HYDRAULIC CYLINDER DRIVES
FOR EXISTING BASCULE BRIDGES

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INTRODUCTION

Purpose

For the past five years, the author has been involved with movable bridge projects, most notably, bascule bridge projects. During this time, the use of fluid power, or hydraulics, as a source of bridge actuation has become more prominent in the movable bridge industry. The expanding use of hydraulics in a field formerly dominated by heavy machinery has lead to the development and implementation of new designs and concepts. This paper presents a review and evaluation of three specific applications of fluid power on existing bascule bridges.

The purpose of this paper is to share with the movable bridge industry several hydraulic cylinder powered bascule bridge applications familiar to the author. The review of each application includes a discussion of the concepts developed for that particular bridge and an evaluation of the application from a retrospective view. The focus of this paper is on the location, mounting and connection of hydraulic cylinders to the movable span and bascule pier rather than the specifics of hydraulics. However, to aid in understanding the material, some review of fluid power for movable bridges is presented.

Background

The author's involvement with hydraulic bascule bridges includes the design of new bridges, the design of hydraulic systems as a replacement for existing machinery, the design of temporary hydraulic systems for rehabilitation projects, and the inspection of existing bridges. The specific bridges presented in this paper are:

Merrill Barber Bridge Over the Intracoastal Waterway,
Vero Beach, FL
- A Temporary System for operation during rehabilitation

Hobe Sound Bridge, Hobe Sound, FL
- A Temporary System for operation during rehabilitation

Parker Bridge, West Palm Beach, FL
- A Replacement System for an existing mechanical drive

In each of these projects, the author was employed by the consulting engineering firm contracted to design the hydraulic cylinder attachment and installation details. The author is grateful for the consent granted by his former employer to present this material.

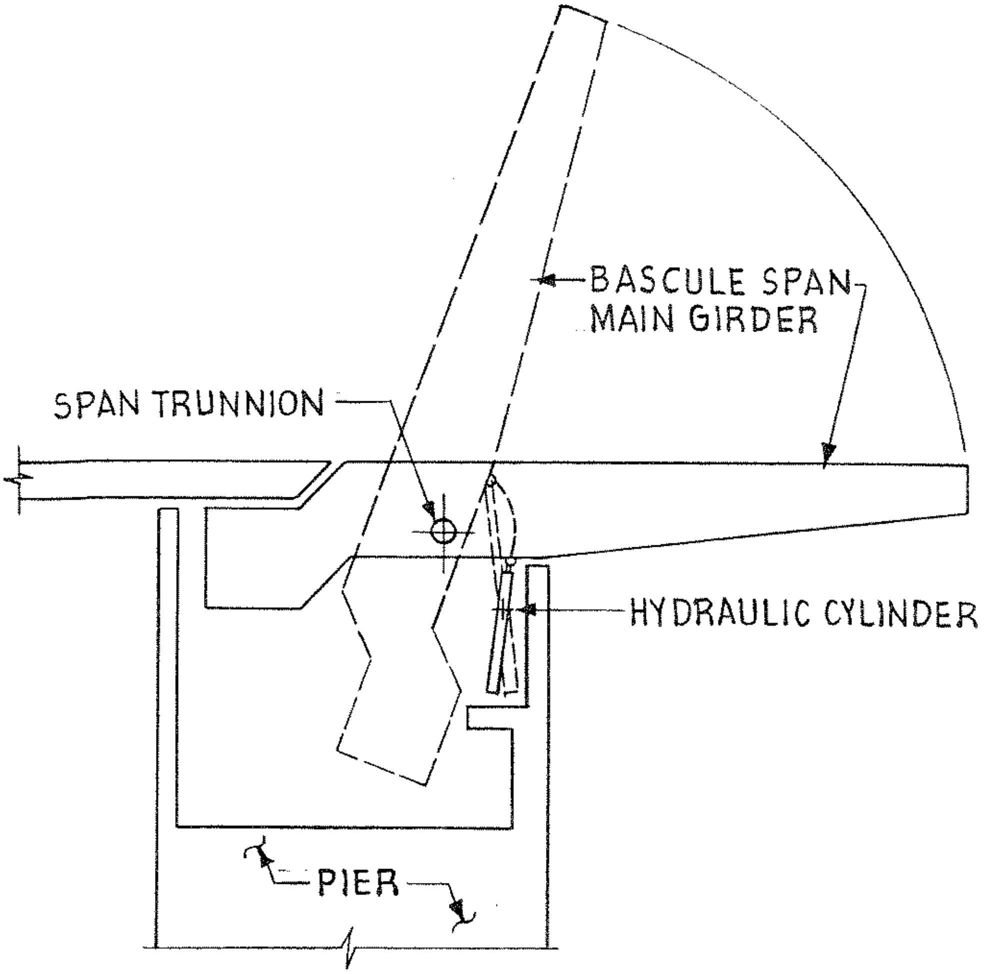
HYDRAULIC CYLINDERS AS A BASCULE BRIDGE ACTUATOR

Hydraulic Power

Hydraulic power, use of pressurized fluid to perform work, is well suited for operation of large mechanisms such as movable bridges. Hydraulic systems provide the mechanical advantage required to move the large masses of swing, vertical lift, and bascule bridges with relatively efficiency. The flexability of hydraulic power transmission systems, as evidenced by elements such as pressure hoses and piping, makes them well suited to the various geometric constraints encountered in movable bridge design and construction. This flexibility is especially valuable when developing a concept for installation on an existing structure.

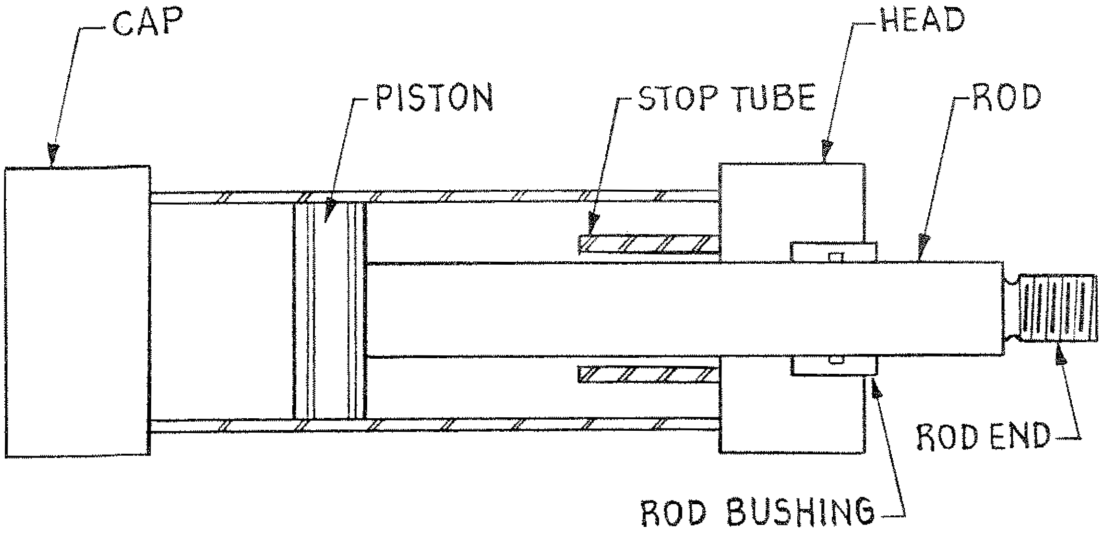
As noted earlier, this paper will not attempt to cover all of the various types of movable bridges, but will focus on bascule bridges and in particular trunnion bascules. Figure 1 is an example of a common configuration for a hydraulic cylinder actuated bascule bridge. In addition, only systems with hydraulic cylinders as actuators will be discussed. Other hydraulic drive systems such as low speed high torque hydraulic motors are not covered.

Hydraulic cylinders are linear actuators, that is, the motion produced by a cylinder is along a straight line with respect to the cylinder. The force developed in the cylinder is the result of fluid pressure acting on the piston. Double acting cylinders, which are commonly used in bridge applications, have pressurized fluid on both sides of the piston, the rod side and cap side (see Figure 2). The force in the cylinder is the result of the difference between the pressure on each side of the piston multiplied by the effective area of the piston. Note that the area on the rod side of the piston is less than the area on the cap side by the cross sectional area of the rod. Pressure on both sides of the piston is necessary to provide adequate control of the cylinder during operation.



HYDRAULICALLY ACTUATED TRUNNION BASCULE

FIGURE I



DOUBLE ACTING HYDRAULIC CYLINDER

FIGURE 2

Geometric Constraints

Hydraulic bascule bridges are usually very similar to trunnion bascules operated by conventional machinery. Instead of a rack attached to the main girders, a cylinder or group of cylinders is attached to each main girder and supported off the machinery platform or the front wall of the bascule pier. Other arrangements are possible but this configuration is most common. The cylinder is usually attached to the main girder because it is the primary load carrying member of the span. It also happens to be a longitudinal member which is advantageous when considering the forces from the cylinder. Loads from the cylinder remain within the plane of the member only for longitudinal members. This will be more obvious after reviewing the motion of a bascule bridge.

Motion of a bascule bridge is primarily one of rotation. With the exception of rolling lift bridges, most bascule bridges pivot about an axis or trunnion. Rotation of the leaf mass is the result of torque applied about that axis overcoming friction, angular inertia, wind, and unbalanced loads. Rotation of a pivoting mass caused by a linear actuator, such as a hydraulic cylinder, involves a combination of several movements.

Motion of the bascule span or leaf and the hydraulic cylinders is defined by three points; the leaf pivot or trunnion, the hydraulic cylinder pivot, and the connection of the cylinder to the leaf. As the bascule leaf rotates, the pivot point at the rod end of the cylinder follows the leaf on a circular path. At the same time, the cylinder must rotate about its support on the fixed portion of the pier in order to follow the rod end as it moves along its arc. As a consequence of this motion, the effective moment arm of the cylinder force about the trunnion varies continuously throughout the rotation of the bridge. Also varying is the angle at which the cylinder force intersects the mounting supports and attachments at either end of the cylinder. This variation is most severe at the connection to the leaf because greater rotation takes place between the rod and leaf than between the cylinder and pier. The difference in rotation occurs because the leaf rotates 60 to 80 degrees typically, while the cylinder rotates only the few degrees required to follow the path of the rod end. It should also be noted, that the force exerted by the cylinder is subject to complete reversal as the actuation may be to push the bridge open or to pull the bridge closed.

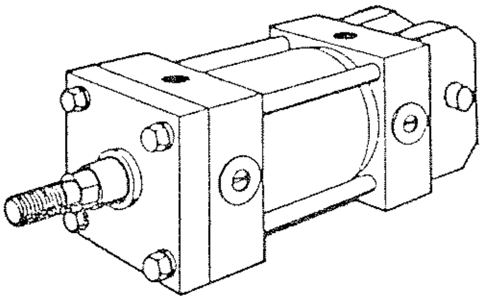
If the hydraulic system is to utilize an economical cylinder size, then the effective moment arm of the cylinder force about the leaf trunnion should be made as large as is practical. The limiting factor to this length will be the maximum length of cylinder which can fit between the machinery platform and the connection to the leaf. Maximum cylinder lengths may also be limited by the buckling strength of the rod specified, depending on the mounting style. The length of the closed cylinder is the sum of the fixed dimensions of the cylinder including head, cap, and rod end plus the stroke and stop tube. Therefore, the length of cylinder will increase directly with an increase in stroke or stop tube. The greater the moment arm the greater the stroke and cylinder length. Similarly, the smaller the effective moment arm the larger the cylinder force required to operate the bridge.

Cylinder Mounting Styles

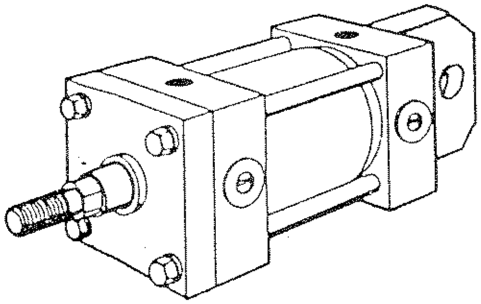
In order to accommodate leaf rotation, hydraulic cylinders must be mounted so that they can pivot about their supports and the connection the the leaf. This is commonly accomplished by using a trunnion mounted cylinder with a pinned rod end. This is one of several mounting styles commercially avalable. Some of the most common styles found in bascule bridges are shown in figure 3. Other mounting styles used on movable bridges include the cap clevis and the cardanic ring. Cardanic rings consist of two rings with trunnions mounted at right angles one within the other to provide freedom of rotation in all directions.

When considering the cylinder as a structural compression member, it is apparent that the head trunnion provides the least unbraced length of the three trunnion positions available. Minimizing the unbraced length minimizes the rod diameter required for a given axial load and will also limit the requirements for a stop tube. A stop tube is used to limit the stresses on the rod bushings and improve the life of the cylinder. Determination of stop tube requirements is beyond the scope of this paper, but it can be generally assumed that the length of stop tube will increase as the tendency for buckling or bending of the cylinder increases. The disadvantage of a long stop tubes is an increase in the overall length of the cylinder equal to the stop tube.

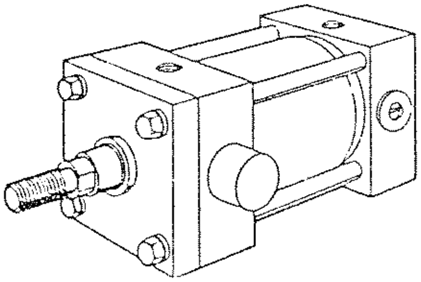
While the head trunnion is preferable from a structural standpoint, it does have one major drawback. The pivot point of the cylinder trunnion is located only a few inches from the rod end when the rod is fully retracted and the bridge is in the closed position. During span operation, as the rod retracts near the closed position, motion or improper alignment of the leaf and cylinder transverse to the plane of the cylinder trunnion, will result in development of stresses in the cylinder bushings and trunnion bearings. This geometry leaves little or no room for compensation of error in the alignment of the cylinder and leaf. For this reason, an intermediate trunnion mount is preferable. Intermediate trunnion mounts can be located near the head of the cylinder to limit the unbraced length of the cylinder, but far enough from the rod end to allow for minor misalignment.



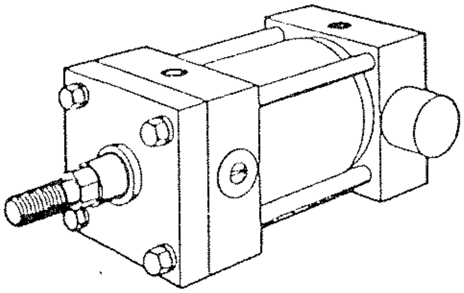
CAP CLEVIS



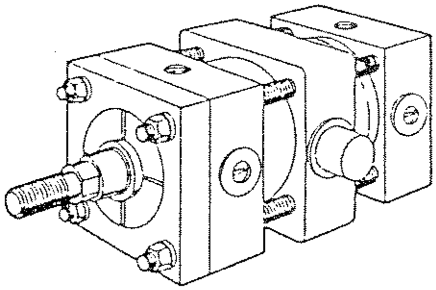
CAP PIVOT



HEAD TRUNNION



CAP TRUNNION



INTERMEDIATE
TRUNNION

CYLINDER MOUNTING STYLES

FIGURE 3

TEMPORARY HYDRAULIC SYSTEMS

The first two projects presented are examples of a temporary hydraulic system designed to operate an existing bascule bridge while its permanent drive system was under rehabilitation. When a bascule bridge is in need of repair or rehabilitation, one of the most critical issues is that of maintaining traffic during the work period. In some cases, the demands for maintenance of marine traffic dictate that the owner must keep the bridge operational. For projects requiring major work on the main drive system, use of a temporary operating system may be the most economical method of satisfying the maintenance of traffic requirements.

The following are examples of rehabilitation projects where the requirements for maintaining bridge operation lead to the design and installation of a temporary hydraulic system utilizing hydraulic cylinders. Once again, the emphasis of this paper will be on the mounting of the cylinders rather than the selection of the operating unit itself.

Development of temporary hydraulic systems in Florida was initiated by the Florida Department of Transportation (FDOT) for use during a large scale rehabilitation program involving over 40 bascule bridges. The prototype system was designed by the FDOT for use at the Dania Bridge over the Intracoastal Waterway in Dania, Florida. This system consisted of a power unit and two hydraulic cylinders for each bascule leaf. The concept was to construct several of these systems for modification and reuse on other similar bridges in the program. Attachment brackets for the cylinders where to be designed and installed on each bridge and left in place for future use if required.

Most of the bridges in the rehabilitation program cross the Intracoastal Waterway and are therefore similar in span size and geometry. This provided the FDOT with the opportunity to utilize one hydraulic power unit design (i.e. pump, motor, reservoir, etc.) to operate most of the bridges under normal operating conditions. This simplification limited the modifications to the temporary system for each bridge to the length, location, and mounting of the cylinders, including installation of brackets and supporting structures. Recognizing that this system was temporary, the FDOT did not specify a system which could meet the requirements for permanent operating systems. This was necessary to limit the system to one of economical and transportable size. This did produce some concerns over projected span operating speed because of the units limited size and power.

Cylinder attachments for the temporary systems were designed for 150 percent of the cylinder force at relief valve pressure, in accordance with the American Association of State Highway and Transportation Officials (AASHTO), Standard Specifications for Movable Highway Bridges, 1978 edition. This force was selected as the design load rather than the operational forces computed in accordance with the AASHTO specifications. The relief valve setting was selected not only to protect the hydraulic system, but to provide adequate forces for leaf operation under AASHTO condition A, normal operation. Conditions B and C where disregarded because of the temporary nature of the system. Again, the disigners recognized that the temporary system would have some limitations in order to remain economical.

Each installation of a temporary hydraulic system provided the designer with several problems. First of all, where could the cylinder be attached to the movable span and fixed pier? The attachment points had to be selected to satisfy both structural and operational requirements such as existing member capacity and cylinder stroke. Next, the brackets and attachments had to be selected and designed to withstand the design load at any angle it could be applied at during operation. The design also had to include complete load reversal. In addition, these problems had to be solved within the restraints of the existing bridge geometry and the power available from the specified hydraulic power unit. In these examples, this meant that the unit and cylinders had to fit around the existing machinery, so that it could be rehabilitated without interruption.

BRIDGE NO. 1 - MERRILL P. BARBER BRIDGE

The Merrill P. Barber Bridge is a four lane double leaf Hopkin's Trunnion bascule bridge crossing the Intracoastal Waterway in Vero Beach, FL. In the process of developing a rehabilitation sequence for the structure and operating system, it became apparent that a temporary operating system would be required. The system to be used was a modification of the hydraulic cylinder system designed for use at the nearby Dania Boulevard bridge by the Florida Department of Transportation. However, while the hydraulic system itself was previously designed, the mounting details for the hydraulic cylinders had to be designed for the specific geometry of the Merrill P. Barber Bridge.

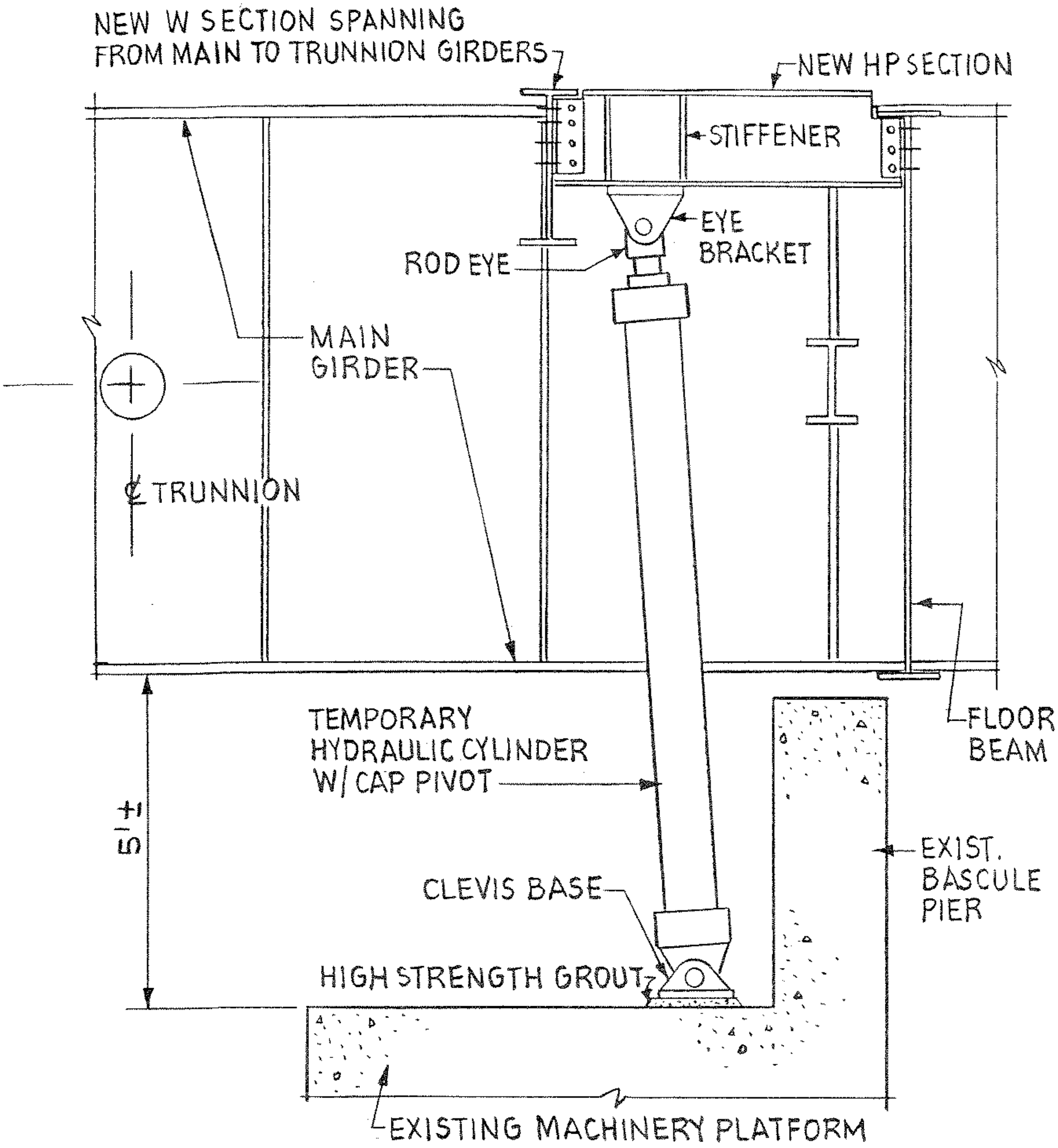
The Merrill P. Barber Bridge is typical of Hopkin's Trunnion Bascules in Florida having two main girders and two trunnion girders on each leaf. The bridge is powered by an electric motor and gear system mounted on a Hopkin's Frame. Power is transmitted to the leaf by two rack and pinion sets located between the trunnion girders. This same design is frequently seen throughout Florida, including the Bridge at Dania for which the FDOT developed their first temporary hydraulic system.

As an engineer for the design consultant, the author developed a mounting system similar to the one used at Dania. There is one geometric feature, common to most Hopkin's Frame Bascules, which severely limits the practical locations available for mounting the temporary hydraulic cylinders. This geometric restraint is the relatively small vertical clearance between the machinery platform and the bottom of the main girders or trunnion girders (usually about 5 or 6 feet). A cylinder length which would maintain a resonable effective moment arm about the leaf trunnion, would not fit between the machinery platform and the main girder or trunnion girder. To fit the cylinder between the machinery platform and the leaf, a connection had to be designed up near the top of the main girder.

The connection developed for the Dania Bridge was mounted on a channel installed between the top of the trunnion girder and main girder. This location provided vertical clearance for the cylinder length required and an adequate moment arm about the leaf trunnion. The reason for not reusing this same design was a matter of structural adequacy. At Dania, the channel was loaded in its major axis when the bridge was in the closed position, but as the leaf rotated the angle of the load rotated towards the channel's weak axis and torsion in the channel developed as a result of the offset of the rod eye with respect to the channel. While this configuration functioned well at Dania, it is not preferable because of the channel's relative weakness in biaxial bending and torsion.

For the Merrill P. Barber Bridge a similar hydraulic system was used with modifications to the mounting bracket support to eliminate the inadequacies mentioned above. Instead of mounting the eye bracket on a channel, it was mounted on an HP section. This member provided adequate section properties in bending and torsion and a wide flange surface for bracket attachment. In an effort to eliminate torsion in the member directly supporting the eye bracket, it was decided to mount the bracket to a longitudinal member which would then be loaded in its strong axis regardless of leaf rotation. For this reason, the HP section was connected between the floor beam and a wide flange beam installed between the trunnion girder and main girder. This configuration provided the rigid connection to the main members of the span and the longitudinal orientation desired.

The connection to the new longitudinal beam was a rod clevis and eye as shown in Figure 4. This attachment allows for the relative rotation of the leaf and cylinder and yet provides the strength required to transmit 150 percent of the cylinder force at relief valve pressure. The relief valve setting was computed based on cylinder forces required for operation under AASHTO



TEMPORARY HYDRAULIC CYLINDER
FOR MERRILL P. BARBER BRIDGE

FIGURE 4

condition A, normal operation.

As was the case with the Dania Bridge, the cylinder was specified with a cap clevis mount for attachment to a clevis base on the machinery platform below. The clevis base was to be anchored to the platform with high strength anchor bolts. The cylinder rod end and cap clevis were selected with commercially available spherical plain bearings to allow some rotation transverse to the plane of leaf rotation. These bearings not only reduce bending and buckling tendencies in the cylinder, but simplify installation by allowing some minor misalignment in the range of one to two degrees to either side.

Evaluation of the Merrill P. Barber Bridge Mounting System

At the time of this writing, the temporary system had been in place and operational for several months. While operation has been mostly normal, there has been one instance of note.

The programmable controller used to operate the temporary system is interlocked with the traffic gates and span locks to prevent span operation while the gates are open to traffic or the locks are closed. During one particular operation, a traffic gate was manually opened. This tripped a limit switch and signaled the programmable controller to stop operation. The programmable controller immediatly shut off power to the power unit. This caused the hydraulic system valves to shut tight while the bridge was opening at full speed. With the fluid locked in the cylinder, it became an almost rigid member until the internal pressure exceeded the relief valve setting. The force generated in the cylinder was sufficient to pull one of the clevis bases off the machinery platform.

Upon further examination it was determined that the force had not exceeded the design force (150% of relief valve pressure) or anchor bolt strength (selected to exceed design load within manufacturers specified strength). The anchor used was an epoxy type and the failure was in the bond to the concrete. This combined with the fact that none of the other three clevis bases moved indicates a localized problem in manufacturing or installation of the anchors. The connection to the leaf and support brakes exhibited no signs of distress.

The concerns over slower operating speeds never developed as the temporary hydraulic system was found to operate the span faster than the original mechanical drive system under normal conditions.

BRIDGE NO. 2 HOBE SOUND BRIDGE

Hobe Sound Bridge is a new double leaf bascule bridge over the Intracoastal Waterway in Hobe Sound, Florida. Even though the bridge is considered new, the bascule spans and machinery were from a temporary bridge built nearly ten years earlier. The spans and drive machinery were partially disassembled and put in storage for several years before the Hobe Sound Bridge became a project. When the project fell behind schedule, the Florida Department of Transportation, elected to install a temporary hydraulic operating system in order to bring the bridge into operation before the holiday season of 1986.

The design configuration of the drive system was floor machinery consisting of a primary differential reducer and two secondary reducers, one located at each of two drive pinions. The two drive pinions engage racks on each of the two main bascule girders. An important feature to note is the minimal clearance between the secondary reducers and the front wall of the bascule pier. This space is not sufficient for comfortable passage of an average size person.

The author's involvement in this project was as an engineer for the consultant hired to design the supports and connections for the temporary operating system. The Florida Department of Transportation decided to use the same hydraulic power unit specified for their rehabilitation projects equiped with two 6 inch diameter hydraulic cylinders. The remaining parameters to be determined by the consultant where the length and location of cylinders and the method of cylinder connection and support.

Unlike the previous temporary installations, the space between the main girder and trunnion girder was not available on the Hobe Sound Bridge because of the presence of the secondary reducers. This fact, combined with the disadvantages of that location discussed earlier, lead to a new evaluation of the location of the temporary hydraulic system. Another important difference between the Hobe Sound Bridge, with floor machinery, and the typical Hopkin's Frame Bascule bridge is in the vertical clearance between the machinery platform and the bascule leaf. Whereas on the Hopkin's Frame bridges the cylinder attachment to the leaf needed to be made up near the top of the main girder to accommodate cylinder length requirements, on the Hobe Sound Bridge, the vertical clearance was sufficient to consider several other locations.

As previously noted, the cylinder location generally considered most ideal is directly underneath the main girders. On this bridge, the area beneath the main girders was not available because of interference with the pinions and secondary reducers. Another span member with good potential for cylinder connection because of its strength and longitudinal orientation, is the trunnion girder. With this in mind, a scheme was developed with the one cylinder placed directly under each trunnion girder.

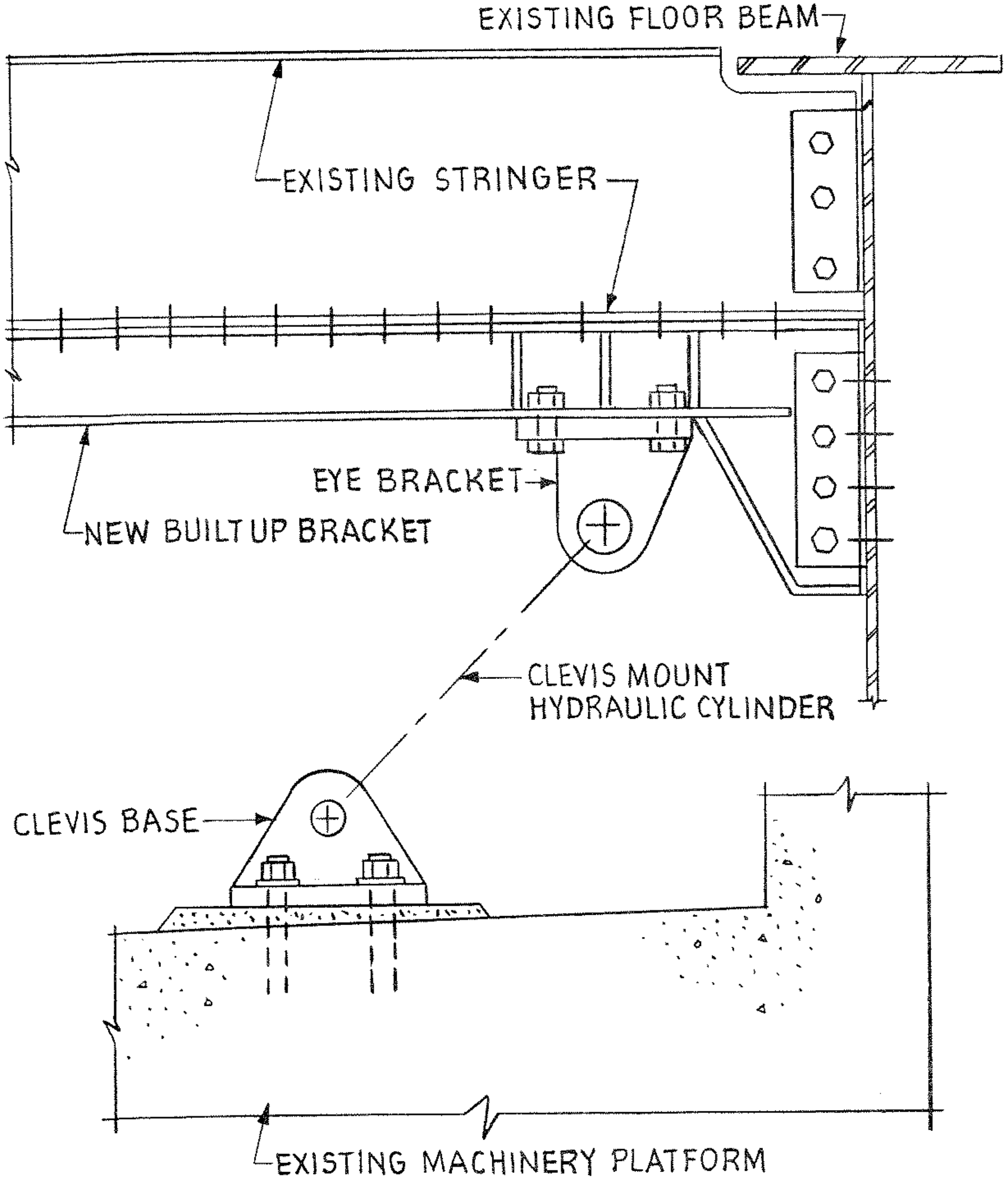
However, the effective moment arm of the cylinders about the span trunnion axis had to be substantially reduced in order to maintain a cylinder short enough to fit under the girder. This concept was workable within the geometric constraints of the bridge, but was found to require excessive cylinder forces because of the small moment arm. A larger cylinder would have been required with an 8 or 10 inch bore. This increase was not acceptable because it would alter the power unit requirements.

In looking for an alternate attachment point which would provide the desired strength and longitudinal orientation, the floor beam and stringers became possible candidates. The floor beam had the strength and could be attached to at many points along the machinery platform. The stringers were not strong enough to withstand the cylinder forces but did have the ideal orientation. After some analysis the stringer location was selected. While structural modifications were necessary to strengthen the member and its connection to the floor beam, the simplicity of the mounting configuration made it the winner. In order to connect the eye bracket to the floor beam, the member would have required the addition of large stiffeners to withstand the torsional loads induced by the offset of the cylinder forces. Every attempt was made to avoid connections which would induce torsion on existing members not designed for such loads.

The next step was to develop a bracket to strengthen the stringer and provide a surface to accept the eye bracket. The result, shown in Figure 5, provided the increase in the stringers bending strength and shear strength at the connection to the floor beam. Bearing stiffeners were provided to prevent web buckling. To reduce the effects of bending in the stringer, the eye bracket was located as close to the floor beam as was practical.

While this configuration limits out of plane loading of the stringer, one more step was taken to eliminate possible torsion on the composite member. Once again, the cylinders were specified with spherical plain bearings in the rod end and cap pivot to allow for few degrees of unrestricted rotation transverse to the plan of rotation, thus eliminating out of plane bending stresses.

The cap pivot of the cylinder was designed to connect to a clevis base located on the machinery platform between the primary differential reducer and the secondary reducer. This location did not interfere with the operation of the existing mechanical system. However, the mechanical systems could not be operated unless the cylinders were detached from the leaf because they would restrain the leaf against movement.



TEMPORARY HYDRAULICS
FOR HOBE SOUND BRIDGE

FIGURE 5

Evaluation of the Hobe Sound Mounting System

Most importantly, the temporary hydraulic system for Hobe Sound was installed and brought into operation in time for the holiday season. As for the mounting and installation of the cylinders and brackets, everything went according to plan. The stringer brackets and eye brackets where mounted first. Then the cylinders were attached to the new brackets and allowed to hang free. The clevis bases on the machinery platforms were located under the hanging cylinders to obtain proper alignment. The spherical bearings in the rod ends simplified this alignment.

Since initial installation, adjustment, and testing, the temporary system has operated well. There are no signs of structural distress in the mounting brackets or structural members of the spans. Once again, the concerns over slower operating speeds did not develop because the temporary hydraulic system was found to operate the span faster than the original mechanical drive system under normal conditions.

REPLACEMENT HYDRAULIC SYSTEM

PARKER BRIDGE

The Parker Bridge is a four leaf bascule bridge in Palm Beach County, Florida over the Intracoastal Waterway. Four lanes of U.S. 1 are carried by two parallel double leaf Hopkin's Trunnion bascule bridges staggered to accommodate a skewed channel. As part of the bridge rehabilitation program, the FDOT decided to replace the drive systems on all four leaves rather than proceed with extensive rehabilitation. Consultants were contracted to prepare alternate contract documents for two new drive systems, one hydraulic and one mechanical. This decsion was fueled by the extensive wear of the existing gearing and Hopkin's Frame.

This project presented several problems in addition to those encountered during design of the temporary systems previously mentioned. Because this was to be a permanent system, it had to be designed for the full loads of AASHTO condition C. In addition, in order to reduce the interruption to marine and vehicular traffic during construction, the new system had to be located so that it could be installed while the existing system remained in operation.

After summarizing the loads on the span from conditions A and C, it became apparent that there were three span member types located above the machinery platform which could possibly withstand the loads, including the main girders and trunnion girders. Unfortunately, the bottom flanges of the main girders and trunnion girders were located only about six feet above the machinery platform. This was not nearly enough space for the cylinder length required if a practical moment arm about the span trunnion was to be maintained.

The other member type with adequate strength and longitudinal orientation was the rack girder, which supports the rack and transfers the driving loads from the machinery to the movable span. The two rack girders span between the counterweight girder and the last floor beam, one at each pinion of the Hopkin's Frame. In addition, the rack girder's bottom flange is located several feet above the bottom flange of the main girder which provides greater vertical clearance for the cylinder. Unfortunately, the Hopkin's Frame is located between the rack and front pier wall, bellow the rack girders. A cylinder location could not be found under the rack girder which did not interfere with the operation of the existing machinery. Therefore, this location was dismissed.

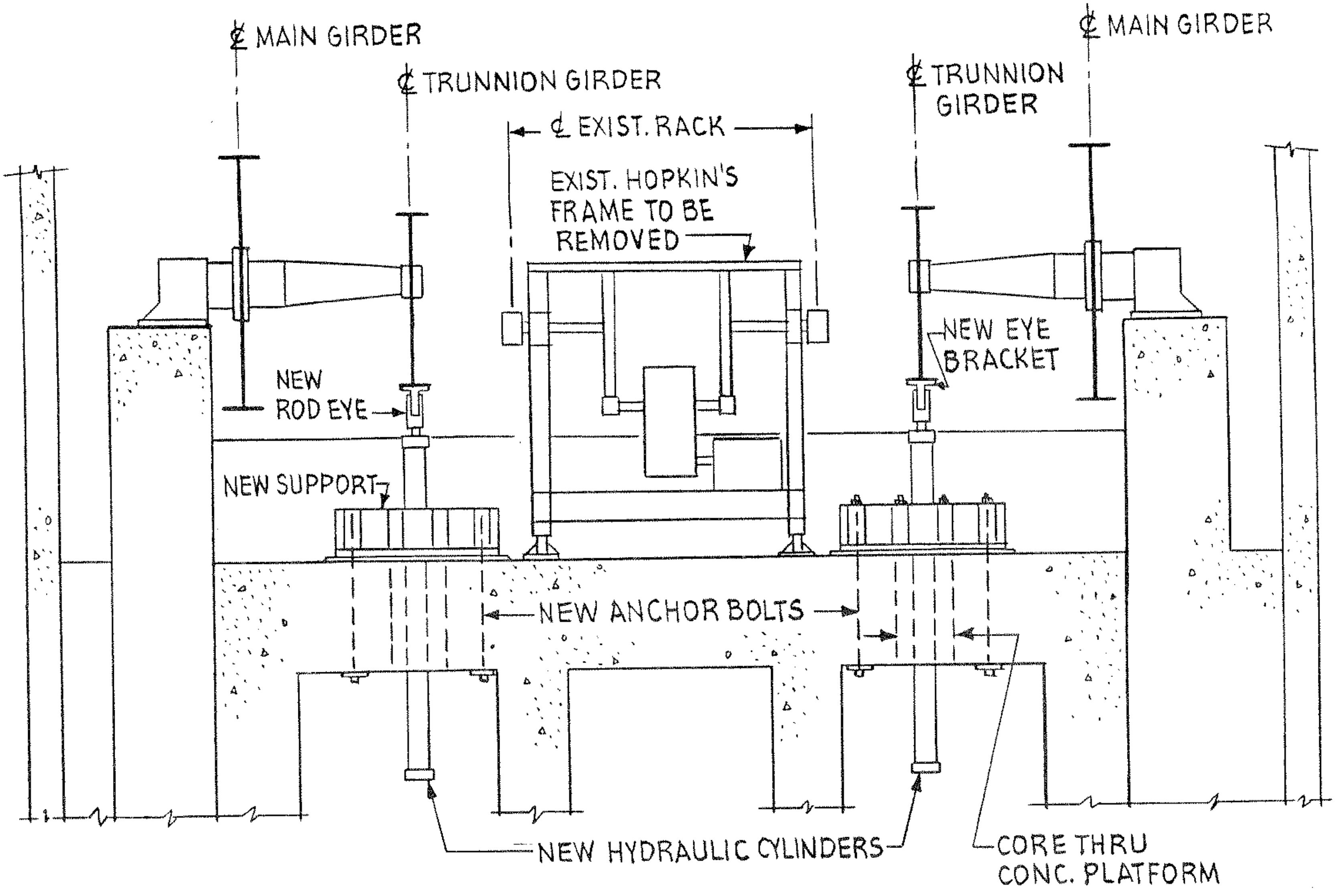
Some consideration was then given to locating the cylinders between the counterweight end of the main girders and the bascule pier below the machinery platform. This location was dismissed because the cylinder stroke was too long and the cylinders would be in an inaccessible area.

After further investigation, an acceptable location was discovered. By modifying the concrete machinery platform a configuration was devised to mount the cylinders under the trunnion girders. To make room for the cylinder under the girder, a hole was to be cored through the platform so that the cap end of the cylinder could be located below the platform (see Figures 6 & 7). This concept was not applicable to the main girder because the concrete pier was solid under the girder. The cylinders were selected with intermediate trunnion mounts located to fit into a bearing support anchored to the top of the machinery platform. This provided sufficient length between the pivot point of the cylinder and the connection to the leaf to allow for minor errors in allingment or sidesway.

The support for the cylinders was designed to allow rotation parallel to the leaf rotation and distribute the loads to sound concrete around the cored hole. Rotational freedom was provided by a pair of pillow blocks with bronze bushings for the cylinder trunnions. To distribute the loads to sound concrete and anchor the cylinders against uplift, the pillow blocks were attached to a steel frame bolted through the platform. The steel mounting surface for the bearings was also designed to provide a shimming surface for adjustment of the cylinder location in the field. A high strength polymer grout leveling pad was located between the support frame and the existing concrete surface to simplify initial alignment and provide shock load distribution.

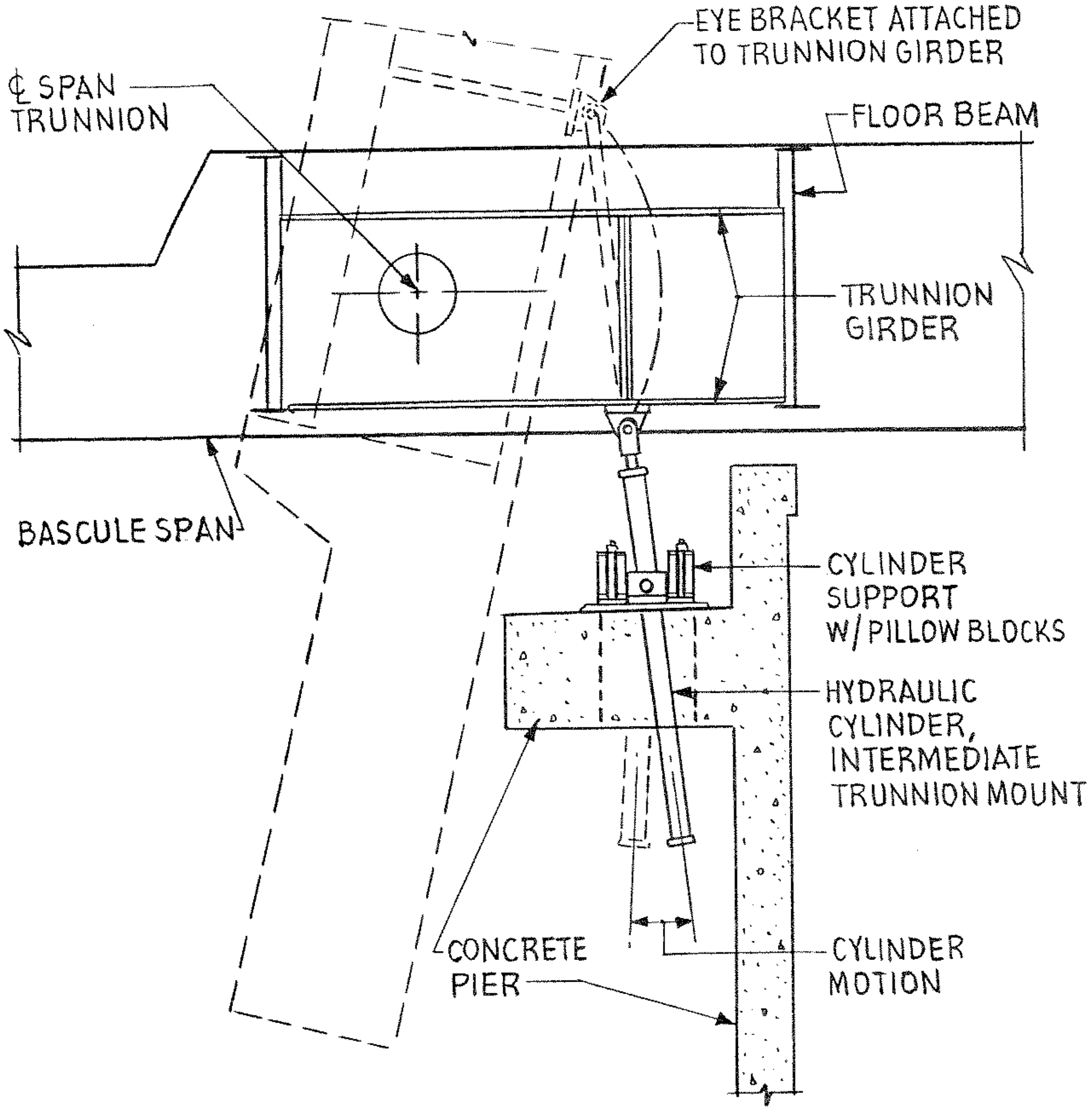
An analysis of the trunnion girder under load condition C revealed it to be of adequate strength in shear and bending. The only design modifications required were the installation of bearing stiffeners at the point of loading. A pivot bracket designed to accept the clevis rod eye was bolted to the lower flange of the girder. This bracket included a spherical plain bearing for the clevis pin. Lubrication fittings were specified for these bearings and the pillow blocks below.

The cylinders selected were 8 inch bore high pressure cylinders with 4 inch diameter rods and a 105 inch stroke. Because of the intermediate trunnion mount only a 12 inch stop tube was required despite the large design loads. The rod clevis for each cylinder was a special design rather than the commercially availably one to accommodate the loads and the spherical bearing of the pivot bracket. The commercially available rod clevis was not large enough to accept the width of the spherical bearing selected in



REPLACEMENT HYDRAULICS FOR PARKER BRIDGE

FIGURE 6



REPLACEMENT HYDRAULICS FOR PARKER BRIDGE

FIGURE 7

accordance with AASHTO. A set screw was specified to prevent the clevis from backing off the rod end.

Evaluation of the Parker Bridge Replacement Hydraulic System

This hydraulic replacement drive system has been selected as the alternate for construction and will be installed on the Parker Bridge in the winter of 1988.

SUMMARY

From the example projects presented here it is apparent that hydraulic cylinder operating systems can be adapted to fit many types of existing trunnion bascule bridges. These systems can be used as temporary operating systems while the bridge is under rehabilitation or as replacement systems for existing mechanical drive systems.

The geometric and structural restraints of an existing bridge may limit the use and location of such hydraulic systems but in most cases will not prevent the design and installation of an acceptable system. However, each bridge must be evaluated on an individual basis to determine the system which best meets the particular needs of that project.

During the course of these three projects there were several issues which were common to all designs. Resolution of these issues became the basis for development of a rational design solution specific to each project. These issues and the parameters developed to resolve them are summarized below.

A. Selection of the cylinder location

- provide sufficient clearance for cylinder length
- locate under main span member if possible
- limit interference with existing structures and machinery
- provide maximum effective moment arm about leaf axis

B. Selection of the cylinder mounting style

- limit restraints on rotation
- limit cylinder buckling length
- provide sufficient length between support points for minor misalignment
- provide for leaf rotation

C. Structural design of brackets and support structures

- select design force based on specific use
- apply forces as near the main members as possible

- apply forces within the strong axis of the member
- do not load existing members in torsion unless they have been designed for such loadings
- design for load directions which vary throughout operation

Following these guidelines, the temporary hydraulic systems for the first two projects presented were successfully designed and installed. Evaluation of the replacement system for the Parker Bridge will have to wait until the system is installed and time tested.