HEAVY MOVABLE STRUCTURES, INC.

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"Innovative Design Solutions to Meet Client Requirements on a Movable Bridge Rehabilitation"

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Innovative Design Solutions to Meet Client Requirements On a Movable Bridge Rehabilitation

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Introduction

In 1994, HNTB Corporation was retained by the South Carolina Department of Transportation to perform the inspection, assessment, and rehabilitation to two of their swing span bridges. The rehabilitation included complete mechanical and electrical replacement along with the replacement of the control houses and structural repairs. The work also included the assessment and repairs for conformance to OSHA.

This paper will go into a brief description of the existing structures and discuss some of the design philosophy for the rehabilitation. Since the rehabilitation was over $6,000,000 and consisted of many details, this paper will only highlight and discuss their impact on the structures.

Description of Existing Structures

The two swing bridges that were rehabilitated are located in Beaufort County, South Carolina. The Lady's Island bridge constructed in 1959 is located directly in the downtown of the City of Beaufort and carries State Route 17 over the Intracoastal Waterway. The second bridge, Harbor River is located approximately 15 miles east of the City of Beaufort and also carries State Route 17 over Harbor River. The Harbor River bridge is the only access to Saint Helena Island and was constructed in 1938. (See Figure 1)

The Lady's Island bridge has an overall length of 2,290 feet, comprised of two approach spans 851 feet and 1,191 feet long on the north and south ends of a 248 foot long swing span. The swing span is a center bearing, modified Warren through truss. In its open position, the swing span provides a 90 foot clear channel on either side of the center pivot pier. Both the wedges and span drive are gear driven systems that are powered by individual electric motors. (See Photo 1)

The Harbor River bridge has an overall length of 2,850 feet with its movable span, located at the two thirds point from St. Helena Island. The Harbor River Bridge is also a center bearing, modified Warren through truss swing span that is 168 feet from end to end. In the open position, the swing span provides a 60 foot clear channel on either side of the center pivot pier. Originally designed as an electric motor powered gear driven span, it had been modified and was powered by low torque, high speed hydraulic pumps which drive both the gear driven wedges and the span drive. (See Photo 2)

Both structures have their control houses located above the roadway at the center pivot. The control houses were old, deteriorated, shingle sided, single room buildings that housed the control desk and the electrical equipment which consisted of relays mounted on open panels. Both structures are manned 24 hours a day, 7 days a week.

From the findings of the inspection, complete replacement of the span drive systems along with the complete replacement of the electrical systems was recommended. These were to be in conjunction with the complete replacement of the operator's control house. In addition to the architectural, mechanical, and electrical repairs was the need to improve operator and maintenance access.

Due to the proximity of these structures to one another and their similar configuration, there was a desire to make the rehabilitation of the structures as similar as possible to minimize the work of the maintenance personnel.

Architectural

The Department had retained a local Architectural firm to develop a preliminary control house arrangement to replace the existing houses on both structures. These new control houses were to have an octagonal configuration to provide a 360 degree view for the operator from the control desk. This control house was to house the control desk, electrical equipment along with a sink and toilet. Close coordination with the Architect was required since the control house had to be enlarged to accommodate all the necessary items. The configuration of the electrical equipment had to be such that no cabinet was higher than the window sill or it would restrict the visibility of the operator.

The construction of the control house consisted of a steel tubular framing for the walls and roof that supported aluminum glazed insulating panels and bullet resistant glazing. The roof was fabricated of standing seam copper panels. Being larger than the existing, the new house was mounted on a 4-inch thick concrete pad and new structural supports. Due to the octagonal construction, the bathroom presented an interesting challenge. Any walls for separation introduced a configuration that is equivalent to a pie slice and for this reason the access for the bathroom was from the outside. This allowed the door to be placed at the widest point for access and the toilet was placed at the most interior point of the small room. A sink was also included, but was placed inside the control room rather than in the bathroom. The reasons were space constraints in the small bathroom and the placement of the sink in the control room allowed the operator to use it without having to leave the room. (See Figure 2 and Photo 3)

The rehabilitation required that the spans remain operational during construction without having a significant closure to vehicular or marine traffic. To achieve this, the building had to be fabricated off site and installed as a complete unit on the structure. During the construction, the existing house was removed and the new house installed by placing it on the roadway and rolling it into position. The removal and replacement of the control house was performed in one evening.

Mechanical

The mechanical rehabilitation of these structures posed many challenges. First was the need for the span drives to be as similar as possible for each structure. Since Lady's Island was the larger of the two structures, the span drive machinery for both structures was sized to operate the larger bridge. For the smaller Harbor River Bridge, the machinery would have greater capacity than required. The new span drive was to be one fully enclosed spiral bevel gearbox.

Special consideration for the design of the span drive had to be accounted for. Vertical clearance was a problem on the smaller Harbor River bridge. The typical two bearing configuration to support the rack pinion was not possible with the introduction of a single gearbox. Therefore, the pinion shaft was designed with a single bearing and a rigid coupling was placed between the pinion shaft and the gearbox shaft. The output shaft of the gearbox was then designed for an overhung load. This way the pinion shaft could be designed as a two span continuous beam with an overhung load and utilize three bearings for its support. Rather than a continuous shaft, a rigid coupling was utilized so the rack pinion could be installed and aligned without the gearbox in place and the gearbox could be removed without removing the rack pinion. Although the Lady's Island Bridge pinion shaft had the conventional two bearing support, the gearboxes were designed identical for replacement capabilities. Either gearbox could be substituted for the other without any modifications.

The brakes and motors on both bridges are also identical, but the motor speed and brake torque setting were lowered to accommodate the smaller Harbor River bridge with its different rack/rack pinion ratio.

This single gearbox design is desirable from a maintenance standpoint, but posed another problem. The existing gear drives for both structures were open gearing and the combination of the wedge and span drive were placed in a balanced arrangement on either side of the center pivot beam. This allowed the machinery weight to be distributed evenly. The new span drive, all located on one side, posed a problem for balancing the span. This balancing problem was compensated for in a unique manner that will be explained later in the paper. (See Figures 3 & 4)

Since the Lady's Island bridge is located over the Intracoastal Waterway, closure to marine traffic for an extended period of time was not possible. Therefore, staged replacement of the machinery was required. To achieve this, the new operating machinery had to be installed prior to the removal of the existing. To do this, a new pinion support beam had to be installed on the side opposite of the existing and the new span drive mounted at that location.

The wedge drive for both spans operated satisfactorily and required only routine maintenance. It was determined that the most cost effective option was to rehabilitate the major components of the wedges and just replace the primary reducer and the motors for the systems.

The original specifications called for the contractor to be responsible for operation of the swing span during construction. The intent of the rehabilitation was to have the contractor manually operate the swing span while the machinery and electrical system were being replaced. Due to the cost, this item was removed. With the elimination of the contractor providing the bridge operation, an alternate solution had to be obtained. The Department asked HNTB Corporation to design a temporary drive that would operate the wedges and the span drive while the system was being rehabilitated. This new system could not be powered by electricity since the incoming service was also being replaced as part to the rehabilitation. For this reason, the temporary drive was to be hydraulic and powered through a gasoline driven power unit. Traffic would be stopped by placing DOT vehicles at each end of the swing span to block the roadway during an opening. This would be done until the new electrical service and the control house could be installed. After that, the gates and signals could be operated by the new system and the span and wedges driven by the hydraulics.

The wedges were to be temporarily operated by hydraulic cylinders. These cylinders were mounted directly to the wedges. This would allow the wedge line shafting to be repaired. The span drive was operated by a low speed, high torque hydraulic motor that was mounted to the existing span drive to allow the removal of the electric motor. Both the wedges and the span drive were operated from a portable power unit that had a valve to select either the wedges or the span drive. The wedges used a push button control while the span drive used a manually operated valve to control the speed of the hydraulic motor. This power unit was first placed on a temporary platform adjacent to the roadway while the house was being replaced. Once the house and its supporting members were in place it was moved to above the roadway. (See Photos 4 and 5)

The centering latches of the swing spans were a repeated problem for the Department and an alternate solution was requested for its substitution. These latches have a tendency of breaking if the span drives to the fully closed position too fast and the latch does not come out of the latch pocket. This had repeatedly happen on both structures and the latch mechanisms were in disrepair. The Department realized that the structure needs to be aligned for driving the wedges, but did not want something that would be a continued maintenance concern. After close coordination with the Department it was determined that the center latch mechanism was to be removed and in its place a combination of a bumper block and lock bar were to be used. The idea was to have the span come to bear on a bumper block when in the fully closed position and lock bars would drive at each end of the span to ensure the span alignment prior to driving the wedges. Originally this bumper block was going to be a rigid post with a rubber element, but there were concerns of damage to the swing span if problems occurred, so the bumper was modified. The bumper block was modified to absorb the impact of the span when coming into the seated position. Springs would compress and absorb the shock. After the span inertia was stopped, the bumper would bring back the span and then the lock bars would perform the final alignment the structure. This bumper was designed to take the impact of the span with either the main drive in creep speed or the auxiliary drive in low speed and the motors not turning off due to a limit switch or control failure. (See Photo 6)

As part of the rehabilitation, there was also the desire to provide a restraint system for the swing spans in case of a hurricane. This system had to be simple, reliable and easily installed. After analyzing the behavior of the structure under heavy wind loads, HNTB Corporation designed a system utilizing clevises and turnbuckles to hold the span down. It was determined that the swing span would try and turn over from the wind loading with the ends of the structure being the most flexible, trying to twist. The end wedges do not provide any restraint for uplift and this twisting of the span would cause it to move off its supports. For this reason, the hurricane restraints were designed to secure the ends of the spans down to the top of the rest piers. This was done by mounting one end of the clevis to the underside of the end floorbeam and the other end to the pier top. In the event a hurricane occurres, the pins of the clevises are driven and the turnbuckles of the system are tightened to hold the ends of the swing span down tight to the wedges. (See Figure 5)

Electrical

The electrical system was also completely replaced. The system was designed to have all the motor starters and relay control system centrally located in the control house. This was done to assist the maintenance department in trouble shooting any problems that may exist by having all the components located in one area. This was not a simple task due to the size of the control room and the restriction of cabinet height being lower than the window sills. To achieve this, every cabinet was a custom made unit that served a specific purpose. There were five cabinets in total. The first was the control desk which housed the relays. The second cabinet housed the drive controller for the span drive and the third cabinet housed the transformers. The other two cabinets housed the circuit panels and motor starters for the gate motors, centering latch motors and the wedge motors. The relays had to be the "ice cube" type to be able to place the needed amount of relays for the interlocking in one cabinet. The use of machine tool relays would not have allowed the system to fit in the limited space.

The span drive motor was determined to be a DC motor to allow for the overhauling loads that a swing span experiences under wind loads and also to provide for accurate speed control. The span drive also had a two speed squirrel cage motor that is used in case of failure of the main drive or relay failure. The auxiliary drive is connected to the span drive through an electrically operated clutch. The wedge motor was a single speed squirrel cage AC motor. The span and wedge drives can also be manually operated from the roadway by a capstan mounted to a vertical shaft.

To facilitate the control change over and to reduce interruptions to marine traffic, the complete electrical system was factory tested and fully installed in the control house prior to being placed upon the bridge.

Since both the structures were similar, the electrical systems on both bridges are identical. The only difference is the speed that the motor is driven since the two structures are different lengths and the ratio of the final open gearing is different. This identical arrangement allows for both systems to be diagnosed the same and requires the maintenance personnel only to have to be familiar with one type of system.

Operator Comforts

Both structures are manned 24 hours a day, seven days a week. There was no running water available and there only existed an electrical toilet that always was a maintenance problem. As part of the rehabilitation, the Department wanted to make every effort to conform to OSHA requirements. To do this, it was necessary to have running water available for cleaning and washing purposes. This requirement is very difficult to achieve on a swing span. The first thought was to provide a small building on the bridge approach, but this was discounted due to the unsightly appearance and the need for the operator to leave the control house to use it. Rather, a toilet in the control house was determined to be best solution. Swing spans rotate about a vertical line and separate themselves from the approaches when open to marine traffic. The installation of water and sewer lines would either have to go under the channel and up the pivot pier or an alternate arrangement had to be determined. The decision was to provide a bladder water tank that would have a pump to maintain pressure for the sink and toilet and a sewer holding tank to collect the discharge from the fixtures. The sewer tank would be cleaned out periodically through an opening in the roadway by a vacuum truck. Although the tank required routine cleaning out, it was felt that this arrangement would meet the needs of the bridge personnel.

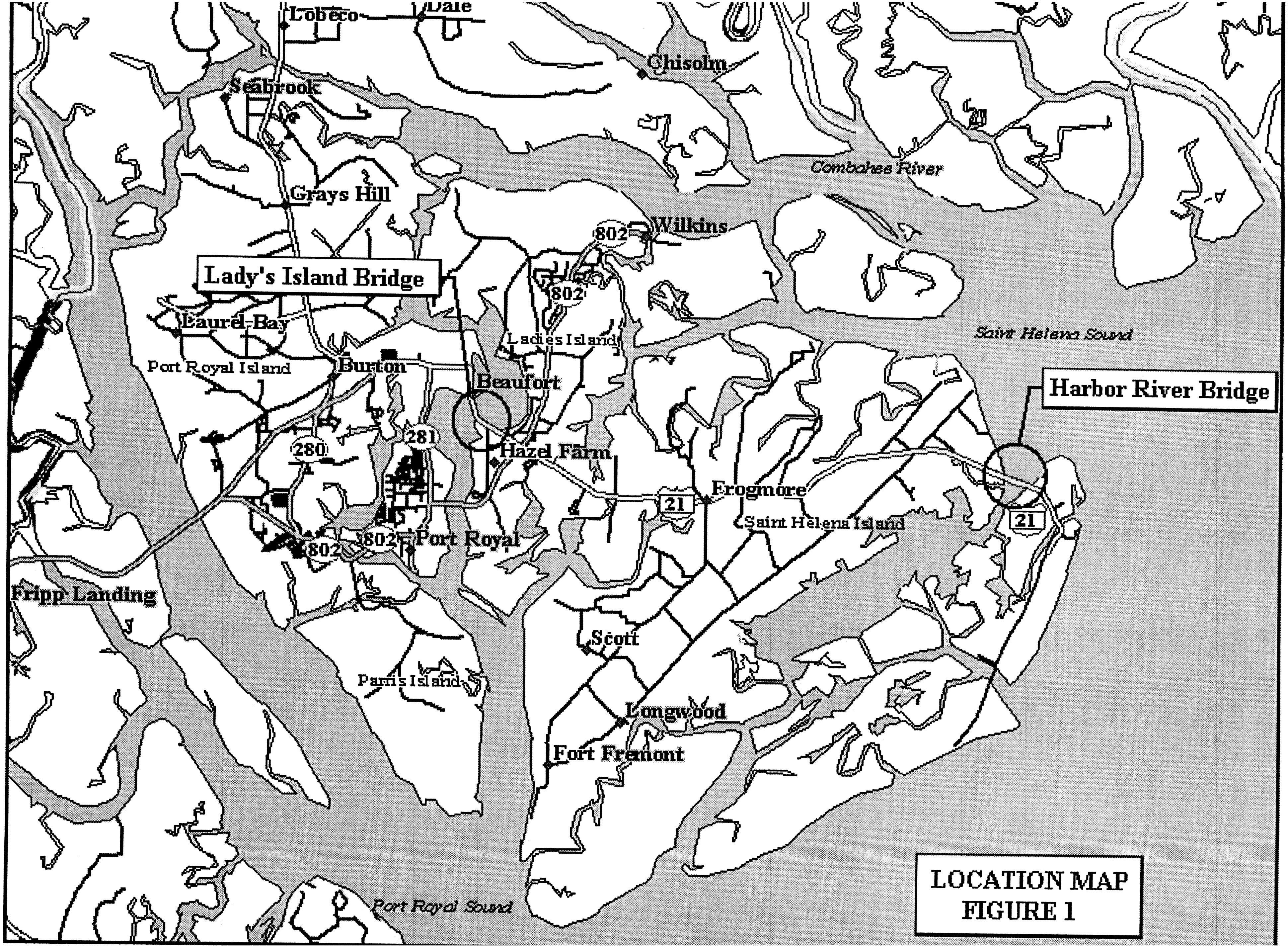
A water line was run on both the swing span and the approach spans. At the end of the swing span, a quick connect hose fitting was installed. An alarm was installed on the bladder water tank to notify the operator when the water level was running low. The operator would walk to the end of the swing span and connect the coupling and open a valve, filling the water tank. When the tank was filled to its proper level, the operator was notified by another indication to turn the water valve off. The water tank was sized to require refilling on a weekly basis. The sewer tank was designed in a similar fashion. When the tank was filled to a certain level, the operator was notified by an indication that discharge was needed. Sufficient additional space was provided to allow for the scheduling of the cleaning out.

Location of these tanks was important. The swing span is the only one of the three types of movable bridges that is symmetrically balanced. Any added weight to the structure needs to be accounted for. This is where the water and sewer tanks came into play. As previously noted, the span drive was replaced with a fully enclosed gear drive that was located only on one side of the pivot pier. These tanks were now able to be used as counterweights by placing them on the opposite side of the pivot point and provide the balance to compensate for the machinery. However, due to the usage the levels of the water and sewer vary and some slight unbalance is present. This does not present a problem since the tanks were placed on the side of the structure where the old span drive was and the original pinion support beam was left in place to provide additional counterbalance. (See Figure 4)

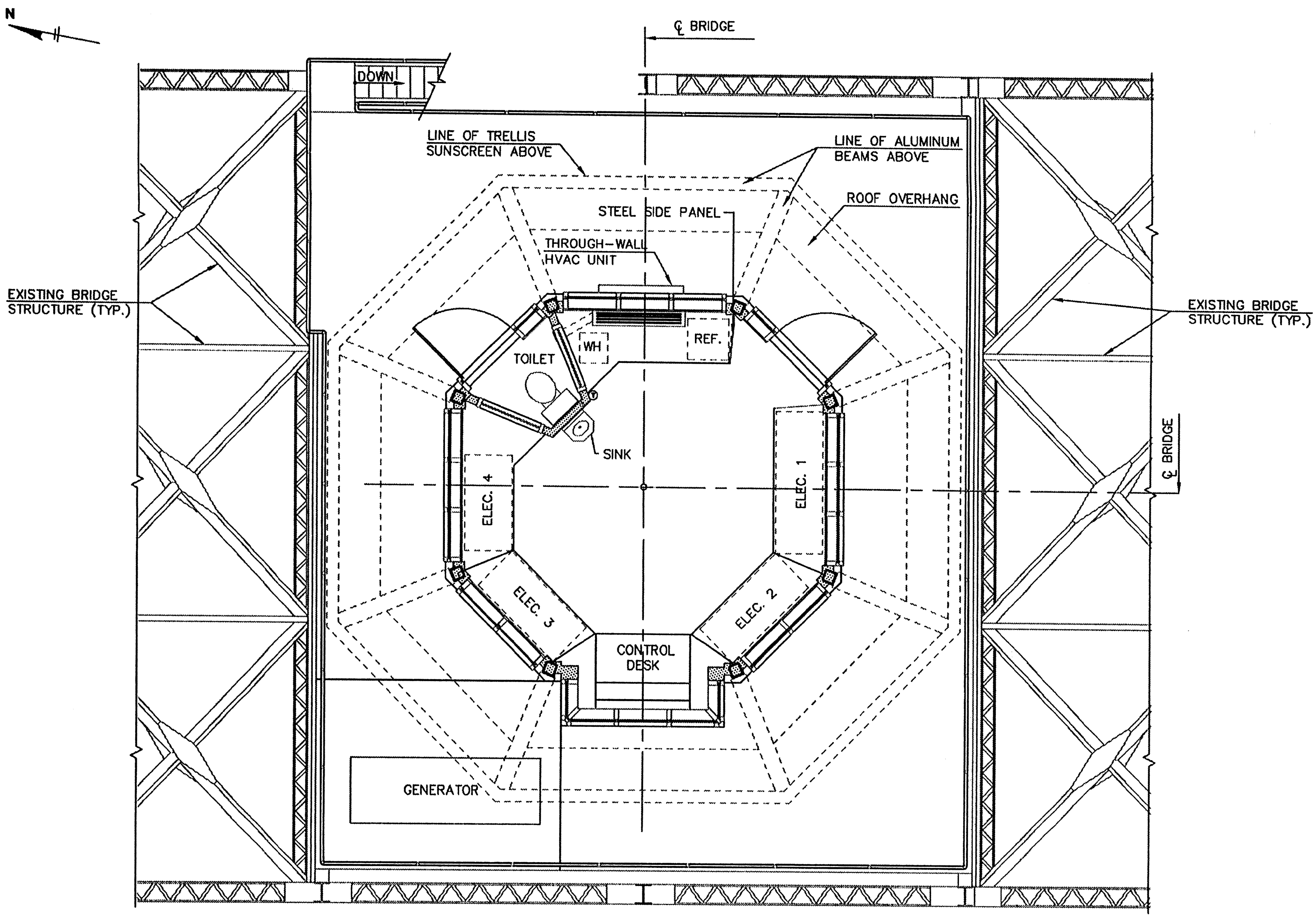
Conclusion

Movable bridges are complex structures that require special care and careful planning. Rehabilitation is even more difficult since there are specific constraints already established on these structures. Not only do the structures have specific requirements regarding configuration, geometry, traffic volume and details, but the presence of machinery, electrical systems and bridge operators adds to the intricacies that have to be addressed. Any modification or alteration affects numerous other factors regarding the structure. Not only does the smallest detail have to be examined, but also how this change affects the overall condition of the structure. This paper briefly described the rehabilitation of two swing bridges and the innovative thinking and design effort involved to hurdle the many challenges that the rehabilitation design requirements required.

Figures and Photograghs

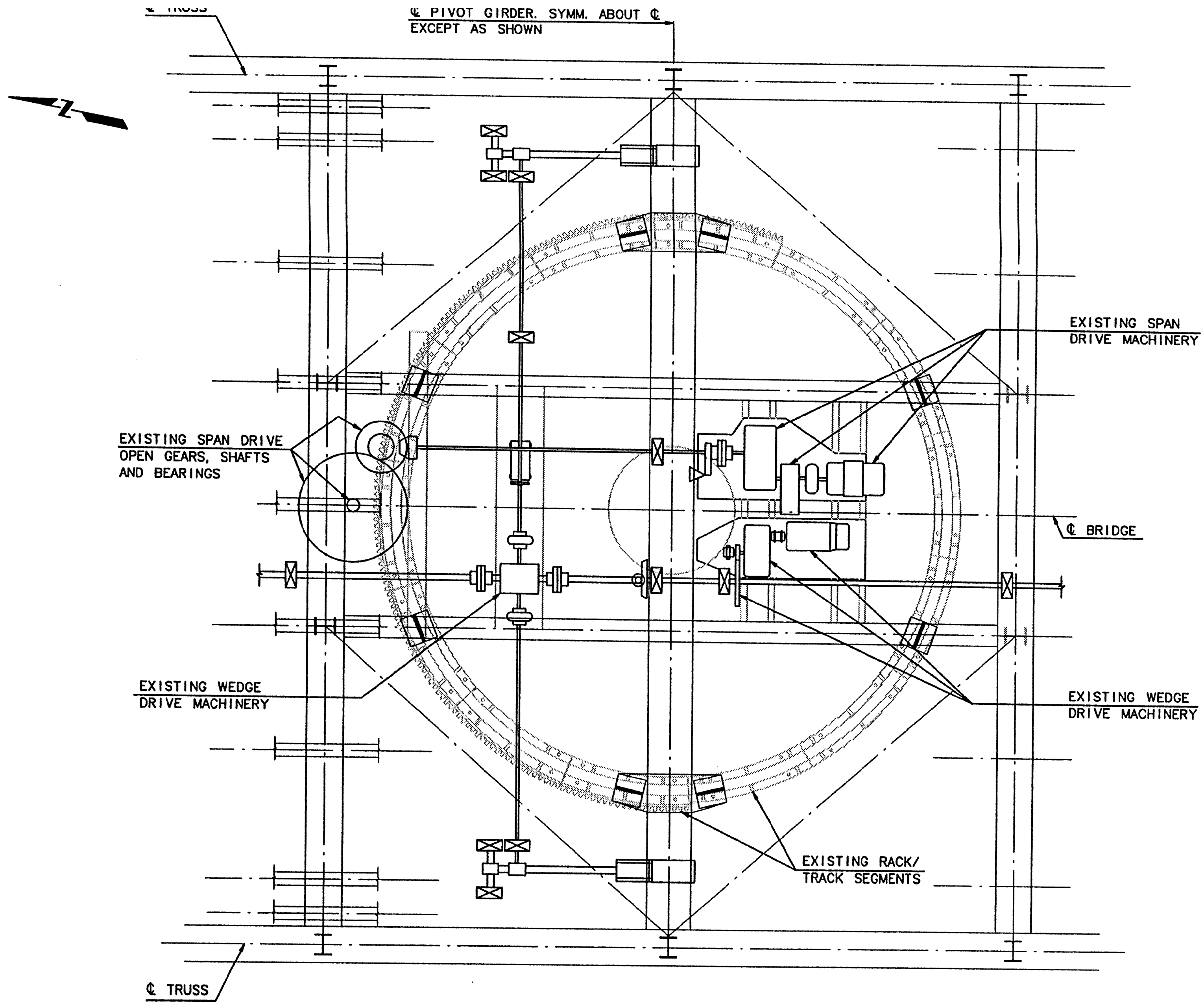


LOCATION MAP
FIGURE 1



PLAN OF CONTROL HOUSE

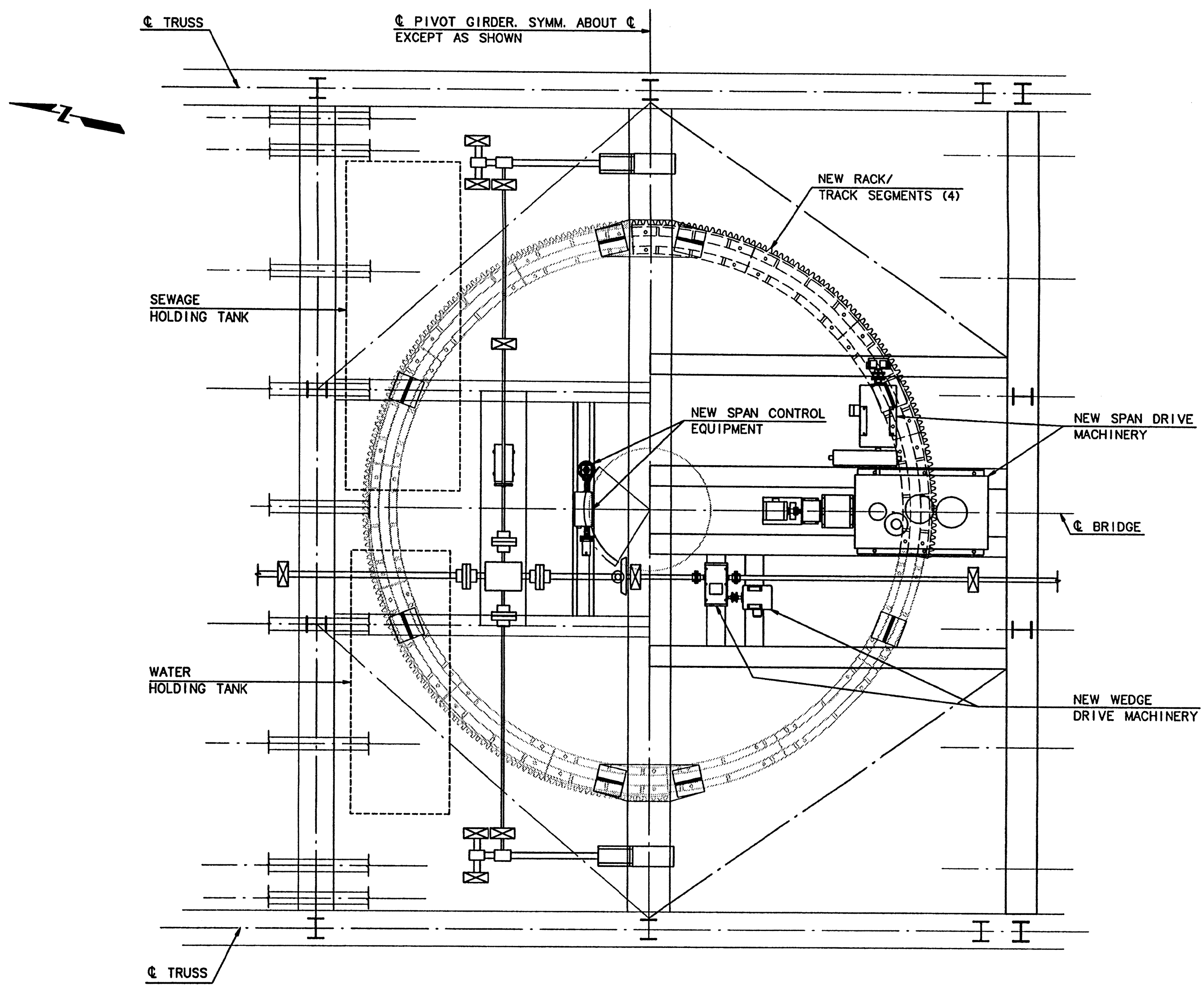
LADY'S ISLAND BRIDGE



PLAN OF EXISTING MACHINERY

LADY'S ISLAND BRIDGE

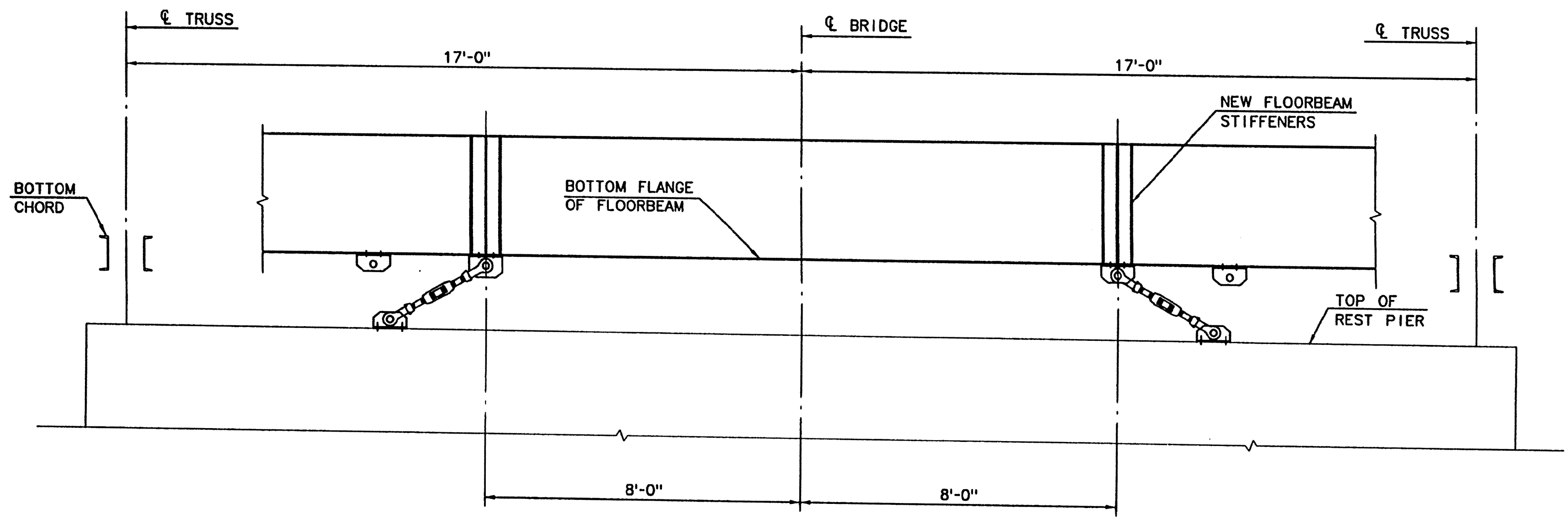
FIGURE 3



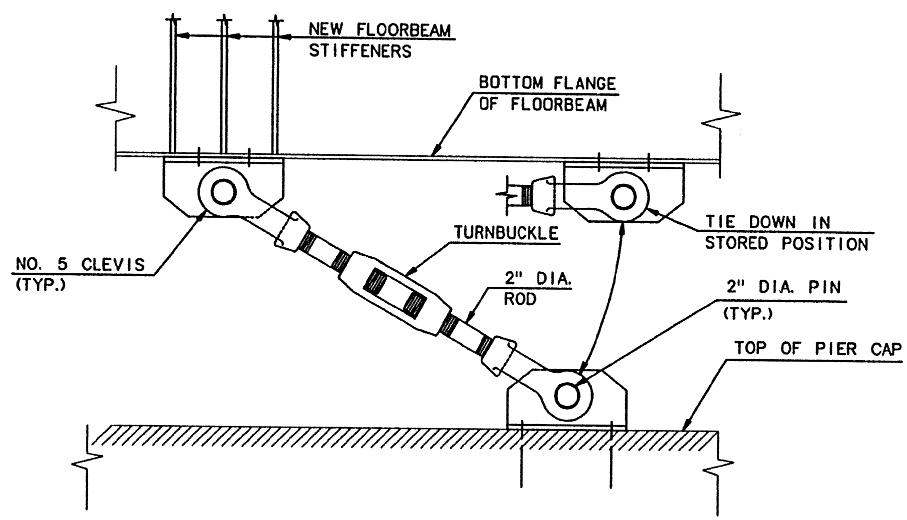
PLAN OF NEW MACHINERY

LADY'S ISLAND BRIDGE

FIGURE 4



HURRICANE TIE DOWN ELEVATION



TIE DOWN DETAIL

FIGURE 5

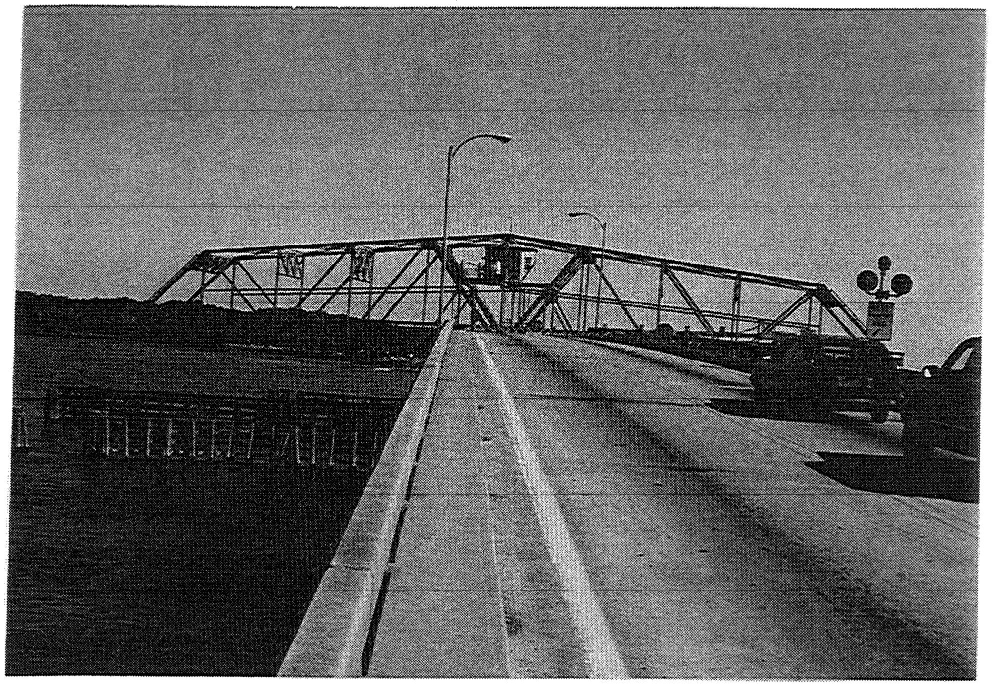


Photo 1: Lady's Island Bridge

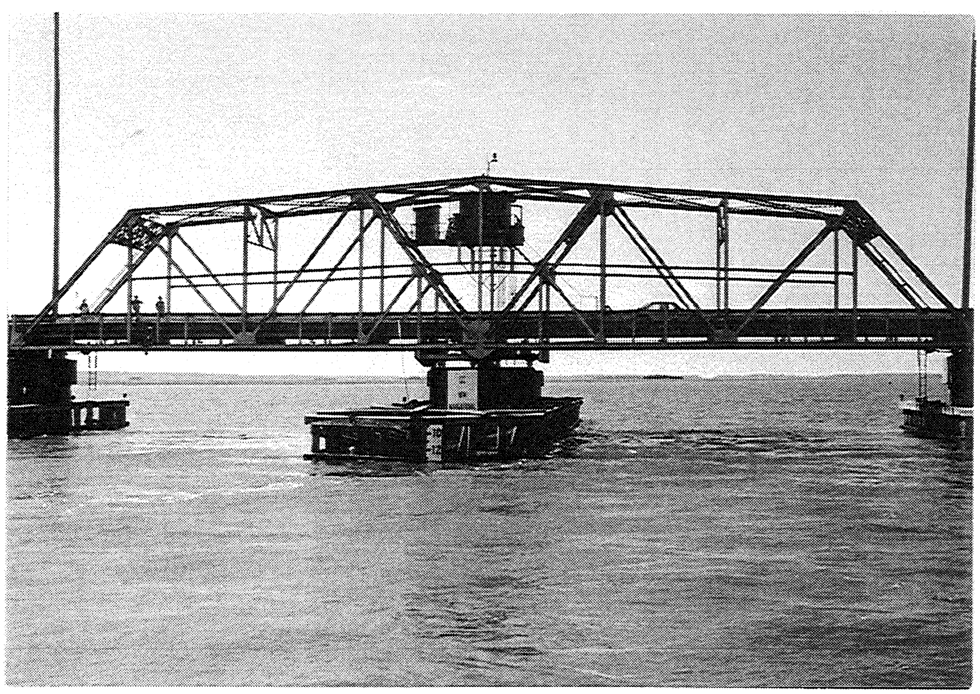


Photo 2: Harbor River Bridge

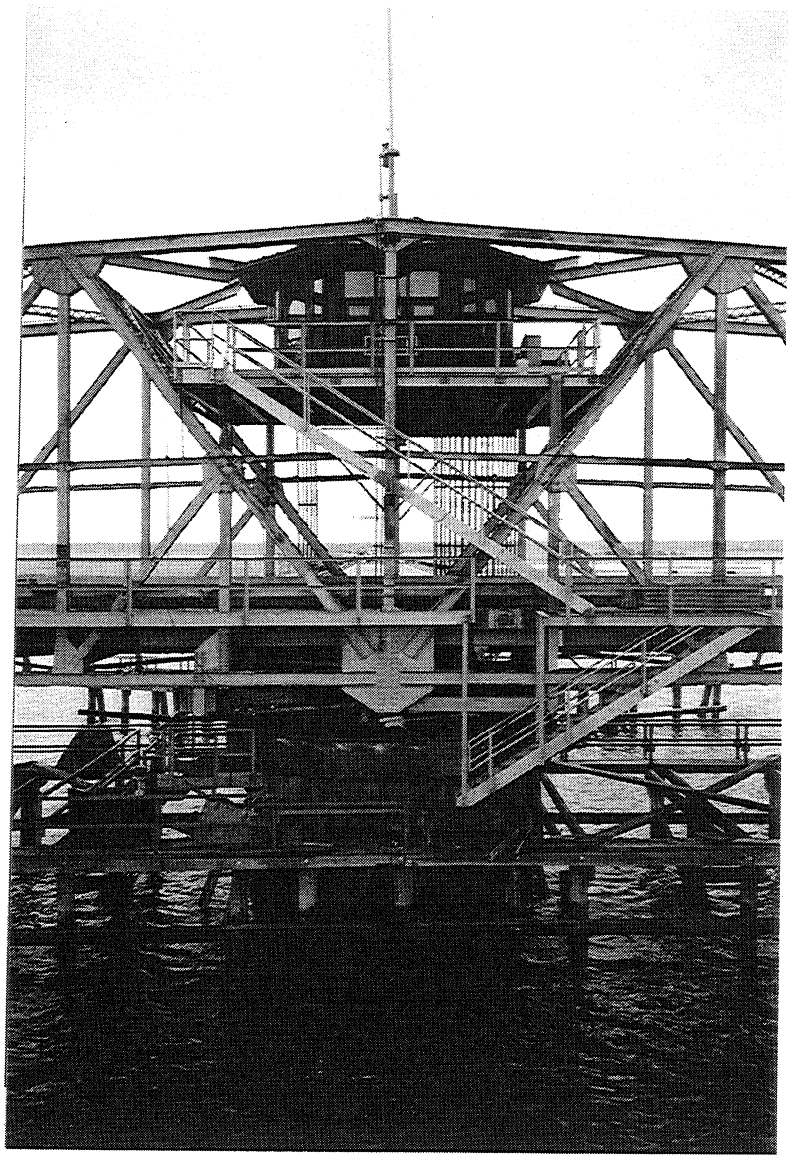


Photo 3: New Control House

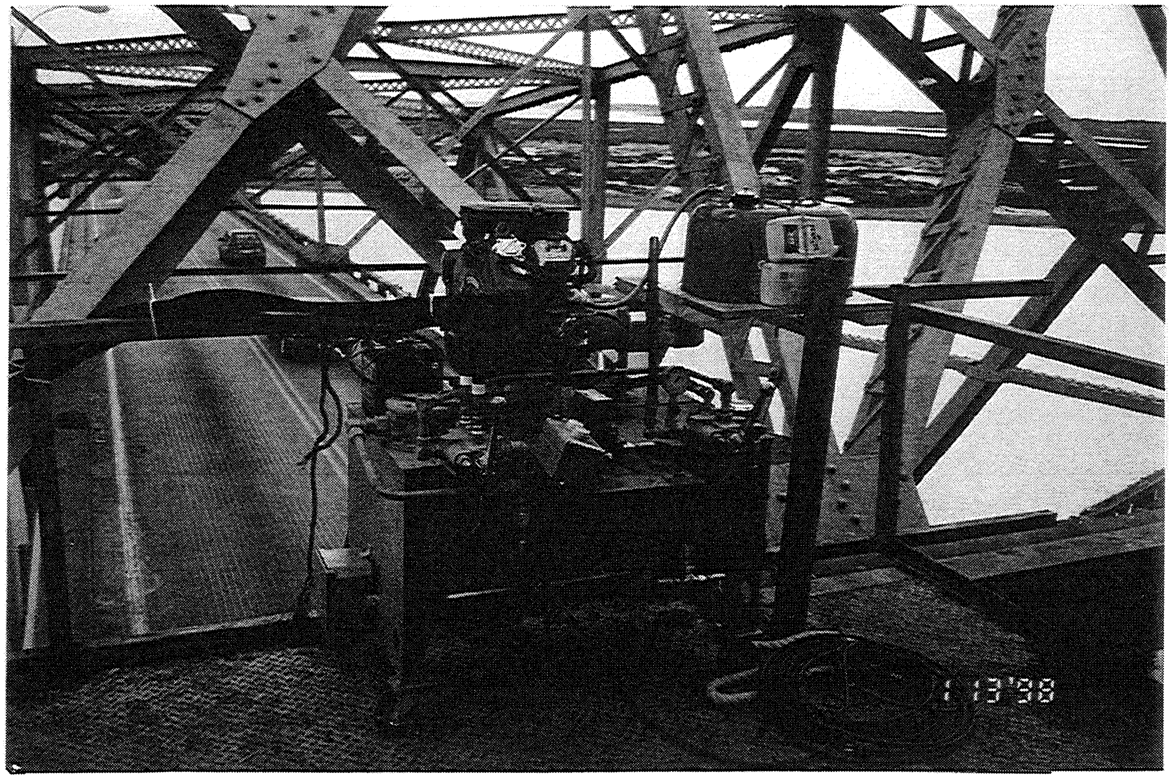


Photo 4: Temporary Hydraulic Power Unit

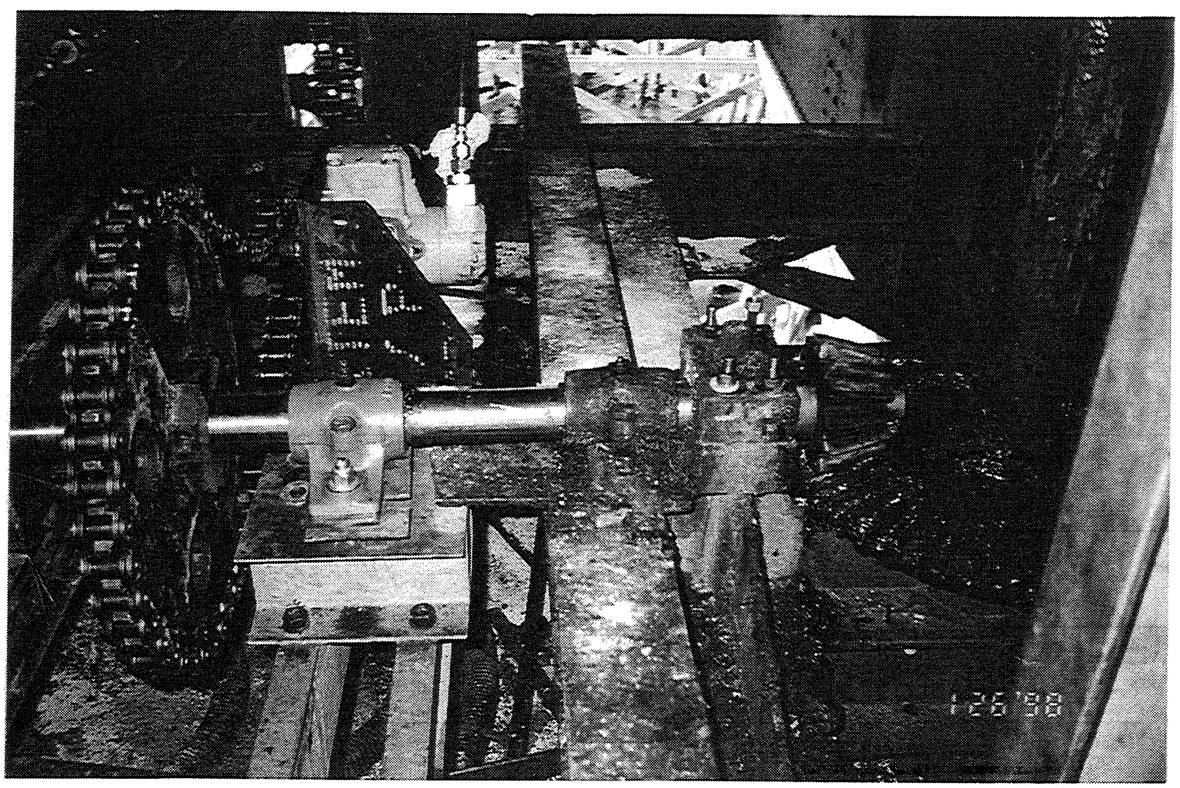


Photo 5: Temporary Span Drive

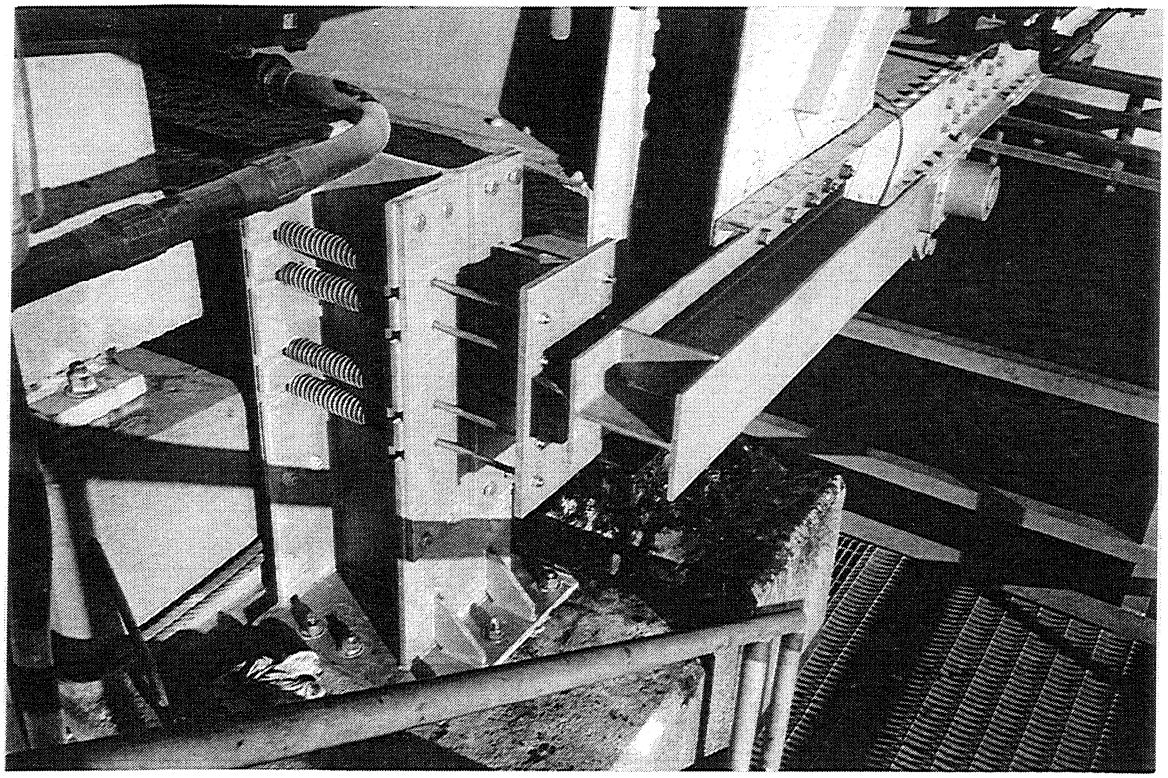


Photo 6: Bumper Block