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"Modern Rehab. Alternatives for Hopkins Trunnion Bascule Brdg."

Introduction

During the post-war construction boom of the 40's, 50's, and 60's, literally hundreds of simple trunnion bascule bridges were constructed over the inland waterways of the coastal southeast. During this period, Nashville Bridge Company took advantage of Leonard Hopkins' patented frame mounted drive machinery to efficiently construct a large number of these bridges. Now only twenty to forty years old, many of these bridges require or are currently undergoing major rehabilitation.

The Hopkins Frame configuration was a proprietary frame mounted drive system that was developed as a Contractor's alternate to the floor mounted drive system typically proposed for these bascule bridges. Although the Hopkins Frame was patented in 1936, its widespread use did not occur until this boom.

The Hopkins Frame offered a number of distinct advantages in construction, installation, and operation. Hopkins described the key feature of the machinery frame in his original patent:

> "It is an object of the invention to provide a construction wherein small inaccuracies in the positioning and erection of the parts may be compensated for and yet the means of forming a connection between the main trunnions and machinery may be properly maintained in engagement."

In other words, the alignment of the rack and main drive pinion was easily obtained and maintained during operation regardless of small errors in frame positioning, due to the unique pinned configuration of the frame (described in detail later in this paper). The frame mounted drive configuration also offered the advantage of shop alignment and testing of equipment. Similar design requirements (i.e., similar span lengths, bridge widths, design loads, etc.) for these bridges resulted in similar overall configurations. This allowed many of the drive machinery components to be standardized providing obvious savings in detailing and fabrication costs.

Despite the numerous advantages, shortcomings in the Hopkins Frame design are the cause of premature wear within components of the drive machinery and the machinery frame. In a number of cases, the Hopkins Frames has also experienced structural failure. Because of the great deal of similarity in the configurations, similar deficiencies are found in most Hopkins Frame drive systems although they vary in severity depending on the age of the bridge, frequency and roughness of operation, quality of materials and workmanship, and degree of continuing maintenance. Over the years, the Hopkins Frame has evolved as improvements were encorporated, correcting to a degree, some of the design flaws. Nonetheless, the drive systems of many of these bridges still require major rehabilitation or replacement.

This paper discusses several modern rehabiltation alternatives that are currently being developed. To understand the factors responsible for the rehabilitation and the development of the various alternatives, the configuration of the Hopkins Frame and its deficiencies should be reviewed in detail.

The Hopkins Frame

Configuration

(Refer to Figure 1.)

Rack & Rack Frame: The original operating machinery designs typically called for floor mounted machinery and a rack mounted to the underside of each bascule girder. The Hopkins Frame configuration, however, utilizes a pair of racks mounted on special frames (rack frames) located several feet either side of the span centerline. The rack frames attach to the underside of special stringers (rack stringers) and additionally frame into the forward counterweight girder. The rack stringers span between the forward counterweight girder and the adjacent deep floorbeam and often additionally function as roadway stringers supporting a concrete filled grating over the machinery area.

Hopkins Frame: The drive train is mounted to one side of a vertical machinery frame (the Hopkins Frame.) The frame generally consists of four (4) vertical members fabricated from wide flange sections. The verticals are connected by a backing plate stiffened with horizontal angles, a single horizontal channel at the top, and a pair of horizontal channels at the bottom. The frame is generally of welded construction.

The frame is clevis mounted to the machinery floor at the bottom of the two outside verticals. The drive pinions are held at a constant distance from the trunnion centerline by link arms. The link arms attach to the cantilevered ends of the main drive shafts at one end and a rack center shaft (steel pipe) at the other end. The center shaft spans between the rack frames, concentric with the trunnion centerline. The pinned configuration allows the frame to be oriented at any suitable angle and the clevis to be mounted at any suitable elevation in obtaining the alignment of the rack and main drive pinion. The alignment of the rack and pinion occurs nearly automatically as the center to center distance is fixed by the link arms. The remainder of the drive machinery is aligned in the shop. (The advantages of the Hopkins Frame configuration become obvious when compared with the painstaking field alignment of the floor mounted machinery.) Alignment is similarly maintained during operation regardless of irregularities in rack/trunnion alignment or frame deformation as the frame is free to rotate to accomodate any radial misalignment.

Bearings: The bearings supporting the drive machinery (typically

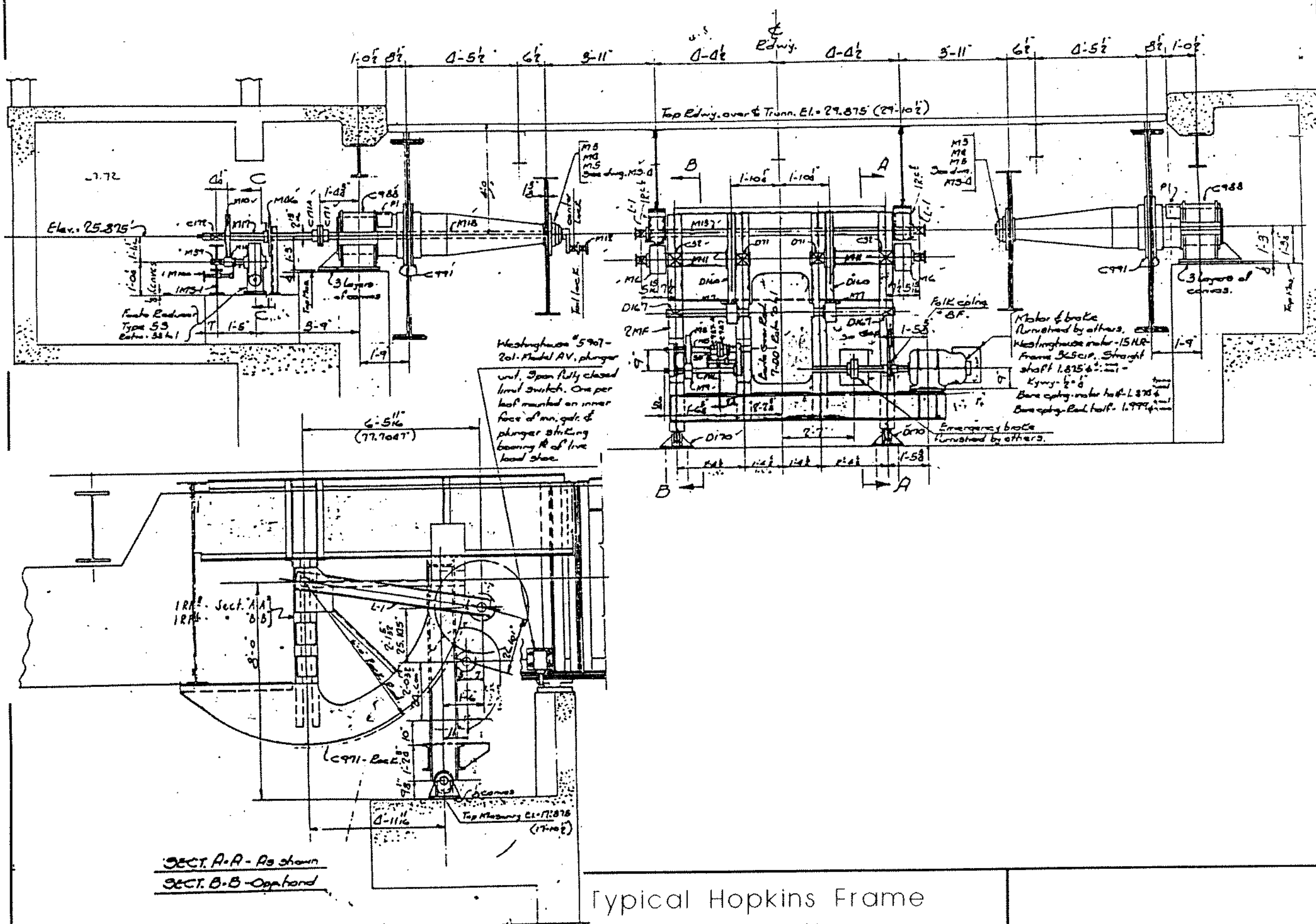


Figure 1

Typical Hopkins Frame Configuration

three (3) pairs) are mounted eccentrically to the Hopkins Frame on bearing pedestals welded to the verticals or backing plate. The base of the bearings are oriented vertically and are typically bolted through the frame with four (4) turned bolts. Shims are provided between the bearings and the bearing pedestals for adjustment. The bearing caps are mounted to the base with four (4) mounting bolts.

The drive machinery for the Hopkins Frame configuration is nearly the same as that for the floor mounted configuration (i.e., they both consist of an electric motor(s), thrustor brake(s), a speed reducer and/or differential assembly and open gearing.) Only the configuration and mounting orientation differ greatly.

Deficiencies

Hopkins Frames exhibit a number of deficiencies which are a direct result of shortcomings in the original design.

Frame Twisting: The racks and main drive pinions exhibit wear patterns that reflect excessive transverse flexure and twisting in the machinery frame. Wear to the rack and pinion teeth is heavier toward the ouside of the teeth in a manner consistent with axial misalignment (i.e., presence of crossbearing and edge loading.) The pinions are cantilevered from the ends of the main drive shaft outside the pinion shaft bearings and inside the link arm bearings. The link arms and bearings do not provide restraint in the same plane, and thus results in torsion and transverse bending of the frame. The horizontal channels and angles lack sufficient stiffness to prevent the undesired deformation.

Bearing Movement: The bearings supporting the main drive shafts exhibit separation between the bearing base and the bearing pedestals and similar separation between the bearing cap and base. The bearings also exhibit vertical movement relative to the bearing pedestals. The movement is typically evidenced during starting and stopping of the span when operation is rough. The orientation of the bearings places the anchor bolts and cap bolts in combined shear and tension. Inadequate bolt tension together with the relatively large bearing forces result in the bearing movement. Frequently, attempts have been made to prevent the movement by welding shear lugs to the frame above and below the bearing bases. The shear lugs typically do not bear directly against the bearing bases and have no means of adjustment generally making the lugs ineffective.

Frame Cracks: Many Hopkins Frames develop fatigue cracks in the verticals or backing plates. Hopkins Frames are subject to cyclic bending and axial stresses and stress reversal. The high stresses are a direct result of the large eccentricities and machinery operating forces, and undersized members. In addition, the frames exhibit a number of fatigue sensitive details in locations where the stresses are high. These include:

- the base of the welds for the connection of the bearing pedestals to the machinery frame verticals
- the holes in the flanges of the verticals for the bearing anchor bolts (especially where edge distance requirements are violated)
- the backing plate adjacent to the welds for the attachment of the stiffening angles.

Many of the newer frames have yet to develop fatigue cracks. Although significant improvements have been made to the Hopkins Frames with regard to fatigue details and stresses, indications are that fatigue cracks may still eventually develop as a larger number of cycles is reached.

Worn Clevis Brackets: The clevis and clevis brackets at the bottom of the Hopkins Frame verticals are typically overstressed as evidenced by the elongated holes for the clevis pins. The overstressing is a result of the large machinery forces and undersized clevis bracket ears and pins. The Hopkins Frames are commonly seen to "jump" during starting and stopping of the span as a result of the wear. In addition, the clevis bracket anchor bolts often work loose in the concrete as a result of the constant impact loading. Normal wear to the drive machinery and fatigue of the machinery frame is accelerated by the rough operation.

Many other common deficiencies are found throughout the drive machinery that are not necessarily related to shortcomings in the Hopkins Frame configuration. These deficiencies will not be specifically addressed here, however.

As a result of the significant deficiencies, major rehabilitation is required to the drive systems on many Hopkins Trunnion Bascule Bridges. The scope of rehabilitation for extending the service life of these bridges another thirty (30) years varies and ranges from partial drive system replacement to total drive system replacement.

Drive System Replacement

Hydraulic Cylinders

Hydraulic cylinder drive systems constitute the greatest number of drive system replacements for Hopkins Trunnion Bascule Bridges to date in Florida and will be a central focus of this paper.

Although hardly a new concept for powering trunnion bascule bridges, hydraulic cylinders have most recently been used in the rehabilitation of bascule bridges as a permanent replacement drive system. The "Hydraulic Trunnion Bascule" was first patented in 1967 by George G. Mooney and Earnest C. "Doc" Driver. Highlights of the patent included vertically oriented cylinders clevis mounted to the bascule pier and underside of each bascule girder and a centralized hydraulic power unit. Hydraulic cylinders have also been used to provide temporary drive systems while repairs to the existing drive machinery were performed. Since their initial use, there have been a number of refinements in the hydraulic drive system with the emphasis on increased service life.

The following describes the development of the hydraulic cylinder alternative and a number of important issues related to the design.

Cylinder Sizes & Locations: In sizing and locating the cylinders, a number of parameters must be considered and balanced. Once the power requirements are determined (i.e., torque about the trunnion required to operate the span ubder the various loading conditions), an estimate of the location of the cylinder ends should be made for trial moment arms. The locations are based on existing span and pier geometric constraints and a preliminary design of the new cylinder support girders. For the various trial moment arms, cylinder operating forces are computed at intervals of span orientation.

Cylinder bores and rod sizes are determined based on acceptable system operating pressures and are checked for buckling resistance at the fully extended length. As the cylinder attachment is moved further from the trunnion centerline the moment arm increases and the cylinder forces decrease (and thus the required cylinder size decreases.) However, as the moment arm is increased, the stroke increases (and thus the overall cylinder length increases) until buckling of the cylinder becomes a problem.

Cylinder geometry is frequently constrained by existing span and bascule pier geometry. Thought should be given towards available overhead clearance and modifications to the bascule span framing. Consideration should also be made in selecting cylinder geometry to minimize modifications to the bascule pier machinery floor.

The preferred cylinder orientation is as close to vertical as possible. Because the cylinders rotate during span operation, a completely vertical orientation of the cylinder is not possible for every angle of span orientation. The ideal orientation is to acheive a vertical cylinder either at a point half-way through the span operation or at the beginning and end of the operation. This is often not practical because of span and pier geometric constraints. Thus, a compromise is typically necessary between the ideal cylinder orientation and required modifications to the machinery floor. Cylinders do not necessarily have to be oriented near vertical. In fact, stresses in the cylinder support girders can be minimized by orienting the cylinder at an acceptable angle. However, the greater the cylinder angle, the greater care should be made in checking the effects of cylinder forces on the existing structure and trunnion bearings.

Cylinder Types & Mounting: The cylinders first used to power trunnion bascule bridges were standard NFPA industrial tie-rod cylinders. Although these cylinders were generally satisfactory for temporary operations, their use in permanent installations has not been without problems. Premature wear of the cylinder rod seals has been a constant maintenance problem as replacement has been required in some cases in less than five years.

As a result, custom heavy duty mill type cylinders are now being considered for use because of their improved rod seals, increased buckling resistance, and overall greater durability.

Proper mounting of the cylinder is of equal importance. Misalignment of the cylinders and/or lateral movement of the span due to wind loads introduces undesired forces on cylinder rod seals. Proper mounting of the cylinders can reduce loads on the cylinder rods. Mountings which allow slight rotation of the cylinders such as clevis brackets with spherical bearings are preferred. Mountings which restrict the rotation of the cylinders such as trunnion mounts or clevis brackets without sperical bearings should be avoided.

As the cylinder length increases, stop tubes should also be used to increase buckling resistance and decrease forces on the rod seals.

Modelling & Analysis: Because of the "teeter-totter" nature of a bascule leaf, there are difficulties in modelling the leaf for a structural analysis. Cylinder forces can not be directly applied to the span because the structure has indeterminate boundary conditions (i.e., the span is allowed to rotate in space about the trunnion.)

To circumvent the instability a different approach to the analysis must be made. Members representing the cylinders are added to the model with the base of the cylinders providing the additional support condition to make the model determinate. A uniformly distributed load is applied normal to the deck (representing wind loads and inertia) together with span dead loads and is increased until the desired reaction in the cylinder is developed. (The AASHTO Specifications for Movable Highway Bridges states that cylinder supports should be designed for 150% of the maximum cylinder forces based on the relief valve setting. Although these forces may not ever be developed in the cylinders, the requirement provides an accepted conservative design.)

The analysis is performed with the span in different angles of orientation, under all combinations of active cylinders (i.e., one or two cylinder operation for two cylinder installations) and for both span raising and lowering forces in the cylinders.

The member forces obtained from this design are used strictly for designing the cylinder girders and bracing and checking the forces in the adjacent deep floorbeam. Other span member forces and deformations are not considered meaningful under these equivalent loads.

Three (3) recent examples of drive system replacement with hydraulic cylinders include the B. B. McCormick and Sisters Creek Bridges in Jacksonville, Florida (currently in construction) and the N. E. 14th Street Bridge in Ft. Lauderdale, Florida (rehabilitation design complete.) These bridges are owned and operated by the Florida Department of Transportation.

Sisters Creek & B. B. McCormick Bridges

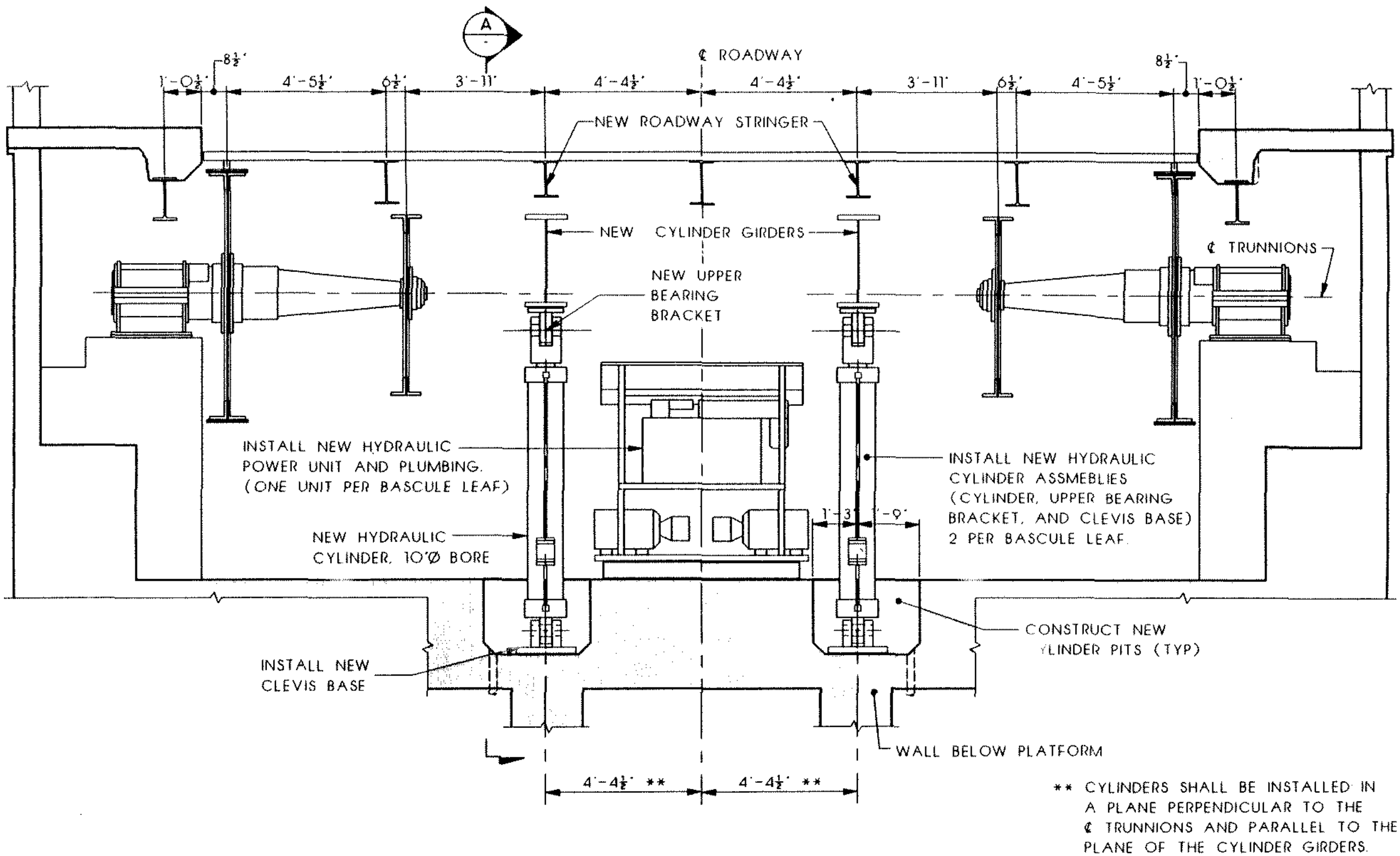
(Refer to Figures 2A & 2B.)

The configuration of the Sisters Creek and B. B. McCormick Bridges are similar and thus have similar power requirements. The two bridges contain a total of three (3) double-leaf spans - the B. B. McCormick Bridge has twin spans and the Sisters Creek Bridge a single span. Each bascule span carries two lanes of traffic and is 122'-6" center to center of trunnions.

The design of the cylinders, mounting brackets, and power units for the two bridges were carried out simultaneously with the idea that the components for all six (6) bascule leaves would be identical. This was to provide economy both in fabrication and in future maintenance and rehabilitation. The two bridges were bid together to ensure that identical components were used. The major difference between the bridges is in span geometry (i.e., differences in span structural framing, bascule pier geometry, and Hopkins Frame dimensions and configuration.) The differences, effect only the detailing of the cylinder mounting.

Each leaf is moved by two (2) 10" diameter bore heavy duty mill type hydraulic cylinders with 6" diameter rods (the first mill type cylinders to be used by FDOT.) The cylinders have an 8'-5" retracted length including stop tubes and end cushions, and a 5'-3" stroke. The cylinders are mounted at a distance of 4'-1 1/2" from the center of the trunnions and are mounted to new cylinder girders that replace the Hopkins Frame rack stringers. Locating the cylinder girders in place of the rack stringers introduces forces most like the original configuration.

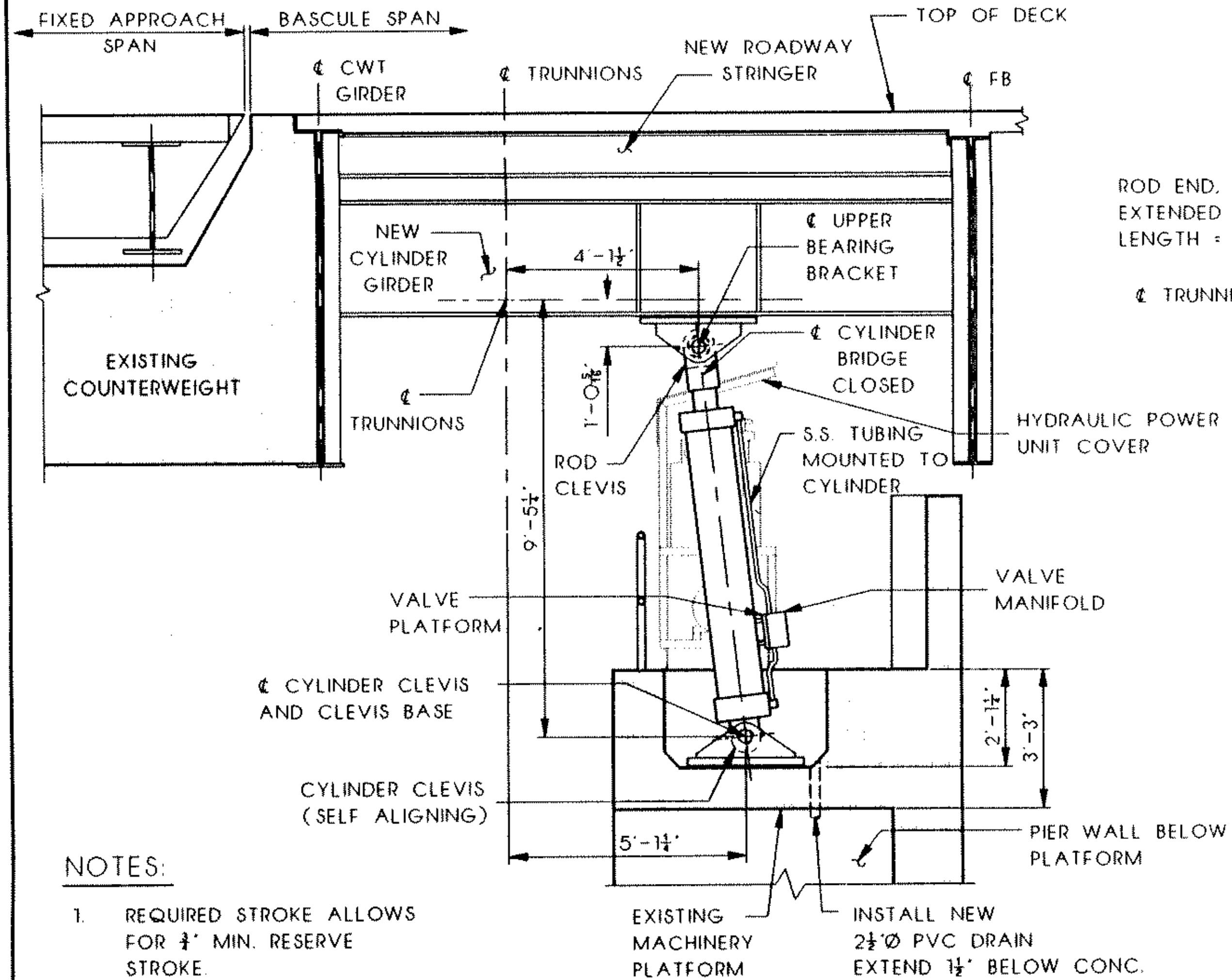
Redundancy is built-in as each leaf can operate on a single cylinder. The cylinders are located relatively close together and the bridge is narrow enough so that span forces and displacements from single cylinder operation are within acceptable limits.



BASCULE PIER ELEVATION

Sisters Creek Br. Rehabilitation
Hydraulic Cylinder Drive System

Figure 2A

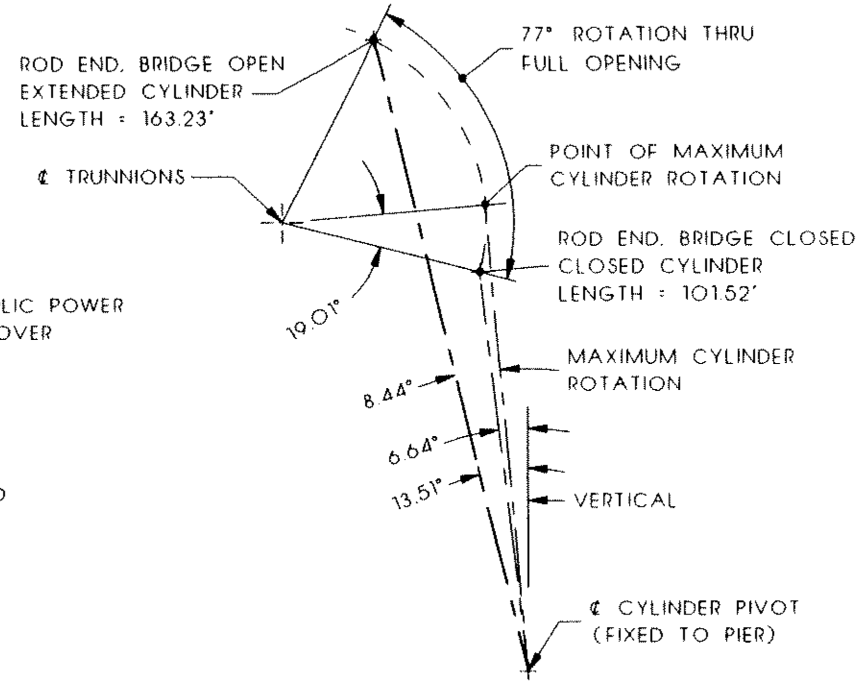


NOTES:

1. REQUIRED STROKE ALLOWS FOR ¾" MIN. RESERVE STROKE.

2. RETRACTED LENGTH ALLOWS FOR ½" NOMINAL RESERVE STROKE BEFORE PISTON BOTTOMS OUT.

SECTION (A / -)



CYLINDER MOVEMENT SCHEMATIC

Figure 2B

Sisters Creek Br. Rehabilitation
Hydraulic Cylinder Drive System

Unlike many cylinder operated bridges, the cylinders are oriented at an initial angle to the vertical of 6.64 degrees (position when span closed) and a final angle of 13.51 degrees (position when span fully open). This configuration avoided having to core completely through the machinery floor which would have required installation of complicated supports below the machinery floor. In addition, the bottom end of the cylinders would not be easily accessible for inspection and maintenance and would be much closer to the severly corrosive salt water. (The bascule piers for both bridges have wet counterweight pits.) This arrangement also significantly reduced the buckling length of the cylinders.

The cylinders for each leaf are powered by a single hydraulic power unit with two (2) 10 hp motors, two (2) piston type variable displacement pumps, manifold mounted valves, and a 100 gallon reservoir. Forces in the cylinders are balanced by the use of a common fluid supply via the main proportional valve. Smooth operation and control of overruning loads is provided by back pressure in the cylinders which is controlled by counterbalance and cross-port relief valves. The valves are controlled through a programmable logic controller by electronic ramp cards. Cylinder relief valves are set at 2750 psi on the Sisters Creek Bridge and 2400 psi on the B. B. McCormick Bridge.

A major concern with hydraulic cylinders is the with wear to the rod seals. Most of the previous problems, however, are a result of the use of less durable industrial tie rod cylinders and improper cylinder mounting. The heavy duty mill type cylinders contain improved chevron rod seals with increased durability. Furthermore, the cylinders are clevis mounted at both ends. The clevis brackets contain a plain spherical bearing which accomodates slight misalignment which may result during installation or from span lateral movement. This significantly reduces wear to the rod seals and further extends the service life of the seals. Stop tubes are provided for reduced bearing pressure and increased buckling resistance.

Bascule span structural modifications primarily include installation of the new cylinder girders. An additional stringer was installed above the cylinder girders to support the roadway flooring over the machinery room and prevent the direct application of wheel live loads to the cylinders. A new stiffener had to be welded to the forward counterweight girder in place of the existing rivetted connection angle because of insufficient capacity. Preheating of the counterweight girder (because of the heat sink provided by the concrete counterweight), stress relieving (via shot peening), and 100% ultrasonic inspection was specified to ensure high field weld quality. Rivets of the floorbeam connection are replaced with high strength bolts. The existing span lateral bracing also had to be slightly modified.

Modification of the bascule piers includes construction of partial depth (2'-0" deep) recesses in the machinery floor for the lower clevis brackets. Modification includes saw cutting and removal of concrete and reconstruction of the floors and walls of the recess using latex modified concrete. Excavation was limited to a depth that did not require strenghtening of the machinery floor. Cylinder mounting brackets are fastened to the floor with hydraulically tensioned undercut anchors.

N. E. 14th Street Bridge

(Refer to Figure 3.)

The replacement drive system for the N. E. 14th Street Bridge exhibits many of the same features as the Sisters Creek and B. B. McCormick Bridges. However, the N. E. 14th Street Bridge carries four (4) lanes of traffic and is 145'-6" center to center of trunnions. Because the size of the span is much larger, the power requirements are much greater.

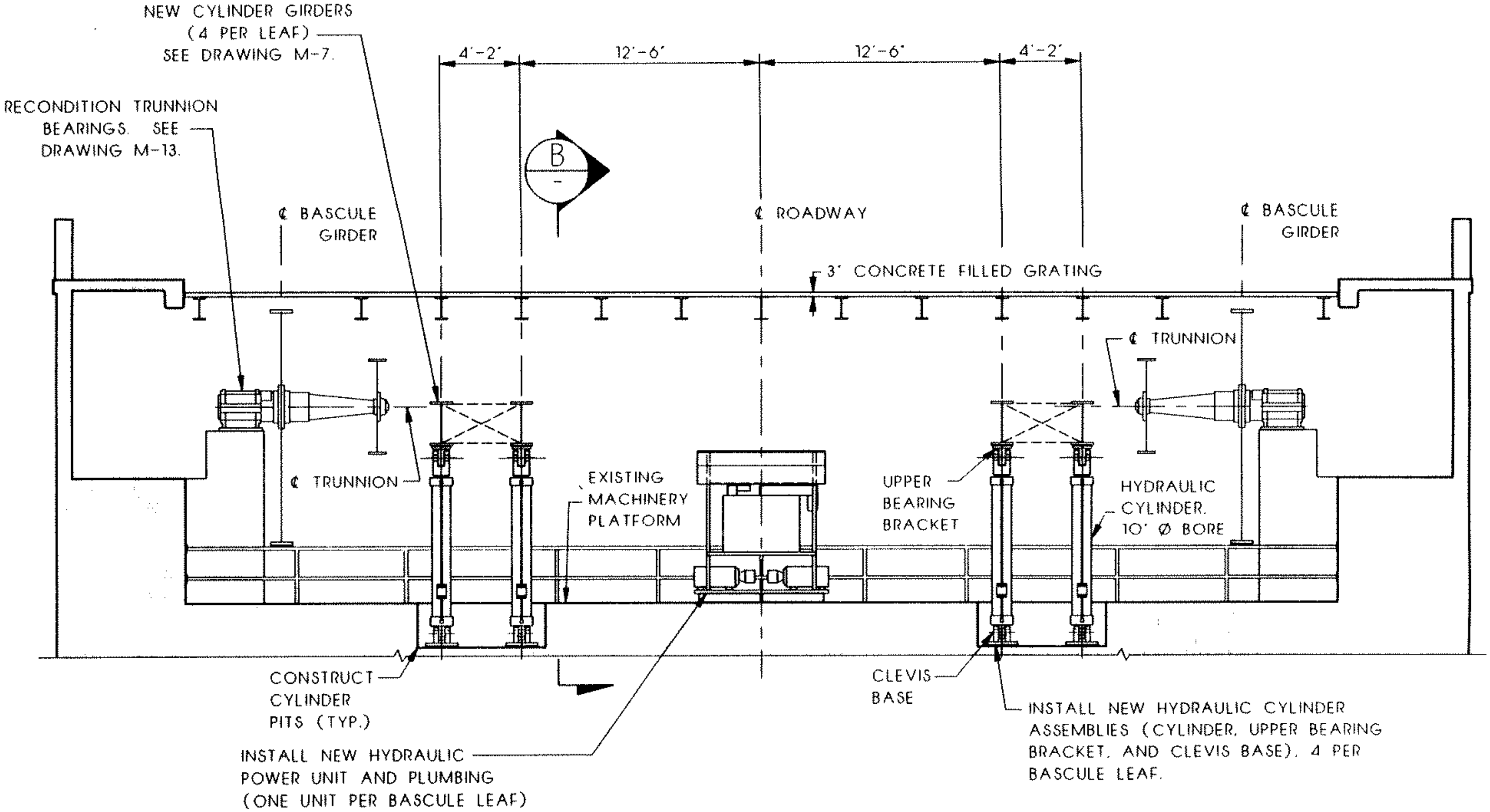
Each leaf is moved by four (4) 10" diameter bore heavy duty mill type hydraulic cylinders with 6" diameter rods located in two pairs. Because of the width of the bridge, single cylinder operation is not practical (i.e., span stresses and differential displacements would be too great without extensive bracing or strengthening.) Instead of operating on two (2) large cylinders under normal operation and one (1) cylinder under emergency conditions, four (4) smaller cylinders are provided with emergency operation provided by two (2) cylinders (one cylinder per pair.)

Due to installation of concrete wheel paths, new heavier span lock guides and receivers, and other structural steel repairs, balancing of the N. E. 14th Street Bridge was a problem. However, the hydraulic cylinders can accomodate larger unbalanced forces with only slight increases in system pressures and thus aided in the balancing of the span.

Economy is provided here in the furnishing of eight (8) identical cylinders and two (2) identical power units.

A single hydraulic power unit is used to power the four (4) cylinders of each leaf. The power units are similar configuration to the Sisters Creek and McCormick Bridges with the exception of larger components to accomodate the greater power requirements. The power units consist of a 20 hp motor, and a 250 gallon reservoir. Forces in all four (4) cylinders are balanced with the use of a common fluid supply and main proportional valve. The cylinder relief valves are set at 2800 psi.

The cylinders have a 9'-3 1/4" retracted length including stop tubes and end cushions, and a 6'-1" stroke. The cylinders are mounted at a distance of 3'-11 5/8" from the center of the



BASCULE PIER ELEVATION

Four (4) Cylinder
Hydraulic Schematic

Figure 3

trunnions. Unlike the Sisters Creek and B. B. McCormick Bridges, the cylinders are oriented such that at a point half-way through the operation, the cylinders are vertical - the ideal orientation.

Although cylinder geometry did not require excavation completely through the machinery floor, the depth of excavation required strengthening of the machinery floor. Because this bridge has dry counterweight pits, constructing supports below the machinery floors was not considered a problem. Relatively simple concrete columns are to be constructed beneath each cylinder between the floor of the counterweight pit and the underside of the machinery floor to support the high cylinder forces. The upper pour of the columns will be made using a non-shrink grout to ensure positive contact.

Improvements in the cylinder bottom clevis brackets were encorporated to aid in the installation, alignment, and future rehabilitation of the cylinder brackets. Instead of mounting the cylinder brackets directly to the machinery floor, mounting plates are embedded in the floor of the recesses during reconstruction of the floors and walls of the recesses. Shear studs are welded to the bottom of the plate for additional shear and anchorage strength. The plates are levelled with levelling screws and are set in place with high strength grout. The plates are inscribed with centerlines to accurately locate and align the brackets. The embedded plates are used as templates for coring the anchor bolt holes. Once the plates are in place, the clevis brackets are aligned and set to the proper elevation with shims. The anchor bolts are placed and extend into the concrete columns which have not yet been poured. Once the cylinders are properly located and aligned, holes for dowells are drilled, and dowell pins are installed. The columns are completed and the anchor bolts hydraulically tensioned. Finally, the holes for the anchor bolts are grouted.

The cylinders are located in pairs directly below existing roadway stringers outside the Hopkins Frame rack stringers. Location of the cylinder girders allows the structural modifications to be performed and the cylinders installed while the span remains in operation under the power of the existing drive system. (The rack stringers and rack frame are to remain to help the balancing of the span.) The cylinder girders are mounted to existing forward counterweight girder and floorbeam welded vertical stiffeners. An additional length of connection plate is welded to the web of the counterweight girder to provide double shear for the bolts. Similar welding requirements to the Sisters Creek and B. B. McCormick Bridges were specified. A connection angle is similarly bolted to the floorbeam. "X" bracing is provided between the cylinder girders in each pair.

Frame Mounted Hydraulic Drive Systems

In addition to the hydraulic cylinder drive systems, several frame mounted drive systems have been used to replace Hopkins Frame drive systems.

Seabreeze Bridge

(Refer to Figure 4.)

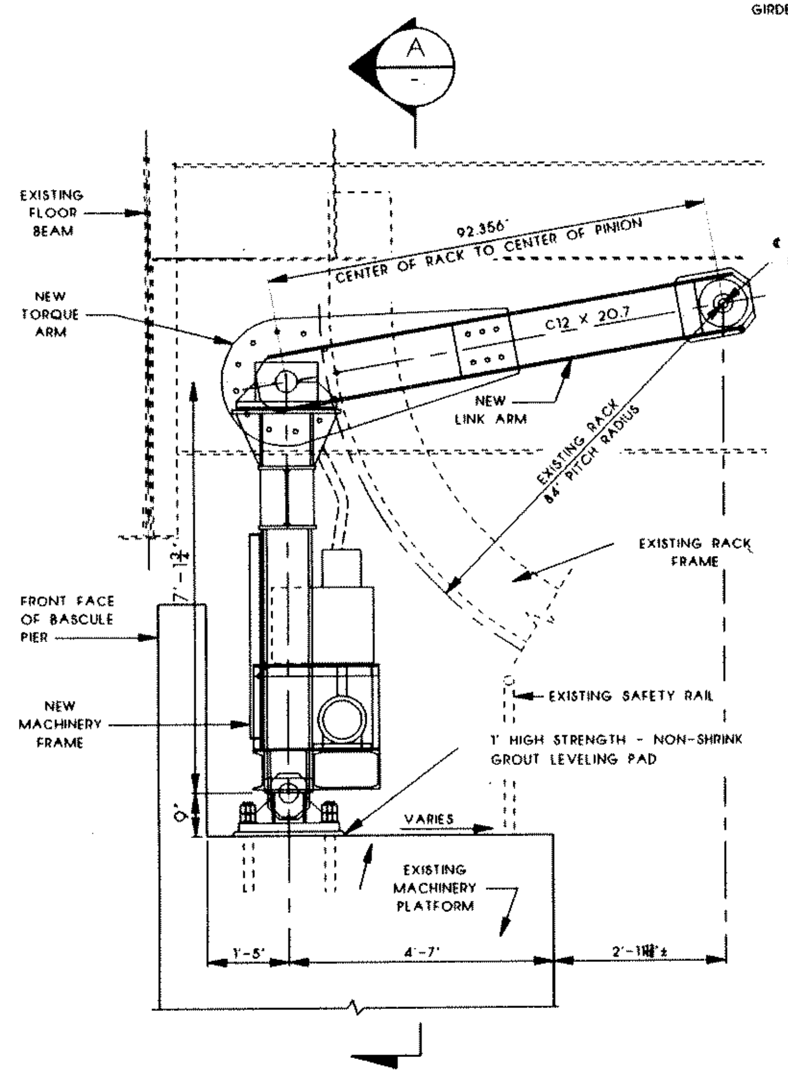
Perhaps the most unique and effective solution to date is the frame mounted hydraulic motor drive system developed as an emergency design/build replacement of the Hopkins Frame drive system for the Seabreeze Bridge in Daytona, Florida. The concept was developed in a joint effort by Jim Phillips of Parsons Brinckerhoff, Mike Hanley of Circuit Engineering, and FDOT's mechanical engineering group.

The new drive system exhibits a number of advantages including the advantages of the original Hopkins Frame pinned configuration and the advantages of modern hydraulic motors, namely the delivery of high torque without extensive gear reduction. Furthermore, the forces applied to the existing structure from the new machinery are very similar to those of the original configuration. Installation of the new frame was performed with minimal disruption to bridge operation and vehicular traffic. The new drive system can be reused in another bridge of similar configuration with only minor modifications once the Seabreeze Bridge is replaced within a few years.

The new drive system is more than just a hydraulic Hopkins Frame drive system. It is a modern hydraulic drive system mounted on an improved frame. The electric motors, thrustor brakes, open gears, pillow blocks and reducer assemblies of the original drive system are replaced by a hydraulic power unit, low speed high torque hydraulic motors, planetary reducers, and hydraulic disk brakes. The existing rack and pinion, rack frame and rack stringers are reused with only minor modifications.

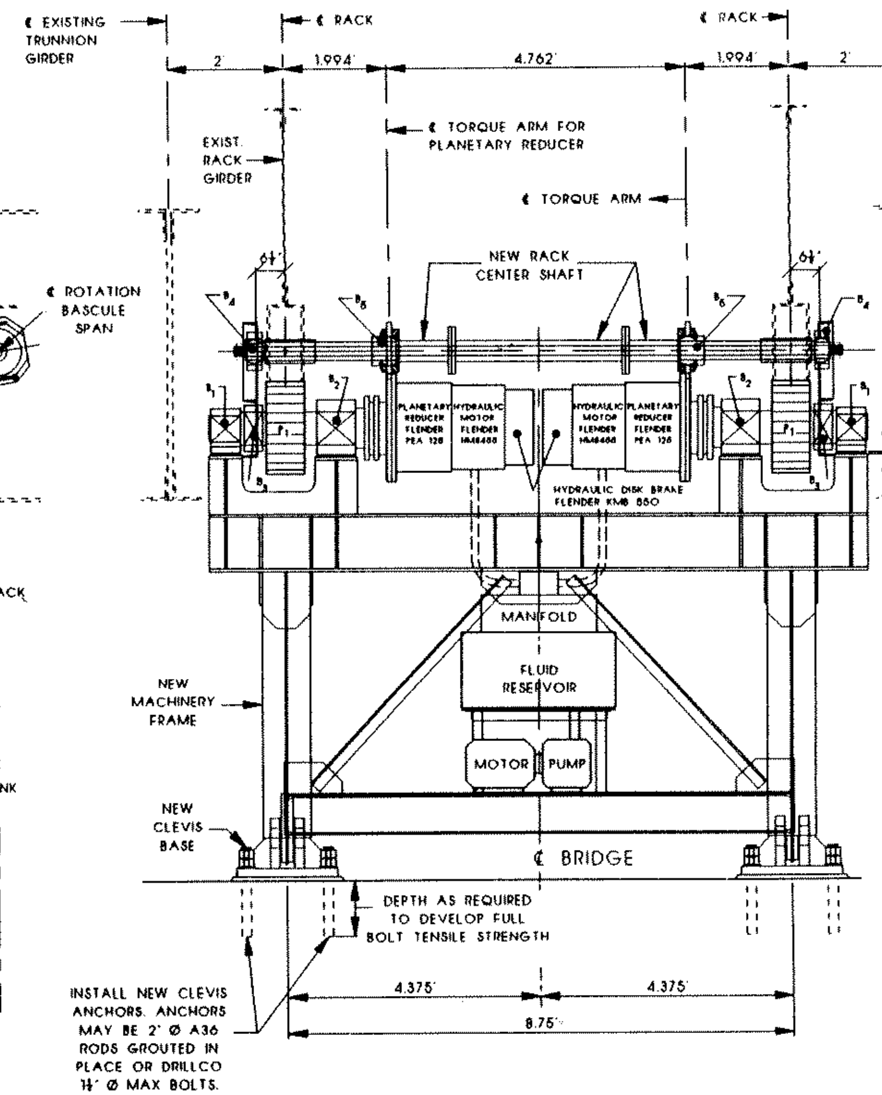
The new frame is simplified and encorporates a number of improvements to eliminate the defects in the original Hopkins Frame configuration. The main drive pinions are mounted between a pair of bearings oriented to reduce tension in the mounting bolts. The bearings are supported concentrically over the frame verticals to reduce bending in the frame. The additional bearing supporting the main pinion drive shaft substantially reduces the twisting in the frame. The clevis brackets are heavily reinforced and are anchored with hydraulically tensioned undercut anchor bolts, thus reducing bearing stresses in the bracket ears and ensuring adequate clamping of the frame to the machinery floor.

Each hydraulic motor unit and pinion are mounted on independent shafts (i.e., they are not physically connected.) To eliminate transfer of torsion from the hydraulic motor units to the frame, the units were designed for shrink disk, shaft mounting and torque



MACHINERY FRAME ELEVATION

SECTION THRU BASCULE PIER
TYPICAL BOTH PIERS



LAYOUT NOTES :

1. SEE SPECIAL PROVISIONS FOR ADDITIONAL DETAILS AND REQUIREMENTS.
2. REMOVE EXISTING HOPKINS FRAME, FRAME LINKS, CLEVIS BASES, AND RACK FRAME CENTER PIPE PRIOR TO INSTALLATION OF EQUIPMENT.
3. ENLARGE RACK CENTER HOLE AND INSTALL NEW RACK FRAME SLEEVES.
4. INSTALL NEW CLEVIS BASES, LINKS, FRAME AND TORQUE ARMS PER SPECIAL PROVISIONS.
5. TORQUE ARM SHALL BE INSTALLED AFTER THE OTHER COMPONENTS ARE ALIGNED AND INSTALLED.
6. ALL DIMENSIONS WHICH REFERENCE EXISTING STRUCTURES SHALL BE FIELD VERIFIED.

SECTION A - A

Seabreeze Bridge Emergency Repairs
Frame Mounted Hydraulic Drive System

Figure 4

arm restraint. The torque arms are restrined by the bascule span at the center of rotation. A new rack center shaft was required to install the torque arms. The new shaft had to sectionalized because of the intermediate mounting locations for the torque arms and the installation of torque arm bearings. The sections are connected with bolted splices. The torque arms are similarly sectionalized and are bolted together after alignment of the rack and pinion are obtained.

The combination of a planetary reducer and hydraulic motor was selected over a motor alone for several reasons. Speed control during starting and stopping would be smoother as the reducer increases motor speed by a factor of approximatley 20. In addition, the planetary reducer substantially reduces the size of the brakes required to hold the span. This was important when considering the large dynamic loads that result from poorly adjusted oversized brakes. The motor and reducer combination was determined to be lighter than a motor alone.

Each hydraulic power unit consists of two 10 hp motors, two variable axial piston, swashplate design pumps, manifold mounted valves, and a 100 gallon reservoir. Torque in the two hydraulic motors are balanced with the use of a common fluid supply via the main proportional valve. Counterbalance valves and cross-port relief valves serve to provide back pressure for smooth operation and control of overruning loads. The valves are controlled through a programmable logic controller by electronic ramp cards.

Other Frame Mounted Drive Systems

Several other configurations have been developed for rehabilitation of Hopkins Frame drive systems. These mostly include modern drive systems mounted on existing Hopkins Frames or on new Hopkins Frames of similar configuration to the original. Modern drive systems, such as high speed low torque hydraulic motors or new electric motors with VFD's, Soft Starts, or other modern motor drives, are generally used as the prime movers. Components of the existing drive machinery and/or the machinery frame are reused as their conditions warrant.

These alternatives are generally considered for newer Hopkins Frame drive systems where much of the existing equipment can be reused. In these newer frames, the original components of the drive machinery and/or the machinery frame are generally still in satisfactory condition. However, deterioration is considered likely to accelerate without the rehabilitation. Reuse of the existing components typically includes removal of the equipment to a shop where the machinery is reconditioned.

Where extensive repair, modification, or replacement of much of the drive train is warranted, these alternatives are generally not warranted. In this case, hydraulic cylinders or a frame mounted hydraulic motor scheme would be more viable.

The primary advantage of the modern drive systems over the original systems is in improved speed control and smoother operation. Much of the wear to the drive train components is generally a result of rough operation during start-up and stopping. For the hydraulic solutions, counterbalance valves and electronic proportional valves serve to provide back pressure for smooth operation and span control against overruning loads. The torque and speed control in the electric motor schemes is provided via programming in the motor drives. These alternatives are most like the original configuration and generally do not require any structural modifications.

Where Hopkins Frames have been replaced, the new frames have typically been improved. Improvements include increased member sizes, strengthening or reinforcing of the pinned connections, and elimination of the worst fatigue details. Clevis pins have been fitted with grease grooves and lubrication lines mostly to reduce corrosion in these critical connections. Other improvements suggested include shear pins or adjustable shear lugs and new turned mounting bolts for the pillow blocks. These improvements still have not fully eliminated the original deficiencies.

Much thought has been given towards a new arrangement of the same machinery components on a new frame to eliminate the eccentric configuration, however, no practical solution has yet been developed. (The drive machinery presented in Leonard Hopkins' original patent was mounted concentrically with the frame verticals. This machinery arrangement was quite different than that used in the actual construction of these Hopkins Frame bridges.)

Summary

From the late 1940's to the early 1970's, the Hopkins Frame offered an ingenious approach to machinery installation. Unfortunately, shortcomings in the design has resulted in premature deterioration of the drive machinery warranting major rehabilitation or total replacement, even though these bridges are only twenty to forty years old. The modern rehabilitation alternatives presentented in this paper, each offer their own advantages in installation, redundancy, span control, continuing maintenance, cost savings, etc. As these modern drive systems have yet to be tested over an extended period of time, it will be interesting to see how well these alternatives perform long term.