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"Bascule Bridge Machinery Design Review - An Owner's Perspective"

by Thomas A. Cherukara, P.E.
Florida DOT

Bascule Bridge Machinery Design Review –

An Owner's Perspective

Thomas A. Cherukara, P.E.
Florida Department of Transportation

Mechanical/ Electrical Section
605 Suwannee Street, MS 33
Tallahassee, Florida 32399
Telephone No. (850) 414-4301
thomas.cherukara@dot.state.fl.us

ABSTRACT

This paper presents an overview of the development and design reviews of bascule bridge projects by the Mechanical/Electrical Section of the Florida Department of Transportation. Simplicity in design, functionality of components and bridge system as a whole, conformance to standards and codes, standardization of elements, and good engineering practices in design and construction are emphasized as they apply to bascule bridge systems. Some key aspects of static and dynamic analyses, wind load analysis, hydraulic analysis, leaf balance analysis, and drive system reliability analysis are presented, with options and opportunities available to design engineers.

The mechanical drive system can be designed at any stage during the design of the bascule bridge, or sometimes even after a bridge is constructed as in the rehabilitation of existing bridges. However, the efficiency, serviceability, functionality, and economics of the drive system could be unduly sacrificed when mechanical system development and design do not progress concurrently with structural development and design. Some design and construction deficiencies encountered on Florida bridge projects are presented to illustrate sound engineering practices as applicable to bascule bridges. Some key aspects of design related to welding, bolting, non-destructive testing, material selection and component detailing are presented to facilitate design engineers' producing construction documents that are adequate and complete.

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INTRODUCTION

Partnership and cooperation, close communication, and collaborative coordination among the project participants are key elements in the planning and implementation of a construction project. The role of a Consultant is to do engineering work, and the Owner pays for the expertise. If the Design Engineer does not have the technical expertise, the Owner ends up doing the engineering for the Consultant, or the project ends up in sloppy design and shoddy construction. If the plans are not detailed adequately, the responsibility in design and some risks in construction are transferred to the Contractor as well. Some construction and management aspects of bascule bridge projects are presented.

The Design Manager must have the conceptual skills to put together the design of different specialties involved and see the bridge from the big-picture perspective. The coordination aspects of mechanical, electrical and structural areas of the bridge are some times not adequately addressed in the design. Designers have in the past failed to pay attention to the mechanical-structural interfaces on bridges that have resulted in design deficiencies and construction delays. Engineering calculations form an integral part of the design. The Bridge Development Report must be supported by preliminary calculations with an analysis of design alternatives. The 30% design submittal must include design criteria and calculation to support major equipment selections. All remaining engineering calculations should be completed and submitted along with the 60% design plans and specifications, leaving only detailing for later submissions. The 100% design must be a biddable and constructible package of plans and specifications. Some technical aspects pertaining to design, detailing, and construction are presented in this paper to assist designers and owners in design and design review.

PROJECT/CONSTRUCTION MANAGEMENT ISSUES

In a contractual relationship between the Owner and a Contractor, nothing is implied. The execution of the Contract is based on the Agreement and its supporting documents. The requirements have to be clear and explicit. The Owner gets only what is shown or specified, and only the way it is specified and detailed.

In case of conflicting requirements between plans and specifications, the specifications take precedence. Specifications set the controlling criteria for construction. Performance specifications without adequate prescriptive standards and details on the drawings leave too much to the discretion of the Contractor. In such cases, shop drawing reviews and approvals suffer. This may lead to Contractor's Requests For Information (RFI), Owner's issuance of non-compliance notices, or construction disputes, delays or claims.

In preparing the bid documents, construction requirements should not be duplicated either within the specifications, or on the drawings, or between the two documents. Keep it simple and clear, and state a requirement only once, where it is most appropriate. Use standard specifications as much as possible. These have been time-tested and tested in courts of law, and the industry is most familiar with them.

Except for the codes enforceable by a jurisdictional authority, all other standards and codes do not apply and cannot be enforced unless specifically referenced in the Contract Documents. There is a misconception even among some experienced consulting engineers and corporate engineers that the Contractor must comply with industry and trade standards, simply because the work is closely or directly related to the trade. For example, unless clearly and distinctly called for, a Contractor is not obligated to provide Non-Destructive Evaluation Reports on a specific weld on a bridge structure, just because a Bridge Welding Code exists.

The bascule bridge industry is changing. The Chicago Types, Scherzer Rollers and Hopkins Frames are slowly becoming chapters in bascule history. Rear live load shoes are rarely used on new designs. There appears to be a trend in the industry to move toward design-build contracts and performance specifications. Without comprehensive prescriptive standards for products, materials and systems, such a transition is risky business. Prescriptive specifications will normally take precedence over performance specifications. If the performance requirements do not conform to the prescriptive requirements, the Contractor is not liable. To illustrate this further, if a bridge designed to open in 65 seconds, do not perform as designed, the Contractor cannot be liable, provided that he has met the prescriptive requirements for the machinery. For example, if the pressure drop in the components is higher than design, or if the pump capacity is inadequate, to provide the required flow and to meet the performance requirements, it is considered a design deficiency rather than a Contractor failure. However, if the Contractor is aware of a design deficiency or discrepancy and he continues work without notifying the Engineer/Owner, he could be held liable.

Design calculations, pump performance curves and leaf balance curves do not belong to the drawings or in the technical specifications. Only information that facilitates the Contractor in preparing the bids and the shop drawings, and that is required for the construction of the facility shall be indicated on the plans and specifications.

On bascule bridge projects, the Inspectors quite often are not familiar with mechanical equipment, components and systems. Unless the requirements are clearly spelled out or detailed, there is no way the Owner can assure a well-constructed drive system for the bridge, which is maintainable and dependable over its service life.

TECHNICAL ISSUES

Material Specifications and Standards

AISI classifications shall not be used to specify steels. Always use ASTM Standards. Material certification requirements must be stated as Supplementary requirements. Specify material in full indicating Grade, Type, or Class and Supplementary requirements, if any.

Welding

The Structural Welding Code AWS D1.1, the Bridge Welding Code AWS D1.5, and ASME Codes for Welding Rods and Welding Qualifications apply only when they are specifically referenced in the contract documents. All of them require Qualification of Welders and Welding Procedure Specifications, along with other requirements. However, except for visual inspection, the methods of inspection, the extent of inspection and the acceptance criteria are not mandatory according to the Welding Codes. Therefore, such requirements must be clearly specified.

A blanket statement such as, "All weldments shall be inspected utilizing non-destructive tests (ie., via dye penetrant checks supported by Ultrasonic Testing or Radiographic Testing) as required by the AASHTO/AWS D1.5 Bridge Welding Code or the Contract Plans," has little meaning in a contractual relationship. Visual Inspection is the only one that is required by the codes. Whatever the intent of the Specification is, in such a case, the Contractor is obligated to perform only visual inspection of the welds.

Bolting

As far as practical, design bolts such that they are loaded in shear rather than in tension. In many bolt assemblies, the tensile loads and preloads cannot be accurately established. Tensile loading of bolts may result in loosening of the assembly if preload is inadequate (see Figure 1). Bolt assemblies with bolt length exceeding 12 diameters shall not be torqued by standard turn-of-nut method. The amount of rotation required in such instances shall be determined by actual tests.

Span locks

Use lock bar of rectangular cross section. The rectangular section provides considerably higher section modulus compared to a square section, for the same amount of material. There is no need to provide relief on the sides of a lock bar (see Figure 2). With split guide shoes, there is no sliding on the sides. Provide male clevis on the bar and use female clevis attached to cylinder rod with a self-aligning coupler (see Figure 3).

Hydraulic Cylinders and Systems

The pressure on the rod side and also on the piston side shall not vary by more than +/- 2% among the various cylinders on a leaf. Some design deficiencies we have encountered include welding failures at gimbal mounts, bearing failures at trunnion pins, inadequate working stroke, leaky seals, and inaccessibility of cylinder manifold from floor level.

Geometric positioning of cylinder relative to leaf shall be optimized. Use only cylinder quality tubing for shell. Material certifications shall be required. Welders and welding procedures must be qualified and the welds shall be tested. The cylinders and the systems shall be pressure tested at 1.5 times the maximum working pressure.

Common problems with hoses include chafing when they are not secured, hose bends in different planes resulting in twisting, improperly cut lengths, and inadequate radii at bends. Use welded joints and fittings with stainless steel tube. Stainless steel tubes may crack while flaring, thus preventing the use of flared connections.

Top and bottom cylinder supports

The welds are subjected to cyclic loading and must be 100% ultrasonic tested. Use complete joint penetration welds. In case of female clevises, provide groove only on the outside. Design the upper bracket to avoid interference at the outer surface of the male clevis, for maximum tilt at leaf full open condition (see Figure 4).

Gears and Speed Reducers

The technical specifications shall be complete in all aspects, leaving no room for interpretations or clarifications. All applicable standards must be referenced. AGMA Quality Number for the gears and Service Factor for the assembly must be indicated. The criteria for testing at 50% to 300% full load motor torque must be stated. Post testing inspection and acceptance criteria must also be included. Gears shall have pitch lines scribed on both sides and match-marked prior to shipping. Material certifications, non-destructive evaluation reports and heat treatment certifications must be reviewed during inspection, and these shall be submitted to the Owner.

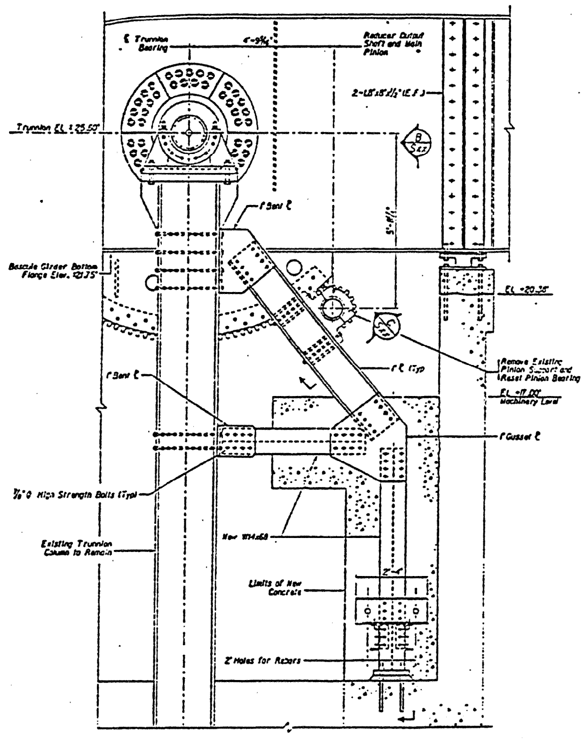

Figure 1: Pinion Mounting Bolts loaded in Tension

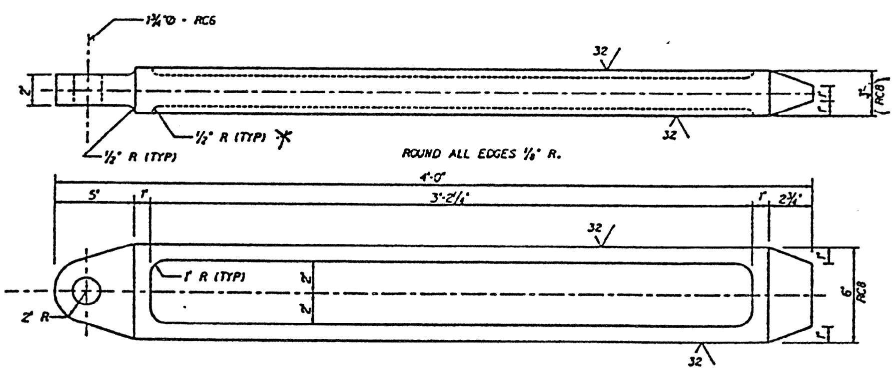

Figure 2: Lock Bar with Relief on the sides

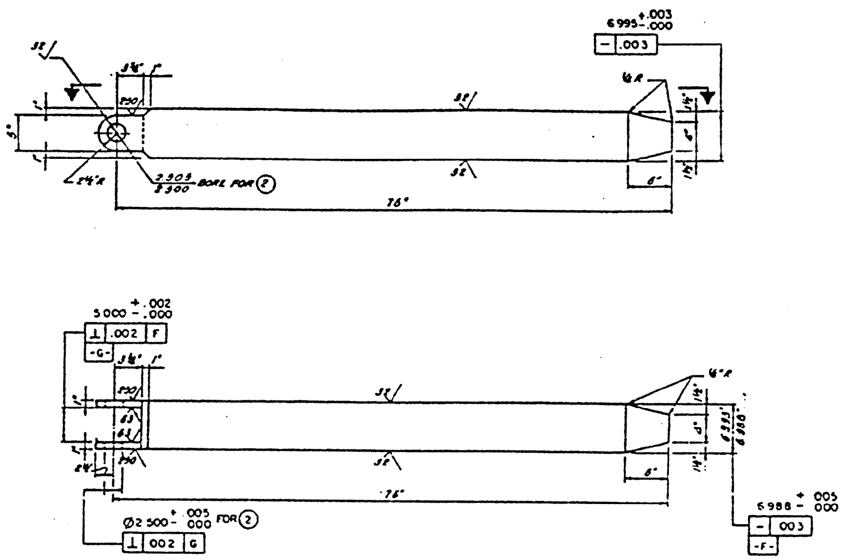

Figure 3: Lock Bar with Square Cross-section and Female Clevis

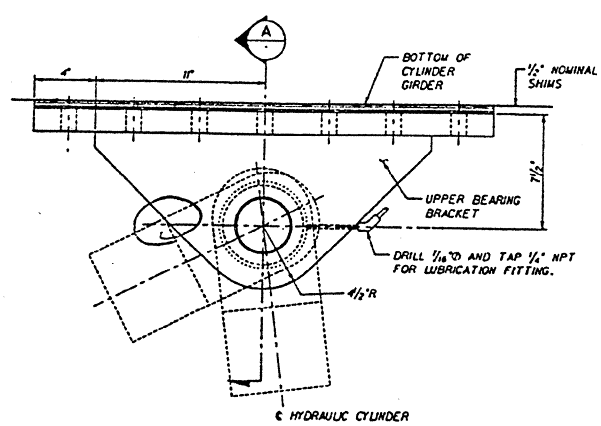

Figure 4: Upper Cylinder Bracket (interference with clevis during rotation)

Balancing

Bascule bridges are not balanced by using wattmeters or by drift tests anymore. Gear drive bridges shall be balance tested by the strain gauge method. Hydraulic cylinder bridges shall be balance tested by pressure measurement and analysis of forces for opening and closing. In addition, the reactions at the live load shoes must be uniform. Acceptable balance conditions must be clearly defined. The balance requirements shall not be duplicated by specifying the unbalance torque and location of center of gravity, the reactions at live load shoes, and the unbalance load at tip of leaf.

Most new bascules are constructed at medium elevations and usually have adequate space forward of the trunnion for providing forward live load shoes. Rear live load shoes are not recommended.

Qualification of Personnel

Qualified Millwrights experienced in bascule bridgework shall perform the machinery installation and alignment. Ironworkers shall not be permitted to perform such functions. A certified Fluid Power Technician shall perform fluid power installation and commissioning. A licensed Professional Engineer must perform the balance testing and the balance calculations.

Maintainability Considerations

Bascule leaf jacking surfaces shall be identified on the leaf and on the pier, and shall be designed to facilitate jacking. Provisions shall be made for securing the leaf in the jacked position. The lay out of machinery and leaf-cylinder geometry shall be designed for optimal use of the machinery area. The drive machinery shall clear the full opening of the bascule leaf. Gauges shall be accessible and easily readable. Filters, inspection covers and lubrication ports shall be accessible for service. Provide a service area of at least 30 inches around the drive machinery. Specify corrosion resistant hardware where appropriate.

Shop Drawings

Require the Contractor to submit comprehensive shop drawing data to facilitate proper fit and hookup of related components and systems, including structural and electrical interfaces. Shop drawings must indicate mass of components and equipment. The Owner cannot review shop drawings that do not include project name and project number. Detailing of bolts and nuts shall be based on heavy series. Surface finishes shall be shown and components shall be adequately detailed to facilitate material procurement and fabrication. Testing and processing requirements must be stated. ANSI Drafting Standards must be followed in preparing the shop drawings.

Inspection, and Preparation and Disposition of Reports

The Non-Destructive Testing (NDT) requirements of welds, castings, forgings and components formed by other means, shall be clearly specified indicating the type of NDT to be used, extent of inspection and acceptance level or criteria. Hub castings, lock bars, pins, trunnions and shafts shall be subjected to ultrasonic inspection. The test reports, material certifications, heat treatment certifications and compliance certifications are to be reviewed and retained by the Owner.

CONCLUSION

The Owner must perform thorough and detailed reviews of the design and the bid documents during the different phases of project development. Only through concerted efforts to avoid conflicts and discrepancies, can the Engineer and the Owner accomplish biddability and constructibility of a project. Construction risk assignments or transfers shall be minimal among the project participants. The Designer must assume the full responsibility for accuracy and completeness of the contract documents.

For successful implementation of a construction project, all project participants must develop a clear and distinct understanding of the roles and responsibilities of each party.