HEAVY MOVABLE STRUCTURES, INC.
NINETEENTH BIENNIAL SYMPOSIUM

October 16-20, 2022

Can Access be in Excess?

Julia Bruce, PE and Manab Medhi, SE, PE
HNTB Corporation

RENAISSANCE ORLANDO AT SEAWORLD
ORLANDO, FLORIDA

Abstract

Access in a movable bridge is important. It needs comprehensive planning right from the conceptual design and planning phase of a project in order to meet the needs of each stakeholder and avoid what can often feel like excessive additions in the later stages of a project. Access can have major implications on several aspects of a bridge project: bridge size, safety, maintainability, aesthetics, construction, life cycle cost and sometimes bridge type, to name a few. This paper discusses a "diagrammatic reasoning" approach that can be used to analyze the access needs of a movable bridge. This approach should be considered at the planning phase of a movable bridge project. For example, space should be large enough for easy access to all machinery and apparatus to facilitate inspection, maintenance and repair. Additionally, affordability of the operator to a practicable clear view of the bridge and waterway traffic shall be considered as paramount. This paper also discusses the code recommendations on access in a movable bridge. Access design in a movable bridge is an intricate task which requires thorough planning and multidisciplinary coordination. This paper emphasizes the fact that the access planning and design of a movable bridge shall be well coordinated among the owner, designer, bridge operator and maintenance team right from the planning phase of a project. If planned appropriately with a practical approach, access in a movable bridge can become an elegant rather than excessive part of the structure.

Can Access be in Excess?

As anyone who has tried to utilize access on a movable bridge can recognize, it can often feel like an excessive amount of effort is required to get where one needs to be, whether climbing hundreds of stairs to reach the top of a vertical lift tower or navigating tight spaces around machinery and moving bridge components. Unfortunately, designing the access on a movable bridge can often feel remarkably similar to using it, requiring an excessive amount of effort. Access design can result in three areas of excess:

1. Excessive Additions or Changes

   No engineer or manager is fond of last-minute changes to design on a bridge project, yet this can often be the case if access details aren't carefully coordinated and discussed between engineering disciplines and the owner. Without a good understanding of access needs or methods, details may significantly change late in the design process, requiring more effort than should be necessary to accommodate these changes. This additional effort requires more meetings, emails, and design work. Overlooking needs could result in changes such as:
   - Widening a landing platform to accommodate electrical components
   - Shifting the elevation of a walkway because it would end up getting hit by balance chains, messenger cables, or other moving parts.
   - Adding emergency egress from a lift span should it be stuck in an open condition.

2. Excessive Amounts of Material

   Last-minute design changes don't often tend towards efficiency. Instead, what may occur is additional stairs, walkways, or ladders bracketed onto any available space remaining at the end of a project. Space is valuable on a movable bridge project, so neglecting to accommodate the right spaces for your access early on can result in winding, labyrinth like paths to get from Point A to Point B that can often result in excessive amounts of material that need to be fabricated and installed. This means the actual access on the bridge can be more complicated than it really needs to be, which also doesn't bode well for inspection or maintenance.

3. Excessive Detailing Effort

   Finally, with all these changes and potentially complicated access pathways, it gets harder to incorporate standard details throughout the design. While a carefully thought out access scheme may be able to capitalize on the use of standard brackets, flights of stairs, and other consistent details, an access scheme that is driven by reactive decisions late in the game inevitably will require either greater amounts of detailing to accommodate changes or else potentially a wholesale redesign of the access details entirely to fit the needs that were only truly discussed later in the project life.

What goes into Access Design Criteria?

As with the design of any bridge component, there are often multiple criteria which may influence or govern the final access design. It is therefore important for the engineer and owner to establish and agree upon a design criteria early on to avoid unnecessary changes to the design at later stages of the project, which may result in superfluous access for the bridge. Depending on the type of bridge and type of access required, various specifications may be considered in the design including OSHA, AASHTO, AREMA, and IBC. There is the potential, even, for different specifications to govern the design and detailing of different portions of the access design. For instance, on a vertical lift bridge, IBC may govern the slope and details of stair treads for accessing the operator's house from the ground, since it is an occupied space, whereas OSHA may be determined to govern the remaining stair details that are used to reach the top of the tower.

For example, the minimum width of stairways adhering to OSHA requirements must be 22 inches, but stairways adhering to IBC requirements must be 44 inches. Likewise, stair riser height and tread length must be 7 inch maximum and 11 inch minimum, respectively, when employing IBC standards, but can be 9 ½ inch maximum and 9 ½ inch minimum, respectively, when employing OSHA standards. Furthermore, OSHA allows the use of "ship-stairs" in place of "standard stairs" where deemed appropriate, especially for locations where access need not be used frequently. If the designer neglects to define the means of access and associated governing standards, significant changes to the layout of the access may occur in order to correct for relatively "minor" details such as the width of stairways and their riser heights. Further discrepancies exist in regard to handrail geometries, loading requirements, tread and traction surface requirements, and ladders.

Additionally, the owner may bring certain expectations in regards to maintenance or inspection that are not covered by the standard specifications. Understanding the owner's needs early on and defining these needs in a design criteria and through the access design approach described in this paper can help reduce the risk of changing details later on in the project.

Why is it Important to Define Access Early On?

The design of movable bridges takes significant coordination between engineering disciplines, owners, as well as other stakeholders such as the public. The result of this coordination is typically an efficient and aesthetically pleasing structure, intended to serve the needs of various transportation modes. Unfortunately, when the access on a movable bridge is not defined and considered early on, elements such as stairs and platforms are simply bracketed onto any available space. Aesthetically, this can draw attention away from the carefully coordinated elements and geometries. Functionally, the amount of material and coordination incorporated for access can increase far beyond the true need when the elements are forced to maneuver around the rest of the bridge. While access should not drive design, it is of value to define the access needs early on to make design-decisions with due consideration to the effects on access.

Movable bridges typically require additional maintenance compared with fixed bridges and access must be provided to perform maintenance duties such as lubrication and inspection. Where the access design is not thoroughly planned out, it can be cumbersome to access the elements needing maintenance, and these tasks may be neglected or performed with less frequency than necessary. This lack of maintenance can affect the long term serviceability and life of the structure and is just one effect that poor access planning can have. Furthermore, because there are many inter-disciplinary elements which must be accessed for maintenance and inspection, it is beneficial to invest the time and effort into the access planning phase to ensure that each component on the bridge can be accessed.

The approach to access design presented in this paper will allow the designer to efficiently determine the access needs of any movable bridge structure, helping to facilitate inter-disciplinary coordination. The approach further ensures that careful planning and communication take place early in the design process, reducing the risk for significant changes later in the design process which may impact the structure aesthetically and functionally.

Diagrammatic Reasoning Approach Overview

The authors of this paper recommend that access design be approached through diagrammatic reasoning. Diagrammatic reasoning is simply an approach to reasoning through the means of visual representation; literally, “reasoning with diagrams”. The approach employs diagrams and imagery instead of simply communicating through language or algebra. Therefore, employing diagrammatic reasoning for access design and planning should be done in addition to a formal design criteria, not in place of developing a design criteria.

The overall approach can be broken down into 3 phases, which culminate in a final diagram communicating the access scheme for an entire bridge:

- First, the designers and discipline leads must determine a checklist of items needing access on the movable bridge. Careful attention must be paid to the varying locations on movable bridges which may include but aren’t limited to Pier Level, Deck Level, Below the Pier, Top of Vertical Lift Tower, etc.

- Second, the designer should discuss with the owner and determine what means of access are expected for each of these locations. Owners may prefer stairs over ladders or vice versa. The designer must also ensure that the appropriate specification will be applied to different areas based on the access and occupancy requirements. If necessary, it may be beneficial to coordinate with a permitting agency in addition to the Owner. Means of access may include but aren’t limited to: stairs, ladders, walkways, gates, rope access, etc.

- Third, the designer should discuss with the owner and determine the access points for each location. It may be beneficial for maintenance activities to have clear means of access between each location needing frequent inspection and maintenance, but a less direct path of access may be acceptable for locations requiring limited maintenance or inspection. Likewise, it may be specified that occupied spaces are provided with multiple points of egress, which must be carefully planned out to provide redundancy in case of emergency.

Approaching access design in this manner ensures appropriate care is given to coordinate between disciplines and with the owner. While the initial planning may begin with making lists, it is helpful to employ diagrammatic reasoning to create a “flow” for the access on the bridge. A simplified example can be seen in Figures 1 through 3. This flow should aid in developing an efficient access scheme, which avoids unnecessary changes later on to reach a point that might have been overlooked otherwise and reduces the risk for superfluous access members. The method described in this paper can be further advanced through incorporating 3D models or animations to communicate the flow of access on the bridge to other designers, the owner, the contractor, or the public.

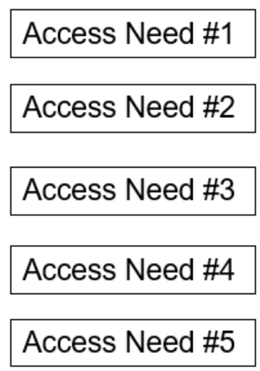

Figure 1 - Step One of Diagrammatic Reasoning: Define Access Needs

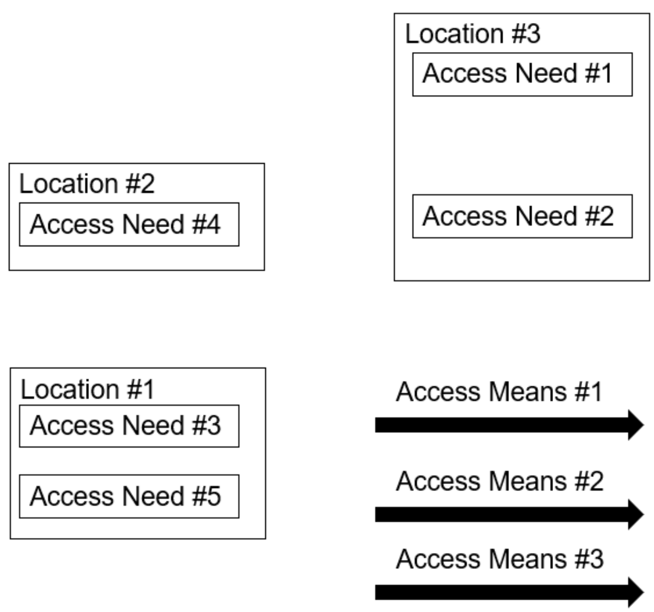

Figure 2 - Step Two of Diagrammatic Reasoning: Determine Access Means

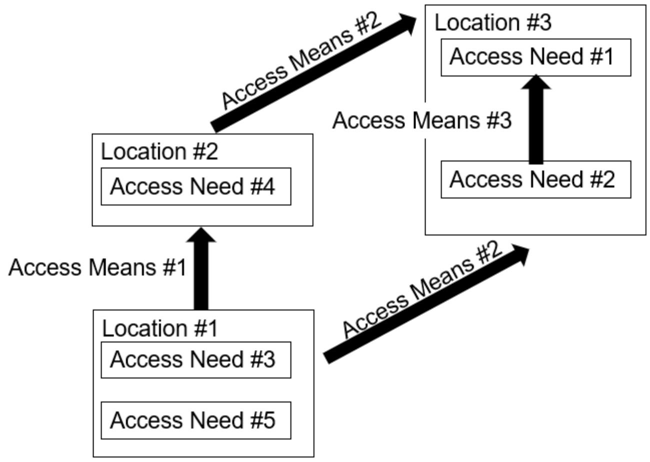

Figure 3 - Step Three of Diagrammatic Reasoning: Designate Access Points

Employing Diagrammatic Reasoning for Access Design:

The examples covered in this paper represent a broad approach to the initial access design and planning for various types of movable bridges. Specific project constraints and geometries will inherently govern the approaches described and the scheme will evolve to meet these constraints. The purpose of the examples is to provide starting point for discussions for each type of bridge.

Trunnion Bascule

Trunnion bascule bridges are unique in the need to inspect trunnion frames and potentially access various levels of machinery and other electrical and mechanical components within the bascule pier.

- Define Access Needs:
  - Below the Pier: Fender System, Counterweight and Balance Blocks, Machinery
    - Top Level: Trunnion Frame, Reducer, Pinion, Rack
    - Bottom Level: Trunnion Frame, Signal Cabinets, Generators, Drainage Pump
  - Bascule Pier Level: Live Load Shoe, Limit Switches, Operator House
  - Rest Pier (if applicable): Centering Device, Span Locks, Bearings
  - Deck Level: Miter Rail Joints, Roadway Joints, Signal System, Span Guides
- Determine Means of Access:
  - Stairs - Consider riser heights and tread depths, handrail requirements, etc.
  - Ladders - Consider the landing heights, the need for cages, vertical v. sloped ladders, etc.
  - Walkways- Consider walking surfaces, walkway widths, etc.
  - Handrails - Consider guardrail requirements, impact loads and ability for grabbing the rail, etc.
  - Gates - Consider if needed, if they will be electronic or manual, if they will be self-closing, etc.
  - Special Requirements:
    - Fall Protection
    - Rope Access
    - Confined Space

- Designate Access Points:
    - Potential flow using diagrammatic reasoning shown in Figure 4.

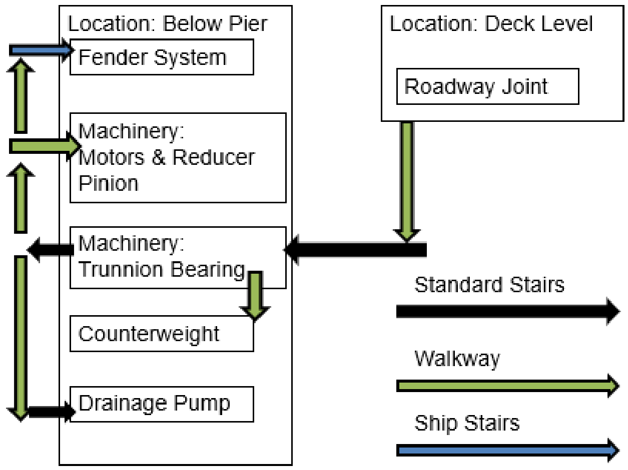

Figure 4 - Diagrammatic Reasoning Employed for Trunnion Bascule

Rolling Bascule

Rolling bascule bridges uniquely require the inspection of the segmental girder and track girder. Additionally, decisions should be made around how to access components in both the closed and open position of this type of movable bridge.

- Define Access Needs:
    - Below the Pier: Fender System
    - Bascule Pier Level: Live Load Shoe, Limit Switches, Operator House, Top of Rack Frame, Pinion, Track Girder
    - Rest Pier: Centering Device, Span Locks, Bearings
    - Deck level: Miter Rail Joints, Roadway Joints, Signal System, Counterweight and Balance, Segmental Girder and Track Girder, Operator House, Machinery Room and Machinery
- Determine Means of Access:
    - Stairs
    - Ladders
    - Walkways
    - Handrails
    - Gates
    - Special Requirements
- Designate Access Points

Tower Drive Vertical Lift

Tower drive vertical lift bridges uniquely require a lot of consideration to be given to various levels of access along the height of the tower. The inspection of mechanical and structural components, including counterweights, guides, and machinery often necessitate varying degrees of access around and even within the main tower members. Elevators may also need to be employed, depending on the height of the towers themselves.

- Define Access Needs:
  - Below the Pier: Fender System
  - Pier Level: Span Guides, Centering Device, Bearings, Span Locks, Air Buffers, Limit Switches, Elevators if Required
  - Deck level: Miter Rail Joints, Signal System, Span Guides
  - Lift Span Top Chord: Span Guides
  - Tower
  - Intermediate: Counterweight Guides, Balance Chains, Limit Switches, Top of Counterweight: Rope Anchors, Jacking Assemblies, Balance, Operator/Control House (potentially off-bridge)
  - Top: Access around Machinery, Gantry Crane, Balance Block Storage, Counterweight Ropes, Jacking Assemblies, Signal Cabinets, Elevators if Required
- Determine Means of Access:
  - Stairs
  - Ladders
  - Walkways
  - Handrails
  - Gates
  - Special Requirements
- Designate Access Points

Span Drive Vertical Lift

Span drive vertical lift bridges uniquely require access to machinery components in various locations, including on the moving span itself. Further consideration may need to be given to the access on the vertical lift span, such that someone on the span can easily egress in the event the span gets stuck in the open condition or along the lift height. Many of the aspects of access design discussed in the tower drive vertical lift must also be employed for the span drive.

- Define Access Needs:
  - Below the Pier – Fender
  - Pier Level - Span Guides, Centering Device, Bearings, Span Locks, Air Buffers, Limit Switches, Elevators if Required, Operating Ropes
  - Deck level - Miter Rail Joints, Signal System, Span Guides
  - Top Chord & Lift Span - Span Guides, Machinery Room, Access around Machinery
  - Tower Intermediate - Counterweight Guides, Balance Chains, Limit Switches, Top of Counterweight: Rope Anchors, Jacking Assemblies, Balance, Operator/Control House
  - Tower Top - Access around Machinery, Gantry Crane, Balance Block Storage, Counterweight Ropes, Jacking Assemblies, Signal Cabinets, Elevators if Required
- Determine Means of Access:
  - Stairs
  - Ladders
  - Walkways
  - Handrails
  - Gates
  - Special Requirements
- Designate Access Points:
  - Potential flow using diagrammatic reasoning shown in Figure 5.

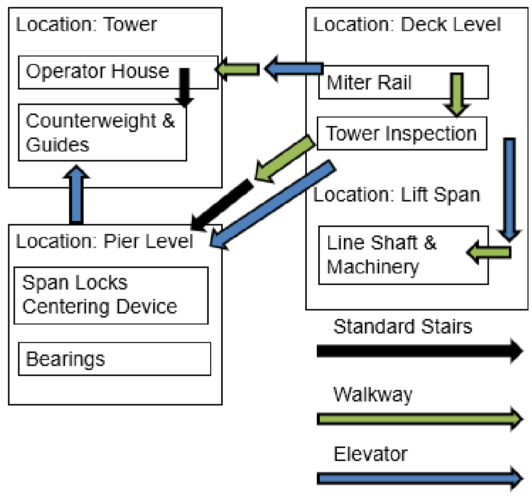

Figure 5 - Diagrammatic Reasoning Employed for Span Drive Vertical Lift

Conclusions

- Without a clear approach, access on a movable bridge can be excessive in function and in effort.
- Access needs and means should be defined early and clearly communicated through the design criteria.
- Diagrammatic Reasoning is a practical approach for developing an efficient and robust access design scheme.
- Diagrammatic Reasoning can be applied for various types of movable bridges.