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"Concrete Swing Bridge Construction Report", J.Clark,
Anderson-Bjornstad Kane Jacobs, Wa.

Concrete Swing Bridge Construction Report

by

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Abstract

A double leaf concrete swing bridge is currently under construction in Seattle, Washington. The two lane bridge spans 480 feet center to center of the two pivot piers. Each movable leaf is 413 feet long and weighs 7800 tons. The leaves rest on nine foot diameter hydraulic "Lift/Turn" cylinders as they are turned into the open position by the double acting hydraulic slewing cylinders.

This paper describes the design reasoning which led to this novel structure, the principal components and the construction progress to date. The bridge, which was described during the 1985 Movable Bridge Symposium, has taught valuable lessons on fabrication and installation techniques of state of the art components and procedures.

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Background

In 1979 a ship struck one of a pair of four lane bascule bridges which carried a main Seattle arterial across the Duwamish Waterway. The bridge was damaged beyond repair. A new high level six lane freeway bridge was constructed and opened to traffic by 1984. The remaining bascule bridge continued to carry local traffic between several related port and industrial areas. This 1927 vintage bascule bridge was slated for rehab or replacement. Since it was determined to be a hazard to navigation by the Coast Guard, it was scheduled to be replaced.

Design of the replacement structure was started in 1983, but construction was delayed until March of 1989 due to funding considerations. The bridge is scheduled for completion in July of 1991.

The Duwamish Waterway is currently designated as 150 ft. wide, but is planned to be widened to 250 ft. The alignment of the road is at a 45° skew to the waterway which dictates a span of over 400 ft. if the alignment is to be maintained. The height of the existing bascule bridge is 45 ft. above mean high water. By setting the new bridge height at 55 ft. the number of openings will be reduced from 21 per day to 7 per day.

Traffic counts prior to start of construction were 3,500 vehicles per day. These are projected to reach 12,000 by the year 2000. Two 11 ft. wide traffic lanes are provided with two feet of median and five foot shoulders. Since pedestrian and bicycle traffic is prohibited on the adjacent high level freeway bridge a 12 ft. wide bike/ped path is provided for an overall structure width of 51 ft.

Bridge Type Selection

Early consideration was given to three bridge types, vertical lift, bascule and swing bridges. The long span and 45° skew angle as well as the right-of-way constraints at the site greatly influenced the selection process. Aesthetics, maintenance costs and the client's strong preferences for a concrete roadway surface also influenced the choice.

The vertical lift bridge required a span length of 500 ft. and a vertical lift to provide 140 ft. clearance. Although this option provided the most conventional solution, it was ruled out because of cost and appearance.

The bascule bridge on a straight alignment was not practical. By introducing "S" curves the skew angle could be reduced to 60° which gave a 386 ft. long span. This is 50 feet longer than the current record bascule bridge but was still considered possible. Further detailed analysis indicated costs would be about 20% higher than the swing bridge.

A swing bridge with pivot piers on each bank offered the most cost effective and functional solutions. With a straight alignment the main span was 480 feet. There was a strong desire to match the aesthetics of the adjacent high level freeway bridge. This bridge was constructed by the segmental concrete cast in place method. Engineering and cost studies indicated that this construction method provided a very cost effective superstructure in this span range. The big question was how could one move such a massive superstructure.

The site had restrictions of proximity to the adjacent high level bridge columns. These columns limited the length of the balancing tail span. The superstructure has 240 foot main span cantilevers and 173.5 foot tail span cantilevers. The tailspans are nearly solid concrete to balance the load. The superstructure has longitudinal post tensioning sufficient to load balance the dead load moments. This provides better control of creep and shrinkage

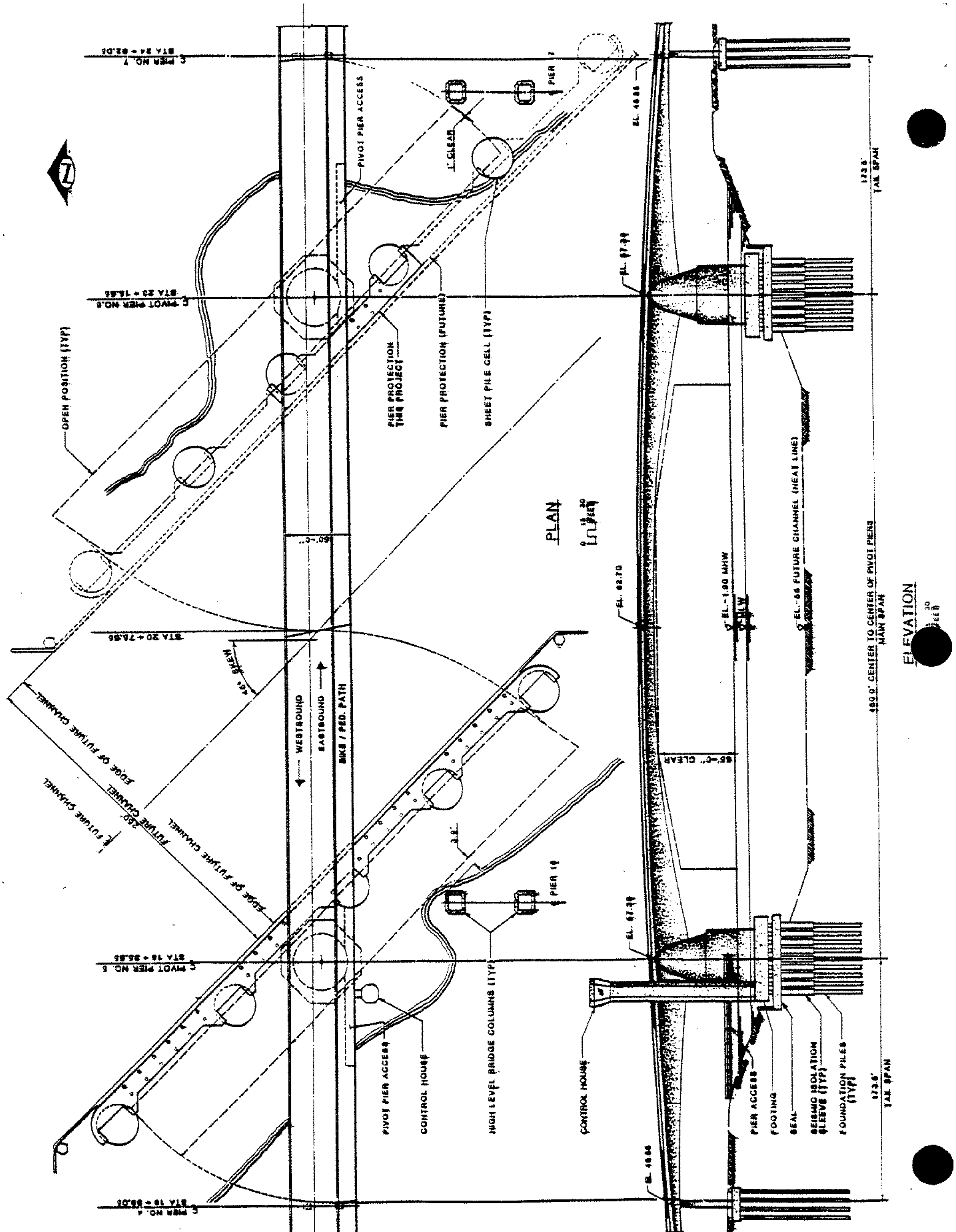

PLAN
ELEVATION
WESTBOUND
EASTBOUND
BIKE / PED. PATH
PIVOT PIER ACCESS
CONTROL HOUSE
HIGH LEVEL BRIDGE COLUMNS (TYP)
PIER PROTECTION THIS PROJECT
PIER PROTECTION (FUTURE)
SHEET PILE CELL (TYP)
OPEN POSITION (TYP)
EDGE OF FUTURE CHANNEL
FUTURE CHANNEL
℄ FUTURE CHANNEL
45° SKEW
PIER 7
PIER 10
℄ PIVOT PIER NO. 5
℄ PIVOT PIER NO. 6
℄ PIER NO. 4
℄ PIER NO. 7
1' CLEAR
PIER ACCESS
FOOTING
SEAL
SEISMIC ISOLATION SLEEVE (TYP)
FOUNDATION PILES (TYP)
173.6' TAIL SPAN
400.0' CENTER TO CENTER OF PIVOT PIERS MAIN SPAN
135'-0" CLEAR
EL. -1.90 MHW
EL. -55 FUTURE CHANNEL (NEAT LINE)
EL. 67.70
EL. 62.70

FIGURE 1

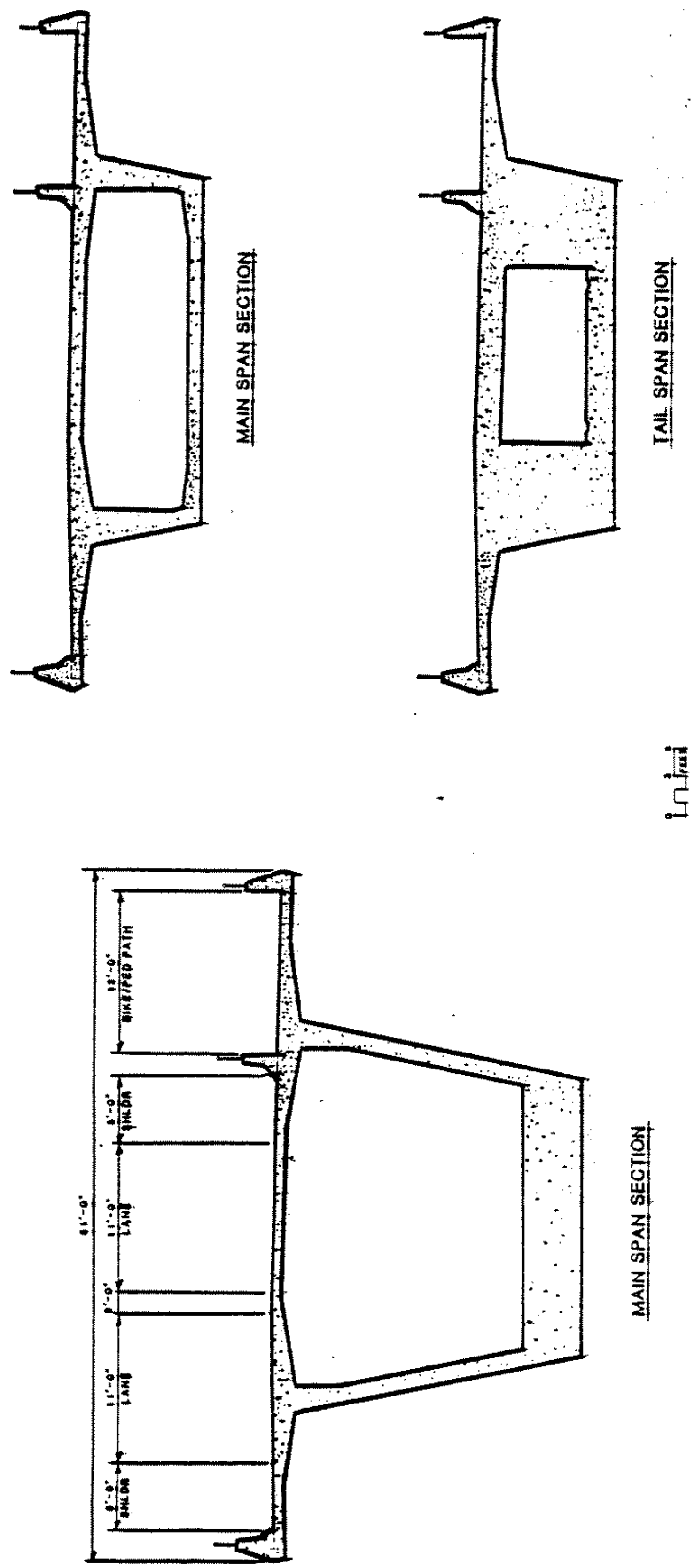


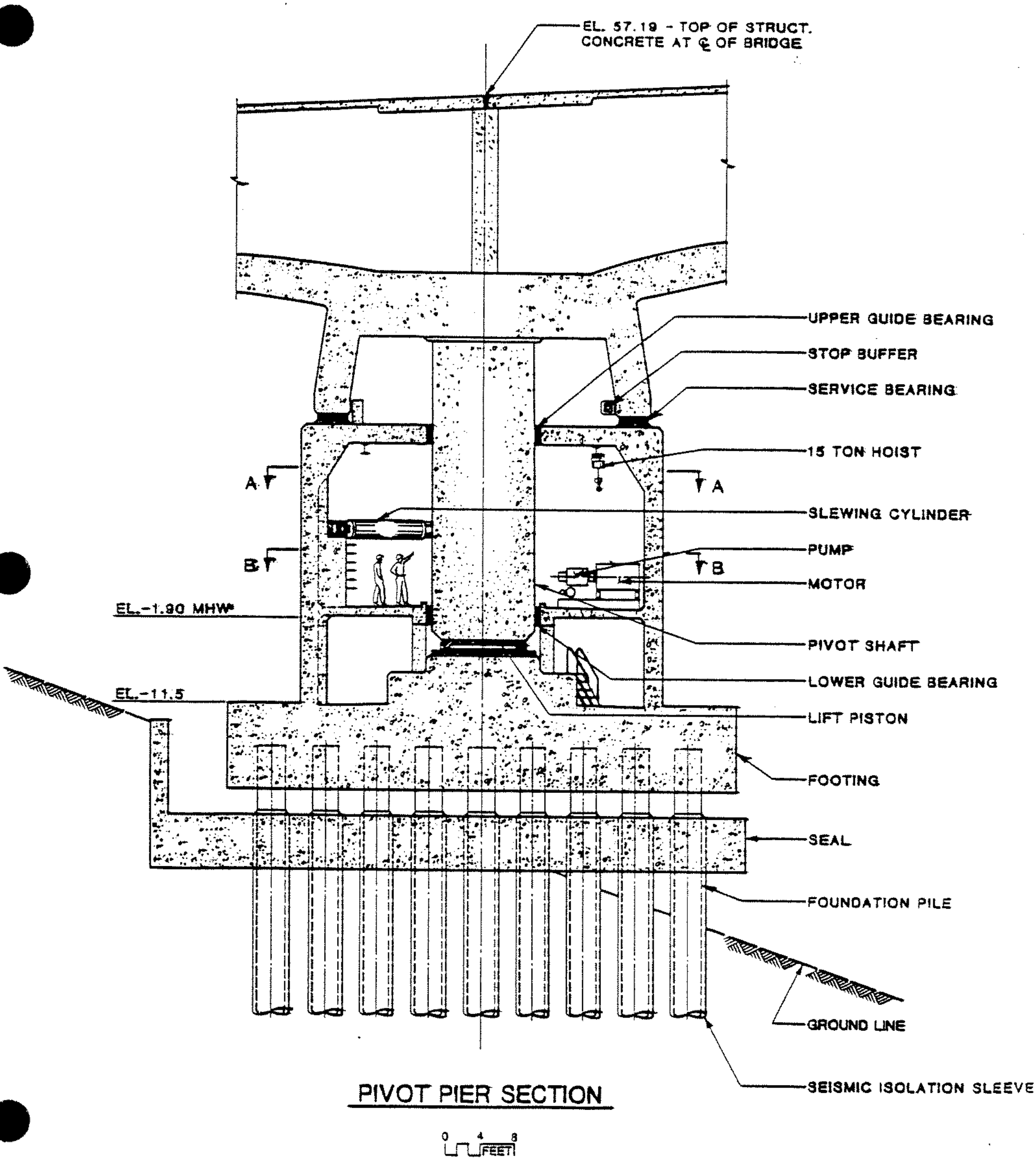
FIGURE 2

camber effects. The layout of the bridge is shown in Figure 1. Cross sections through the concrete box superstructure are shown in Figure 2.

Movement Mechanism

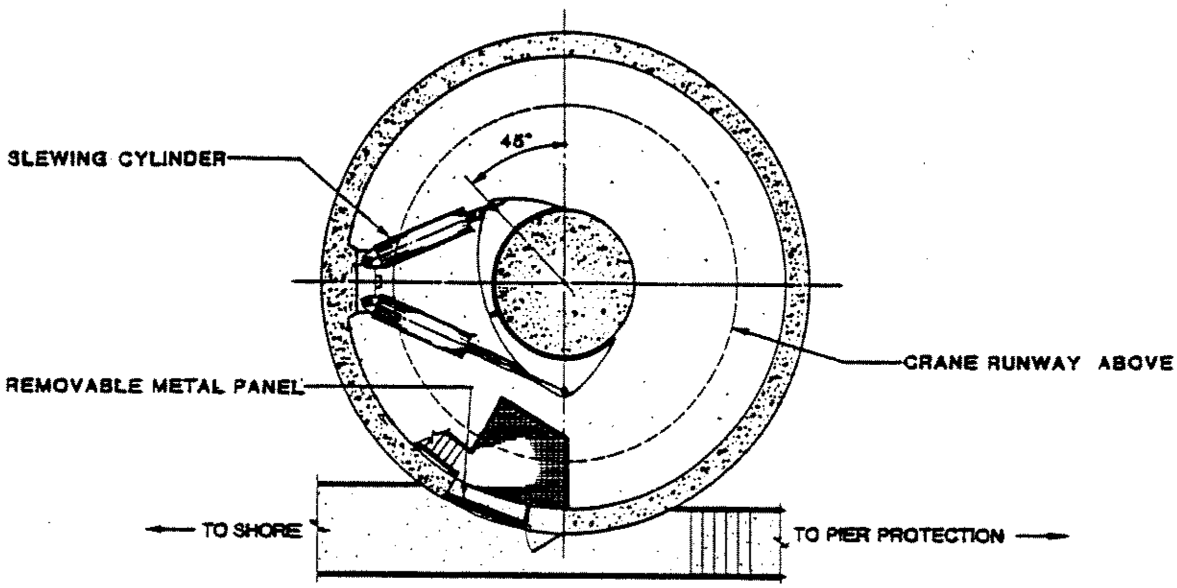
Each of the main span superstructure elements weighs 7,800 tons (15,600,000 lbs). The conventional swing bridge mechanisms were investigated and found to be beyond their practical limit. Bronze spherical bearings were possible, but replacement would be very difficult. Balance wheels become impractically large and heavy. Seating wedges that were capable of carrying such heavy loads (including earthquake loads) were beyond any practical limit of size and reliability.

It was decided to try an entirely new combination of mechanisms to move this massive weight. Figure 3 shows a section through the pivot pier. The superstructure normally rests on a ring of service bearings around the top of the pier housing. When an opening is to be initiated, the superstructure is raised on a 12 foot diameter pivot shaft by a large lift/turn cylinder at the base of the shaft. This lift/turn cylinder raises the superstructure about one inch clear of the service bearings. The bridge is then free to rotate on the oil bearing provided by the lift/turn cylinder. The turning motion is controlled by a pair of slewing cylinders attached to arms on the pivot shaft. While the bridge is being moved, it is held plumb by bearings which guide the 12 foot diameter shaft at the upper and lower floor levels. These elements can be seen in the sections of Figure 4.

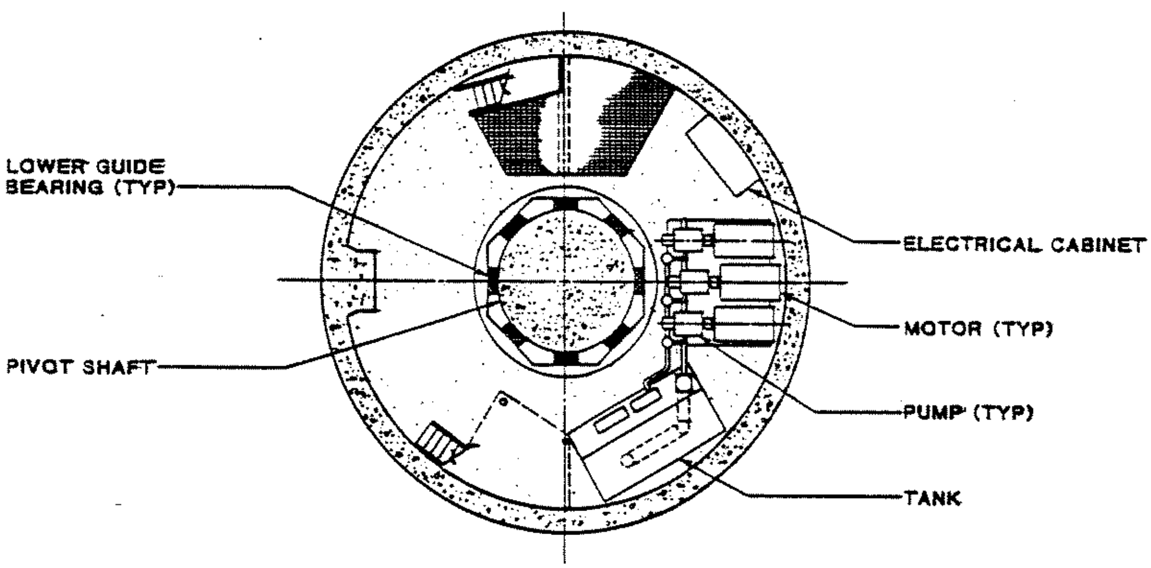


PIVOT PIER SECTION

FIGURE 3



SECTION A-A



SECTION B-B

FIGURE 4

The criteria provided by the client was to perform a full opening in two minutes (120 seconds) after the traffic barriers are set. This determined that a 200 HP hydraulic drive unit was required. To provide redundancy three 100 HP drive units are used in each pier. Two are normally alternated but the bridge can operate at one half speed on one unit. The bridge can also be operated on one of the two slewing cylinders at reduced speed. There is a 500 HP standby generator in each pier to cover power outages.

The pier housing and mechanical components are arranged so that any element including the lift piston, slewing cylinders, hydraulic pumps and generator can be removed for replacement. A 15 ton hoist is provided for easy handling of these elements within the pier.

The structure has rather conventional center lock and tail lock pins. These pins are located on the longitudinal centerline of the bridge because the concrete box superstructure has great torsional capacity. The center and tail lack pins are hydraulically driven.

Construction Progress

As of this writing (June 1990) the bridge is about 50% complete. The two pivot piers are nearing completion and the segmental construction of the superstructure is about to begin. All of the mechanical components have been fabricated and installed, but have not as yet been operated at full load.

There was considerable concern about the constructability, reliability and wear characteristics of the lift/turn cylinder. This cylinder is nine feet in diameter with a five inch stroke. It operates at 1700 psi pressure. To address these concerns a one half size test model was fabricated and operated through 25,000 cycles of operation. This represented 10 years of projected wear. Several things were learned from these tests:

- The proposed fabrication techniques were practical.

- Wear and friction was less than 1/4 the conservative estimates made during design.

- Stick friction occurred between the seals and the chrome wearing surface at the very slow operating speeds. This was mitigated when the cycle time was increased in the depressurized mode allowing the seals to recover. Adding an anti-friction additive to the hydraulic fluid also lessened this phenomenon.

- A grease fitting between the upper seal and the wiper seal reduced the friction and wear on the back side of the upper seal.

- Life expectancy of the seals is projected at over 25 years if they wear like the tests.

During fabrication and installation of the mechanical components, the design team worked closely with the contractor and the fabrication subcontractor. Several minor details were revised to make welding more accessible and fabrication easier. Many of these revisions were made at the suggestion of the fabricator. In the case of the service bearings which were built up of layers of teflon, stainless steel, A-36 steel plates and "fabrica" a contractor value engineering redesign was adopted which performed the same function at much less cost. On the heavy weldments which connect the slewing cylinders to the pivot shaft, the specified steel was modified to facilitate ease of welding.

The contractor coordinated closely with the design team in developing the installation techniques for the mechanical elements. The contract stipulated several shop fit up and run out tests in addition to tight tolerances on the installed mechanisms. The 12 foot diameter pivot shaft, for instance, was specified to have a runout tolerance of 0.015" on the guide bearing journals. Dialogue between the contractor and the design team was essential in working out an appreciation of the need for these tight tolerances. Because of this cooperative effort the installation went smoothly and all of the tolerance requirements have been met. The lift/turn cylinder and pivot shaft have been checked and operate smoothly, although only under partial load at this time.

The hydraulic system has been preassembled and shop tested. The controls system is designed using "Square D" P.C. units which are being preassembled and will be bench tested prior to installation. Ever effort is being made to build in reliability and redundancy in these systems. Although there is a strong desire to build in safeguards against improper signals, this desire is being balanced by the need for consistent, reliable and simple systems.

Conclusions

Although this state of the art bridge is far from complete, the progress to date is very encouraging. With the successful completion movable bridges will take another forward step. This bridge type would appear to offer a cost effective solution in the 300 foot to 600 foot span range.

The bridge is being built by the joint venture of Kiewit - Global of a cost of $33,500,000. This is within 2% of the engineers estimate. The owner is the City of Seattle. Design consultants are the West Seattle Bridge 2 Design Team, a joint venture of Andersen Bjornstad Kane Jacobs, Inc., Parsons Brinckerhoff Quade and Douglas, Inc. and Tudor Engineering Company. Hamilton Engineering Company assisted in the design of the hydraulic system and Sverdrup Corporation assisted in the design of the control system.