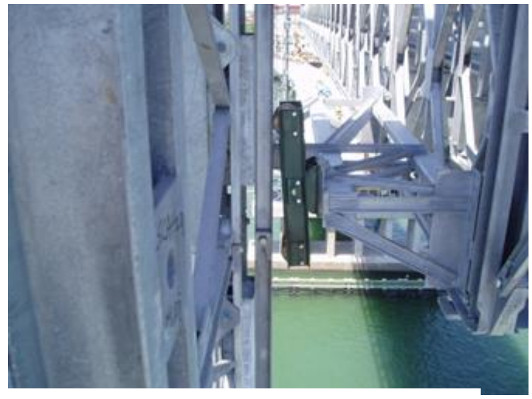

FIGURE 22: Span Guide Rollers

The towers in the final installation are considered braced cantilevers by utilizing the crossheads and the gantry connections as bracing elements against horizontal loading in each axis. A unique side note is that the controlling design case for the towers is typically during the construction phase when the towers are freestanding prior to installation of the crossheads for lateral bracing. With the counterweights in the span closed position at the top of the towers, the tower is subjected to wind loading as unbraced cantilevers, many times over 150 feet tall. This condition is further discussed in the construction section for vertical lift spans.

The Acrow crossheads house the counterweight sheave cassettes and operating rope sheaves for the uphaul rope system. The tower locations relative to bridge centerline, which is dictated by the lift span roadway and footwalk configuration, then dictate the span of the crossheads. Crosshead design is based on the resulting span between towers at each end of the bridge, combined with the counterweight rope loads and sheave cassette structure weight. Additionally, the crossheads provide support for the overhead gantry and machinery pallet positioned on the gantry. The resulting crosshead design utilizes deep rolled-shape girders supported with simple bearings at each tower as shown in Figure 23. A full walkway system is provided on each crosshead for inspection and maintenance purposes, as well as access to the gantry and equipment pallet. The towers typically utilize a ladder/platform system from roadway level for access to the crossheads and gantry for inspection and maintenance.

FIGURE 23: Crosshead/sheave pallet and bearing

Counterweight Systems

To achieve the required span balance dictated by project specifications or sound design practice for machinery sizing, each corner of the lift span is connected to concrete counterweights housed within the towers to avoid locating the counterweights over traffic or walkways. The counterweight ropes are attached to the span trusses with a counterweight rope system allowing the counterweights to travel vertically within each tower utilizing a roller/guide system to assure smooth operation. Each counterweight consists of multiple precast blocks poured around tubular frames (see Figure 24) to accommodate the threaded Macalloy bars that provide the connectivity between the counterweight ropes and the counterweight blocks shown in Figure 25. The frames are provided by Acrow to assure proper alignment of the precast blocks that are poured on site by the contractor.

FIGURE 24: Counterweight Macalloy frame

FIGURE 25: Counterweight rope connections at Macalloy bars

The towers are configured to support the counterweights on frames in the span-closed position utilizing sliding needle beams to support the counterweight system in the towers during the construction phase (see Figure 26). This facilitates the initial installation and attachment of the counterweight ropes, as well as maintenance during span operation. The pre-stretched counterweight ropes are sized and selected to minimize cable and sheave size, while optimizing the quantity of ropes and sheaves for cost considerations. The counterweight ropes are connected to the Macalloy bars at the top of the counterweight blocks and travel over the sheaves pre-mounted in the sheave cassette at each end of the crosshead beams. The sheave cassette is typically manufactured, galvanized, and then machined to achieve uniform surface conditions for the sheave bearings as depicted in Figure 27.

FIGURE 26: Counterweight frame

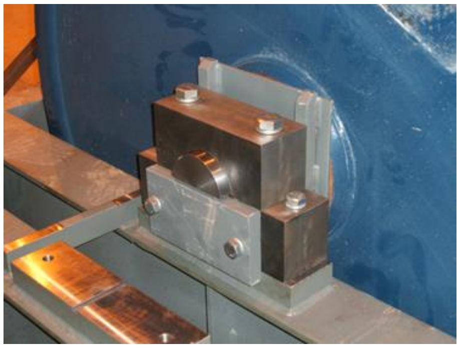

FIGURE 27: Sheave Bearing

The sheave cassettes can be pre-assembled in the crossheads and trucked to the site as a complete assembly depending on routing of the permit load for each crosshead. Similarly, the cassettes can be shipped independent of the crosshead system for installation at the site based on contractor preference, shipping logistics and costs, and availability of cranage at each end of the span.

Each counterweight is sized to provide equal line loads for span operation, which may require unique counterweight configurations for each side of the bridge, dependent on the presence of a footwalk system causing transverse eccentricity of the lift span. During final setup of the lift span machinery, adjustment of the net span weight is achieved with small, steel ballast plates for fine-tuning each corner. (See Figure 28)

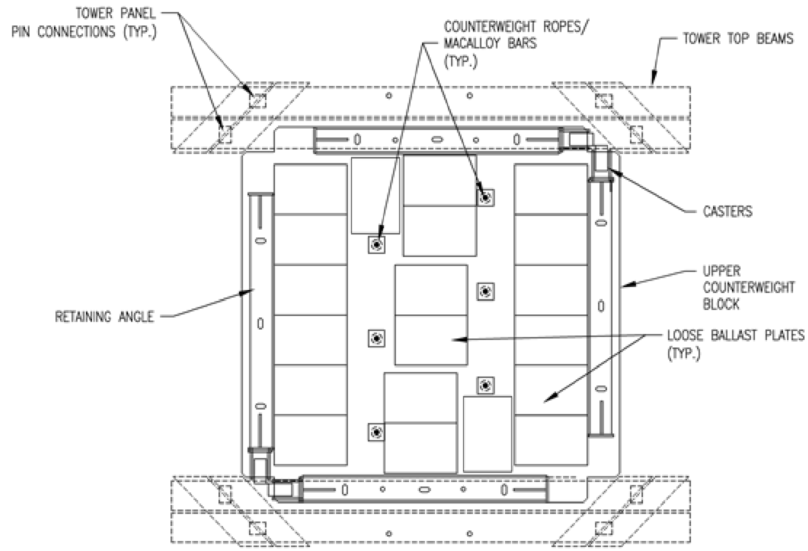

FIGURE 28: Counterweight ballast plates

Gantry/Equipment Pallet

The overhead gantry provides support of the centrally located machinery pallet, a walkway system to access the machinery, control and power conduits and wiring, and other miscellaneous components. The gantry structure also braces the towers longitudinally and provides access for maintenance workers to cross from one crosshead across the gantry to the other crosshead and towers. The gantry span is comprised of Acrow 700XS bridge components as shown in Figure 29 with the side truss construction dictated by the span and machinery loading. The gantry is supported on each crosshead with support frames and simple support bearings pinned for stability and thermal movements. (Figure 30)

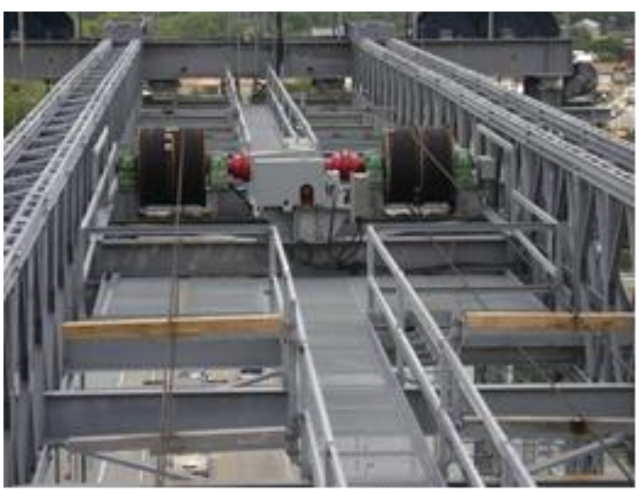

FIGURE 29: Gantry System

FIGURE 30: Gantry support frame at crosshead

FIGURE 31: Pre-assembled Machinery Pallet

The typical machinery pallet arrangement includes a steel support frame, a 3-phase, 480-volt drive motor, conventional gear box, rope drums, along with motor and machinery brakes utilizing conventional thrustor brakes for both operation and maintenance purposes. (see Figure 31) The pallet frame is supported in the gantry on Acrow transoms connected to the truss bundles. The pallet can be pre-installed on the gantry prior to erection of the gantry at the contractor's discretion. The drive motor and gearbox are sized strictly adhering to the AASHTO Movable Bridge Code and span operating requirements. The machinery pallet is shop-assembled in the controlled environment to achieve the necessary alignment of the motor, gearbox, shafts, and drums in a shop environment. Optional auxiliary motor and drive components can also be provided as dictated by project specifications. The dual rope drums are located and configured to provide both uphaul and downhaul operating ropes for simultaneous movement of each corner of the lift span.

The fundamental criteria for sizing the mechanical drive system is the gross weight of the lift span and the net, balanced weight of the lift span. Once the lift span configuration is established to meet the design Code, the actual weight of the lift span can then be established. A typical lift span weighs between 150-250 kips as a completed structure. With the actual lift span weight established, the design loads for the mechanical drive system are then evaluated and sized for all operational conditions dictated by the Movable Bridge Code. Based on the resulting range of line loads and wire rope size combined with span cycle times, the motor, gearbox, drums, shafts, and brakes are then sized in strict accordance with the Movable Code and machinery design guidelines. The resulting drive system sizing and arrangement dictates the support frame configuration and component details so the equipment pallet can be integrated with the Acrow gantry support elements.

Operating Rope System

The operating ropes for the uphaul and downhaul system are routed from the machinery drums to each corner of the bridge utilizing the necessary sheave arrangement for horizontal or vertical changes in rope alignment to achieve the required connections to the lift span. Rope connections are attached to the lifting frames at each corner of the lift span to provide uniform loading on the lift span trusses along with an adjustable rope-tensioning system to provide equal loads in the 4 lift ropes. (Figure 32).

FIGURE 32: Counterweight & downhaul/uphaul rope attachments at span lifting frame

The 8 operating ropes provide uniform span movements for both span raising and lowering by virtue of the common drum shafts and rope reaving configuration on the drums. In order to maintain minimal tension on the operating ropes while not in operation, a rope tensioning device is provided for each of the 8 ropes. The tensioning device also provide overload protection for the span operation system. Utilizing a unique cantilevered arm system for the deflector sheave, excessive rope tension resulting from an obstruction or conflict in the span movement will lift the cantilevered arm to trip the overload limit switch shutting down the system and alarming at the control console. (See Figure 33 & 34)

FIGURE 33: Uphaul overload device

FIGURE 34: Downhaul overload device

Hydraulic Lift Span

A unique set of site conditions prompted the development of 2 vertical lift bridges utilizing hydraulics for span movement in lieu of the standard rope operating system. The proposed lift spans at the Unionport, NY project were required for barge movements in Westchester Creek in Bronx, NY. However, the lift spans were to be located directly under the interstate structures for I-95 and I-278 with extremely limited vertical clearance between the roadway and the underside of the structures. (see Figure 35) This condition precluded the use of the conventional Acrow Vertical Lift Span system using a rope drive system mounted on an overhead gantry.

FIGURE 35: Unionport, NY Site conditions

An alternative system was designed and approved utilizing hydraulic rams in each tower to raise and lower the span with the standard Acrow counterweighted span-balancing system, thus minimizing the load demand on the rams. The unique site conditions also resulted in minimizing the vertical span lift requirements, further lending to the practical use of hydraulic rams with a total extension of 20ft. Working closely with the EHM team, the hydraulic system and integration with the Acrow lift span was developed and installed to the satisfaction of the construction team and City of New York.

Working within the extreme site constraints and limited vertical clearance under the existing structures, the hydraulic rams were integrated into the standard Acrow towers at each corner of each lift span and connected to the underside of the concrete counterweights to retract the cylinders to raise the span-heavy structure. (Figure 36) Similarly, the span lowering was controlled by the hydraulic control system devised by EHM for smooth operation within the stipulated cycle time dictated by the City.

FIGURE 36: Hydraulic ram attachment to counterweight

Control Systems

The control system for the Acrow Vertical Lift Spans utilize conventional PLC controls typically designed and provided by Acrow's controls subcontractor. The control system provides typical traffic and span controls and interlocks provided on movable bridges. A control cabin is typically positioned for clear visibility of pedestrian and vehicular traffic, as well the waterway traffic and channel, and houses the PLC and MCC for gate operators and lift span controls. The bridge tender utilizes a touch screen control console with a mandatory footswitch situated in the cabin to provide the necessary sight lines. (Figure 37)

Field devices for lift span operation include conventional monitoring and control provisions utilizing limit and rotary switches. The drive system controls include typical motor monitoring devices for current, temperature, and voltage, along with brake position indicators and remote brake controls. Span position is typically provided by rotary switches mounted directly to the common drum shaft to accurately convert shaft rotation to span position on the operator's console.

Limit switches are also mounted on the towers to prevent overtravel of the span in both alarm and E-stop conditions depending on span position. Additional limit switches are provided at each uphaul control arm to provide E-stop when rope tension exceeds design limits for worst-case span operation conditions. Final span seating is monitored at each lift span bearing typically with proximity or lever-arm limit switches as selected by the contractor.

FIGURE 37: Typical HMI panel

The typical span operation sequence follows a conventional lift span process and initiated by the bridge tender with a single push button for all steps and subsequent span raise as programmed in the PLC:

- Warning horn blasts
- Traffic signals turn red on both approaches
- Warning and barrier gate lowering
- Command to the drive to initiate the span raising operation under creep speed
- Automatic ramping up of the motor/drive system to full speed at a pre-set span position
- Automatic ramping down to full stop at pre-set span positions
- Switching navigation lights to green

Similarly, the span lowering sequence would proceed in reverse until the 4 span seating switches at each span bearing are tripped indicating satisfactory span position to allow traffic to cross the span. Upon satisfying the 4 seating switches, the drive system continues to overtravel and assure rope tension is relieved and avoid any live load effects transferring into the operating rope system or components. Once the span is fully seated, the traffic control devices follow a conventional sequence of group raising of all gates and switching traffic control lights to green and navigation lights to red.

The PLC system is programmed and fully shop- and site- tested to demonstrate proper operation, including extensive alarm and malfunction conditions that can be anticipated under normal as well as unexpected conditions. The control console provides graphical representation of the span position, brake status, motor amperage and speed, and span seated conditions. Pre-established alarm conditions are programmed into the system based on setpoints and operational parameters dictated by Acrow and the drive equipment components. Alarm screens allow the bridge tender and bridge owner to monitor and record warning and alarm conditions with timestamps to evaluate conditions during and after an event. Preferably, the control system provider also has remote access to the PLC via modem and phone connection to monitor, evaluate, and troubleshoot conditions and alarms or faults. Most faults can also be cleared remotely with certain faults mandating on-site evaluation and resolution of certain critical conditions and to assure that safe conditions exist at all times.

Construction Sequence/Procedures

Construction of the Acrow Vertical Lift Bridge system requires close coordination and collaboration between the contractor and Acrow engineers to optimize and expedite the process, and assure safe and effective assembly and erection of the various elements of the bridge installation. As a modular system, the assembly of each Acrow element is straightforward and generally repeatable for the erection crew. Acrow field representatives provide daily support of the planning and implementation of each aspect of the bridge installation to assure proper assembly processes and results.

Typically, the sequence of assembly and erection is towers, counterweights, crossheads, gantry/equipment pallet, and finally the lift span during regulated channel closures dictated by project specifications and Coast Guard restrictions. Tower sections consisting of the 4 truss panel sides, angle brackets, and internal guide elements are typically assembled offsite or on barges in 10 foot segments. Once all connecting bolts are torqued, each 10 foot segment can be lifted and pinned to other segments. (See Figure 38)

The height of each pre-assembled section of a tower is dictated by the contractor for handling and transportation to the bridge site. By maximizing the height of each section, it minimizes the number of lifts required to complete each tower. Each of the 4 towers are then erected, plumbed, and baseplates grouted as an initial step in the installation process.

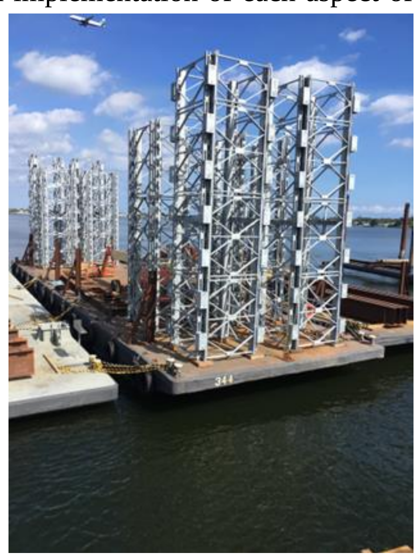

FIGURE 38: Pre-assembled tower segments

The overhead gantry is then pre-assembled offsite on a barge or on land and transferred to a barge for shipment to the bridge site. The assembly of the gantry is a simple, straightforward process since it consists of individual side truss panels, transoms, and bracing members identical to a typical Acrow panel bridge.

In order to expedite the erection process and resulting channel closure during the gantry installation, the complete gantry is pre-assembled on a barge for transport to the site. (Figure 39) The contractor's decision to install the pre-assembled equipment pallet on the gantry prior to erection of the gantry is dependent on crane capacity and availability, recognizing the additional weight of the pallet mounted on the gantry requires significantly larger crane(s) for erection of the gantry. This option is compared to the need for an additional heavy lift to subsequently erect the pallet onto the gantry at some point after the gantry is erected in the gap.

FIGURE 39: Pre-assembled gantry on barge

The next steps in the erection process requires close coordination and explicit planning in order to assure the time between start to finish is minimized. Once the 4 towers are in place, the following steps must be completed in the sequence of:

- counterweight installation in two towers at one end of the lift span
- installation of the gantry at that pier
- repeated process at the other pier
- installation of the gantry.

The counterweight installation process requires the individual previously-cast concrete blocks (typically 15-20 tons each), to be lifted above a tower individually and lowered down onto the support frame positioned in the highest counterweight position near the span-closed position (Figure 40). The support frame utilizes retractable needle beams to provide temporary support during counterweight installation and prior to connection to the lift span ropes when the needle beams are then retracted for normal operation.

Considering the mass of the concrete at the very top of the cantilevered towers and vulnerability to wind loads during the entire process and the resulting stresses in the tower, it is preferred that the operation for these steps occur in a continuous, 24-hour/day window with close coordination for channel closures and water traffic typically being the controlling factor. (see Figure 41).

FIGURE 40: Counterweight segment installed in tower

FIGURE 41: Partially installed counterweights

The goal is to erect each crosshead (Figure 42) to provide transverse bracing of the two towers and to then install the gantry to tie all towers together and provide bracing of the towers in each axis of the towers. (Figure 43).

FIGURE 42: Crosshead lift-in on towers

FIGURE 43: Gantry lift-in

Once the gantry and equipment pallet are in place, final power and control wiring connections can be made to allow drive and brake operation from the control cabin. Once the drive system is tested for proper operation, the operating ropes can be installed in preparation for the connections to the lift span when it is in place.

Parallel to the electrical work proceeding, the contractor can install the counterweight ropes from the tops of the counterweights at the Macalloy bars adapters, drape the ropes over each pair of sheaves in the sheave cassette on the crosshead assembly, and let them hang down to the base of the towers for final connection to the lift span frames once in place. Once the drive and brake systems are functional, the operating ropes can be attached to the drums and reaved through the various deflector sheaves in anticipation of final connections to the lift span at start-up (Figure 44).

FIGURE 44: Operating ropes on dual drums

The final steps of the installation require all systems to be functional and ready to begin span operation. This includes full control and instrumentation systems, power to all devices, cranes and rigging in place, adequate manpower to perform the various parallel activities during the closure, (typically on a continuous basis with adequate site lighting), along with adequate manlifts to access and service various points in the bridge from the approach spans.

In order to expedite the activities during the final channel closure window, the lift span is also pre-assembled, (with or without decking depending on the cranage on site), and mounted on a barge to float into place in the channel for lifting into position. Since the lift span is typically longer than the opening between the towers, it is common that one or two bays of the lift span are temporarily removed until the span has cleared the towers. Once in position, the remaining bays are attached to complete the lift span structure, and then lowered onto bearings (Figure 45).

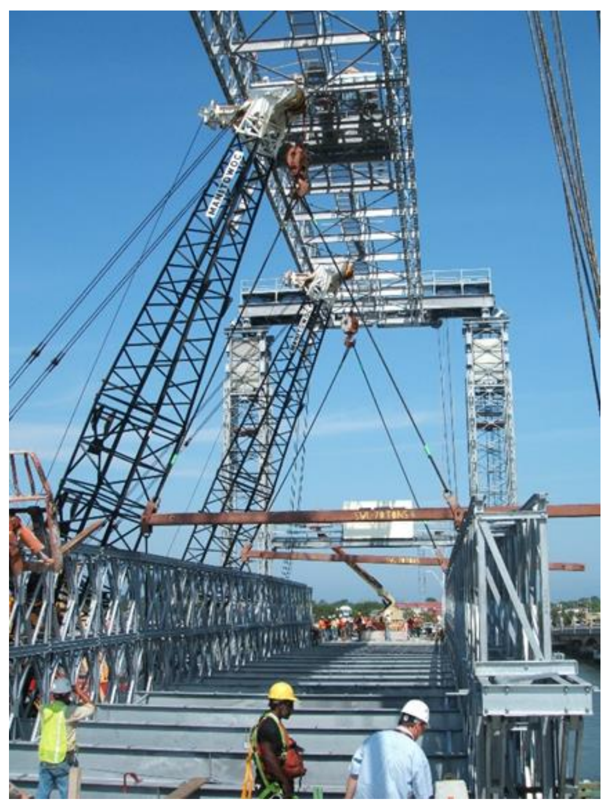

FIGURE 45: Lift span installation

At this point multiple, parallel activities occur, including the final installation of the deck system and footwalk components as necessary on the lift span, final reaving and connection of the operating ropes at each corner of the lift span, final connection of the counterweight ropes at the truss frames, and final connections of field devices required for the testing phase. Once the lift span assembly is complete to achieve the final weight of the span, the counterweight ropes can be tensioned since they are slightly lighter than the corner reactions of the lift span.

The process to mobilize the counterweights to take on the load of the lift span utilizes a unique jacking system to tension the load in the Macalloy bars and counterweight ropes to actually lift the full counterweight and support frame system up slightly to retract the needle beams, thus allowing the counterweights to hang freely in the towers (Figure 46). This process is repeated to engage the counterweights in each tower.

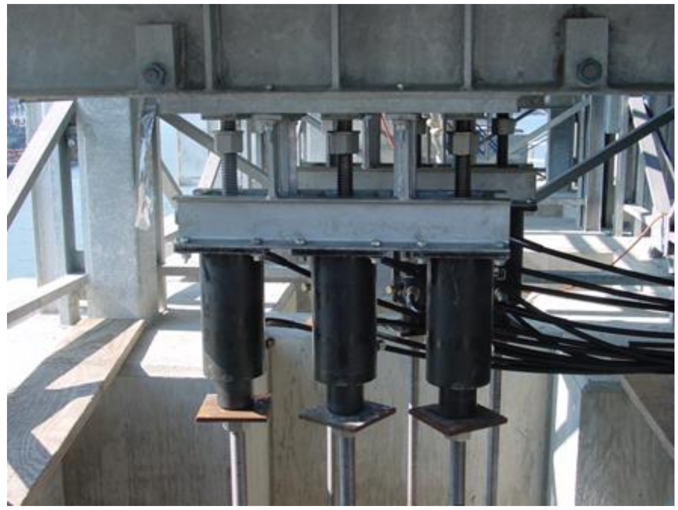

FIGURE 46: Counterweight jacking system

The final step of preparation for testing is to attach the downhaul and uphaul operating ropes at each corner of the lift span, and tension them with the turnbuckle at each lift frame. The uphaul and downhaul rope tensioning arms are loaded with counterweight blocks to pre-tension each operating rope and adjust for proper alignment of the 4 uphaul arms with the overload limit switch at each. The lift span is now ready for final setup of instrumentation and field devices in advance of span testing.

Commissioning/Training

The initial steps in start-up and testing require collaboration with the construction team and controls subcontractor to walk through the pre-established testing program. Once all ropes and connections are completed, and the span seating limit switches are positioned and proved out, the span testing can begin. The span is typically lifted and lowered in small increments at creep speed to assure all connections are secure, that no obstructions exist for either the span or counterweights (temporary or otherwise), and to perform fine adjustments on the brake setting routine and timing. The span position indication device is set and calibrated to assure that the PLC and the operator are seeing accurate span positions throughout the full travel of the span.

Once the start-up team is satisfied with a smooth operation through several cycles, the span operation is increased to normal speed to verify operation and that proper start, ramping, and stop positions are correct. Once the typical span operation sequence is verified as repeatable without alarms or errors, the final control testing program can proceed to demonstrate full span operation and alarm/fault incidents tested and demonstrated to the owner and bridge tender(s).

Operator training would then commence to familiarize the tenders with each aspect of the bridge system, perform the necessary training to operate the span and understand all alarms, faults, and fault-clearing procedures.

Brute Force Bascule Spans

Basic Configuration & Systems

An Acrow Bascule Bridge utilizes a brute force operating system without the benefit of a counterweight to offset the span weight for the drive system. Due to the typical nature of this bridge type being temporary, the cost and structural requirements to include a counterweight system is uneconomical for the Acrow bridge supply, as well as a foundation system to accommodate a conventional counterweight. As a result, the Acrow Bascule bridge system consists of the bascule span, an Acrow back span, a wire rope mechanical drive system, along with masts to provide improved geometry for the line loads to perform the span lift. (see Figure 47)

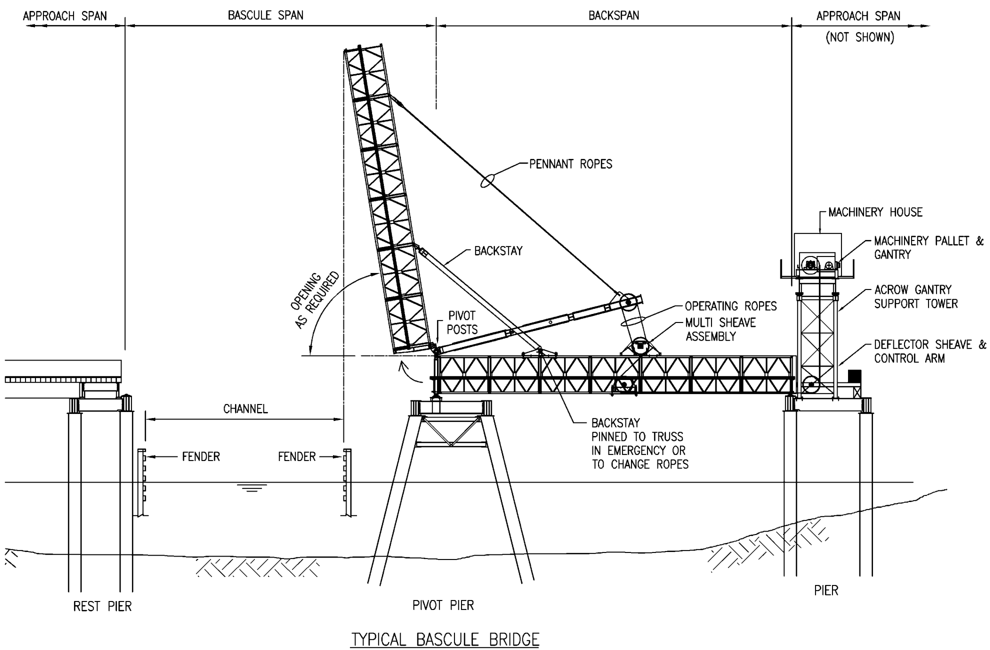

FIGURE 47:

Bascule Span

The bascule span configuration is driven by the roadway width, pedestrian requirements, and clear span requirements dictated by the channel width and fender system configuration. The span utilizes the conventional Acrow panel bridge system with through truss bundles, transoms at 10 foot centers, and the Acrow orthotropic deck panels utilizing an epoxy aggregate riding surface. A cantilevered footwalk can be accommodated as required by site conditions and project requirements. In the event a single footwalk is required, a span counter-balance system is located on the opposite side of the span in order to achieve a balanced DL condition for the rope drive on each side of the bridge. (Figure 48)

FIGURE 48: Bascule span with footwalk and counterbalance svstem

The bascule span is supported in the closed position on conventional bearings at the landing pier and steel trunnions at the pivot pier. The trunnion assembly also supports the mast system to collect the large forces and reactions at that location. A typical 2-lane bascule span with a single footwalk is 60 foot and weighing ~90 kips. A backstay is provided on each side of the bridge to prevent overtravel of the span in the unlikely event of wind-driven overtravel, but also utilized to pin the bascule span to the back span trusses in an overtravel position for maintenance purposes. (Figure 49)

FIGURE 49: Backstay and mast assembly

Back Span

The back span provides the support of the bascule span at the pivot pier and is critical as a reaction point to resist the brute force operating rope reactions generated from the drive system for span operation. The back span is also a conventional Acrow panel bridge utilizing similar components with the addition of the operating rope sheaves and backstay receptacles for stowing the span in the maintenance position (Figure 50).

FIGURE 50: Operating rope sheave set

The pivot post/trunnions provide connectivity for all truss lines in the bascule and back spans, as well as the reaction point for the mast and associated operating rope reactions. The pivot posts are special elements utilizing DU bearings and line-bored for a common shaft arrangement for correct and critical alignment and connectivity to the trusses on each side of the post. (Figure 51)

FIGURE 51: Pivot post assembly

Panel Bridge Approach Spans/Wedges

It is common for the engineer or contractor to select Acrow approach spans leading up to the back span and bascule span. The panel bridge spans for a conventional detour requires angular “wedge” sections to achieve the curved roadway in each approach to the bascule and back spans. The wedges typically consist of conventional steel framing with a precast or CIP concrete deck.

Operating Rope/Mast System

The key design element for the brute force bascule system is the operating rope and drive system that performs the span operation. In order to achieve the necessary geometry and reduced line loads to lift the tip of the span, the operating ropes are reaved over multiple sheaves mounted in a rotating mast system in order to improve the mechanical advantage on the rope system (Figure 52). The masts are then connected to the bascule span with pennant ropes attached to each truss bundle on the bascule span. (Figure 53)

FIGURE 52: Masts and frame

FIGURE 53: Pennant rope attachment

The operating ropes are routed from the rope drums on the mechanical drive through multiple sheaves in the back span and up to the masts on each side of the bridge. Each rope sheave is secured to the back span truss system to resolve the line load forces into the back span as a reaction point for the net forces. (Figure 54)

FIGURE 54: Operating rope sheave

The operating ropes also utilize a rope tensioning device with a pivot arm counterweighted to provide the necessary balance and arm position and maintain rope tension on each side of the bridge. (Figure 55) The pivot arm device is also used as an overload device to trip an overload limit switch when the line load exceeds a pre-determined limit indicating an obstruction or restraint to span movement.

FIGURE 55: Operating rope overload protection system

Mechanical Drive System

The rope drive system utilizes a machinery pallet similar in nature to the vertical lift span system, but with only one rope on each side of the span to handle lifting forces and lowering of the span by gravity. Considering the fact that the bascule span weight is not offset with a counterweight, the line loads are significantly greater than for a vertical lift span. The design line loads are established for all load cases and combinations per the Movable Bridge Code and dictate the wire rope size, resulting sheave diameters, drum diameter, and motor/gearbox size and configuration.

The pallet is shop pre-assembled on a gantry assembly to assure quality control for component alignment (Figure 55). The gantry assembly includes access walkways for initial setup and eventual maintenance of the drive system. The motor is 3-phase, 480 volt with typical rating at 150-200 HP. The conventional OTS gearbox is similarly sized per code with the input shaft positioned to accommodate the layout and available room for the pallet. The rope drums are placed on a common output shaft to assure uniform rope payout for uniform span control. Motor and equipment thrustor brakes are employed and sized for the applicable loads per Code and manufacturer's recommendations. Clearly the brakes are critical elements of the drive system since they are the only restraint to prevent the bascule span from uncontrolled lowering under gravity forces. An auxiliary motor and/or drive can also be provided for emergency conditions or equipment failures.

FIGURE 56: Pre-assembled gantry/machinery pallet

A preferred location for the equipment pallet is on an elevated frame over the roadway (Figure 57) for improved access via a ladder system. A contractor-supplied enclosure is typically provided for protection from environmental elements and for ease of maintenance and inspection of the equipment in the machinery house. The machinery house and gantry/pallet is typically supported on Acrow-supplied towers that also house the rope deflector sheaves and the line tensioning arm on each side of the span. By connecting the deflector sheave/tensioning arm to the end of the back span, it allows the line load forces to be resolved within the back span structure.

FIGURE 57: Gantry and support towers

Instrumentation/Control Systems

Control Cabin

The Operator's Cabin is typically located alongside the spans for full access and sight lines to the approach roads and channel. As in the Vertical Lift bridge, the PLC, operator's console, MCC, and brake resistor are all located in or adjacent to the cabin.

PLC Control System

The bridge control system is PLC based with minimal field devices for simplicity and cost control. As in the Vertical Lift system, the PLC is pre-programmed for span operation, alarm and fault indications and resolutions, and typically accessible to the controls subcontractor through modem/phone connections for remote trouble shooting and resolution of unforeseen conditions and operational issues after commissioning.

Field Devices

The typical field devices used for the bascule bridge installation include:

- Motor data for amperage, voltage, temperature, etc
- Rope overload limit switches
- Seating limit switches
- Span overtravel limit switches for warning and E-stop conditions
- Rotary switches mounted on the operating rope drum shaft to monitor span position
- Inclinometers mounted on the span trusses to monitor the span angle and potential skew of the bascule span during operation

As for all movable bridge installations, each device is verified and tested during the span commissioning and start-up process to verify connectivity and proper operation, along with the PLC logic for normal and emergency span operation sequences.

Rope Drive Motor Control

The mechanical rope drive system and rope/span speed is monitored and controlled throughout the full span cycle using a conventional VFD motor control. Considering the varying line load to raise the non-counterweighted span from the seated position up until it is in a fully open position, the starting amperage and line load are maximum as the span is coming out of the seated position. As a result, the drive system and speed settings are established for optimum motor current as the span opening is initiated.

Due to the layout and geometric design of the operating rope sheaves, the mast arrangement, and attachment point of the pennant ropes on the bascule span, the line load then decreases as the span is raised to a fully-open position. The span length, raised angle, and position relative to the fender system is configured to provide unobstructed clearance within the operating channel. At the fully-open position the span DL is still adequate for stability under the design wind load, even if the wind direction is directly against the underside of the bascule span.

For the brute force bascule span, the lowering process and control are critical to assure a safe and controlled lowering. With the severe line load into the mechanical drive motor, it is necessary to control the line pull on the drive and motor utilizing a dynamic braking resistor to dissipate the regenerated power from the motor. This solution has proven effective and reliable to maintain a safe span lowering process.

Span Operation

Traffic Control Elements

Typical of any movable bridge system, the traffic control system for the approach spans is integrated with the span operation sequence to assure safe span movements and protect vehicular and pedestrian traffic. The traffic control lights, gates, and nav lights are controlled through the PLC program in a typical sequence until all gates are down and verified. This provides the permissive to begin the span opening cycle.

Span Raise

The initial step in the span raise sequence is to ramp up the drive system to tension the operating ropes which are typically slacked at the end of each cycle. Once the ropes are tensioned, the drive motor starts the lifting process in creep speed due to the severe line loads until the span is approximately open by 10° when the drive ramps up to the full, normal speed. The span position is monitored with the rotary resolver attached to the drum shaft and verified by the inclinometers mounted on the bascule span trusses as backup and a failsafe system regarding overtravel and potential skew of the span.

As the span opening approaches the fully-open position, typically 75° – 80°, the drive ramps down to creep speed prior to a normal stop at the fully-open position. Once in the full open position, both thrustor brakes engage to secure the drive shaft and rope system and nav lights are turned green.

Span Lower/Motor Resistor

Span lowering is initiated by the operator at the console with the first step to ramp the motor up against the brakes to prove torque, followed by the simultaneous brake release. Due to the severe gravity forces to pull the span down, the braking resistor is engaged to provide a controlled payout on the operating ropes and transition the span-lowering into a normal speed condition. Utilizing the rotary encoders for span position monitoring, the drive is then ramped down to a creep speed as it approaches the landing span bearings. Upon full lowering and verification of both seated limit switches, the drive continues to lower the mast slightly and remove tension in the operating and pennant rope system. The drive is then de-energized and thrustor brakes engaged as permissive for a group raise of traffic gates and to then turn the traffic signals to green and nav lights red.

Summary

The versatility and adaptability of the Acrow panel bridge system has proven to be a practical, cost-effective solution for various types of movable bridge applications for both temporary and permanent installations.