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Proposed Concrete Swing Bridge

Projet de pont tournant en béton

Projekt einer Beton-Drehbrücke

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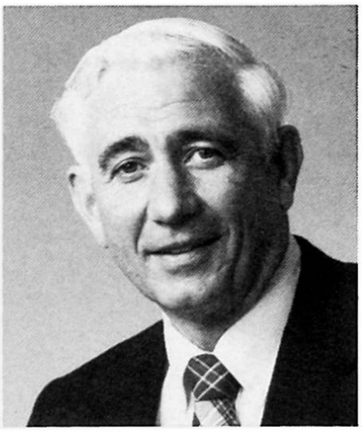

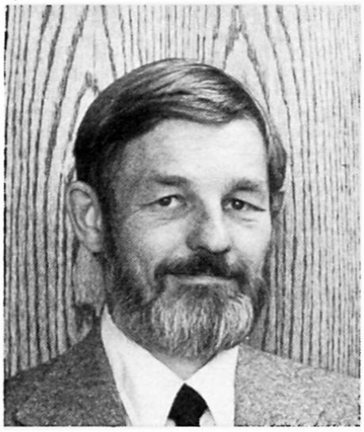

SUMMARY
A double-leaf concrete swing bridge with a span of 146 meters between pivot piers has been proposed as a replacement for an existing bascule structure. The drive mechanism proposed is hydraulic and incorporates a 25 millimeter vertical lift to raise the movable leaves off of closed position service bearings.

RESUME
Un pont tournant en béton avec une ouverture de 146 mètres entre les piles a été proposé en remplacement d'une structure basculante actuellement en service. Le mécanisme de transmission proposé est hydraulique et incorpore un levier vertical de 25 millimètres pour soulever le pont de ses appuis.

ZUSAMMENFASSUNG
Eine Doppel-Drehbrücke aus vorgespanntem Beton mit 146 m Spannweite zwischen den Drehpfeilern, ist geplant, als Ersatz für eine bestehende Zugbrücke. Mit einem hydraulischen Mechanismus wird die Brücke um 25 mm von den Auflagern abgehoben und gedreht.

Future widening of the Duwamish River Waterway in Seattle has necessitated construction of two major bridges. A high-level bridge was completed in 1983 and carries the majority of vehicular traffic over the busy waterway. Provisions for local access, pedestrian and bicycle traffic requires the replacement of the existing low-level bascule bridge which restricts the horizontal clearance available in the channel. This paper describes the concrete swing bridge proposed as one alternate for the replacement. The major components of the proposed structure and its machinery and some of the critical design problems are discussed.

The movable portion of the proposed bridge will consist of two asymmetrical movable leaves with the joint at mid-channel (Figure 1). Layout to maximize horizontal navigation clearance within constraints established by the columns of the adjacent high-level bridge resulted in each movable leaf having a main span cantilever of 73 m (240 feet) from the pivot pier to the center joint and a tail span of 53 m (173.5 feet). The bridge carries two lanes of vehicular traffic on a 10.4 m (34 feet) wide roadway and a 3.7 m (12 feet) pedestrian and bicycle path. Total overall width is 15.2 m (50 feet). The approaches are prestressed concrete I girder construction.

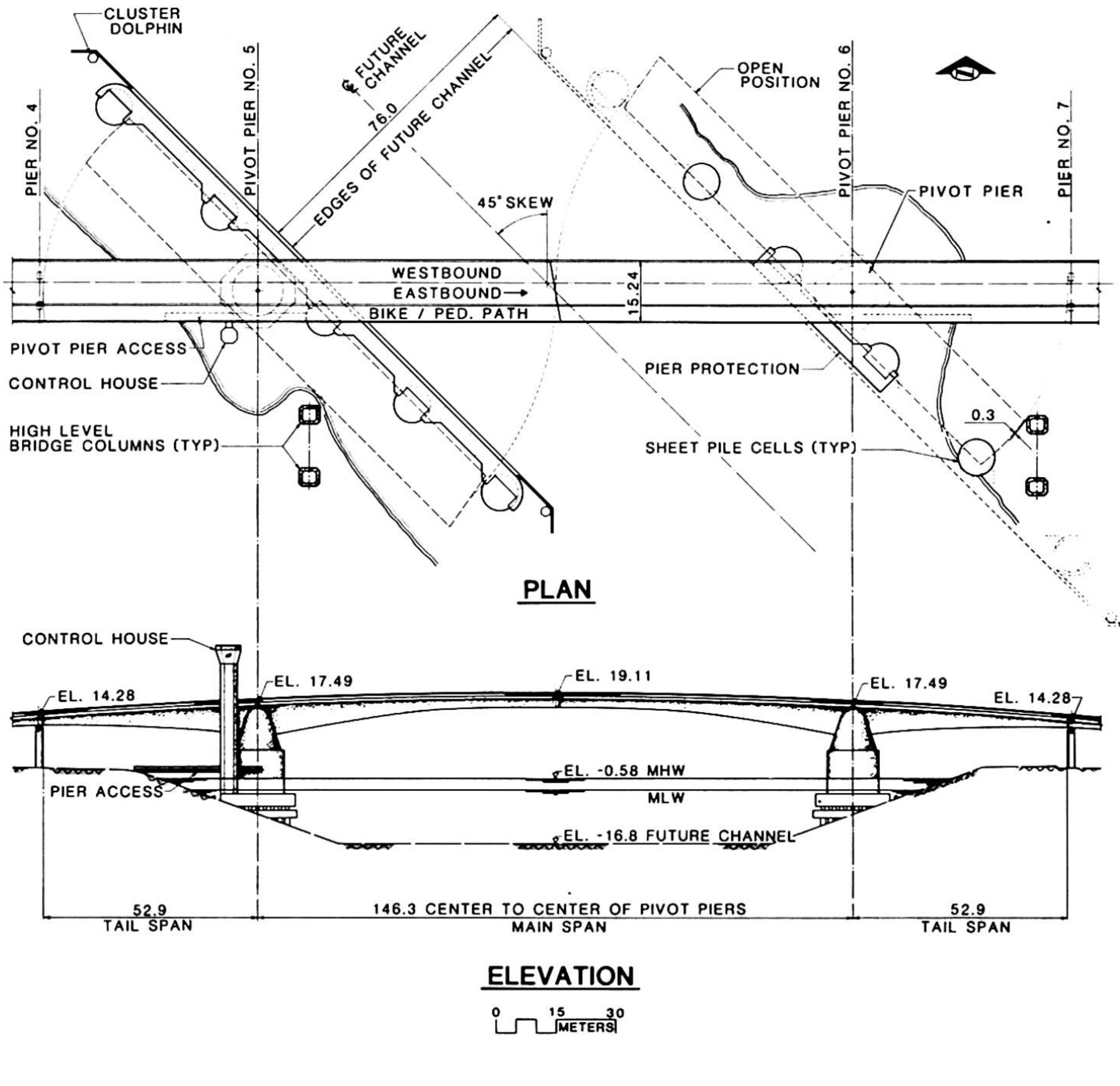

Figure 1

The project is located in a moderately active seismic zone and detailed consideration was given to the seismic design criteria. Seismic studies established the probable ground motion corresponding an earthquake which has a predicted return period of approximately 500 years. At this level of excitation, reparable damages would be anticipated.

1. Superstructure:

The proposed movable portion of the structure is a double swing span with identical asymmetrical leaves of single cell prestressed concrete box girder cross-section.

Longitudinal post-tensioning for the concrete box girder is designed to balance the dead load of the structural concrete and superimposed dead load (overlay, rails, etc.). Additional provisions for camber control include the installation of at least two ducts for installation of future tendons, at least two unbonded tendons (greased and wrapped) in each leaf, and detailing to provide anchorages for external tendons inside the box.

"Ballast" concrete placed in the tail span to achieve static balance about the pivot pier is made by widening the webs of the box girder as required. The additional concrete will be standard weight 2560 kg/m (160 pcf). A minimum of 1.2 m (4 feet) wide void is provided for access to the end of the tail span. Total mass of each movable leaf is 7,080,000 kg (7800 tons).

The plinth at the pivot pier (Figure 2) serves as the transition element between the box girder and the supporting substructure and is sized for load distribution to the supports. The plinth provides two separate load paths for the vertical loads, moments, and shears. Load transfer in the normal service or closed position is through the outer shell of the plinth to the service bearings located at the top of the machinery housing. Load

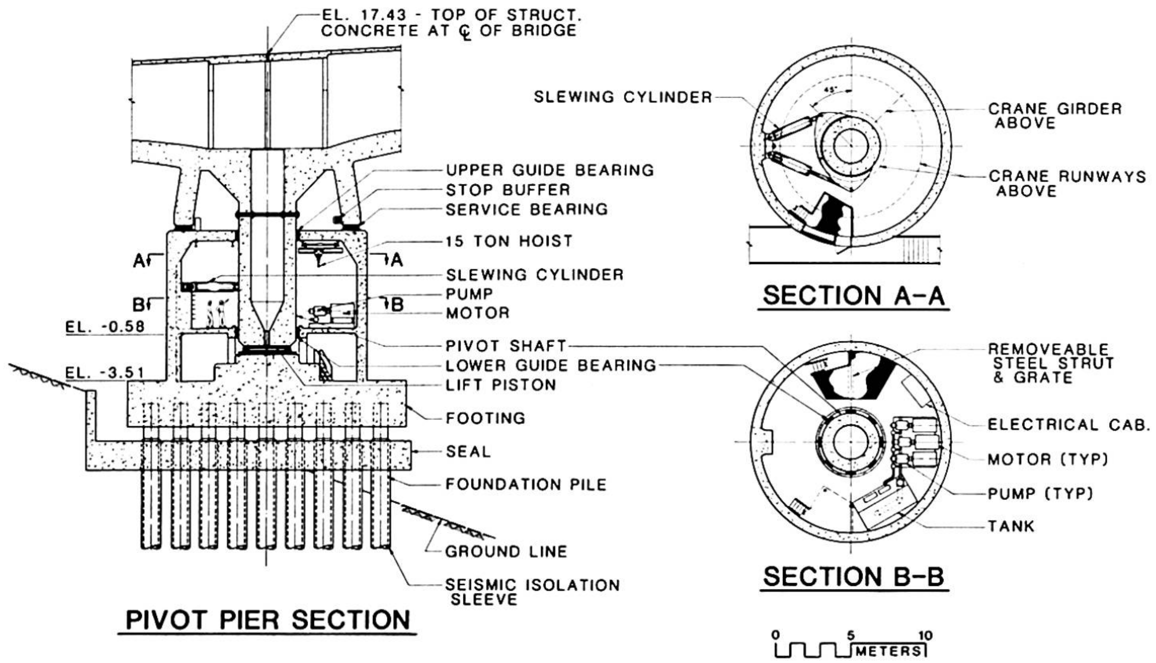

Figure 2

transfer in the slewing or open position is through diaphragms and the base slab into the pivot shaft to the guide bearings and lift piston. The pivot shaft is 3.66 m (12 feet) outside diameter with a 2.13 m (7 feet) diameter void. The shaft is composed of a pair of concentric steel shells stiffened by bracing and diaphragms. The annular space between the shells is filled with high strength concrete which is made composite with the steel shells.

The shaft not only serves to lift the superstructure free from the service bearings, but also to stabilize the bridge against overturning moments due to wind or accidental eccentricity during the swing operation and to carry the swing torque from the slewing cylinders to the superstructure.

2. Substructure:

The cylindrical machinery housing (Figure 2) transmits the superstructure loads in the closed position down through the walls to the foundation. Lateral loads are carried through the service load bearings by friction and are resisted by the cylindrical walls in flexure and shear. In the open position, the machinery housing provides stabilization against lateral loads by supporting the guide bearins at the roof and machinery floor level. In normal operation there is only a small component of force normal to the walls because of the arrangement of the slewing cylinders. In the case of single cylinder operation or other source of unequal slewing cylinder force, this force is carried to the roof and machinery floor diaphragms by the piston shaft and a stiffening girder at the wall.

The foundation for the swing bridge is to be composed of 32 each 0.9 m (36 inch) diameter concrete filled steel piles. These piles will be driven to a hard glacial till layer, approximately 50 m (160 feet) below the surface.

A significant problem with pile foundations is location of the pivot pier in the slope of the future channel. Pile foundations placed directly on this slope would result in a large variation in pile lateral stiffness depending upon the elevation of the slope surface. This would lead to uneven distribution of shear loads to the piles and eccentricity of the pile group shear resistance with respect to the supported mass. This eccentricity would lead to increased seismic response forces from excitation of torsional response modes.

The seismic isolation scheme developed was to separate the seal and the footing. The foundation piles would be separated from the seal by sleeves extending down into the soil. The sleeves would be larger diameter piles which would carry the weight of the seal to the slope soil. The annular space between the foundation pile and the sleeve pile would be backfilled to Elev. -13 m (-44 feet) with granular material. The annular space above that level would be left open. The purpose of the sleeve piles is to create a uniform level at which the lateral soil support for the foundation piles begins. All piles of the group will thus share the shear loads equally and the exicitation of torsional response modes will be minimized. The space between the seal and the footing would be formed and supported on the seal such that the supports for the footing pour would not be capable of transmitting shear loads.

3. Machinery:

A single center lock is provided at the center joint between the two movable leaves. This lock prevents relative vertical or horizontal deflection between the two leaves thus maintaining a smooth riding surface. The torsional stiffness of the box girder is such that one center lock is deemed adequate for controlling relative displacements due to live load.

Service bearings are located at the level of the roof of the machinery housing. These bearings carry dead load, live load, wind, and seismic loads directly to the walls of the machinery housing when the bridge is in the closed position. There are 16 bearings for each leaf equally spaced around a 10.7 m (35 feet) diameter circle. Each bearing is a reinforced elastomeric bearing attached to the supertstructure and bears against a steel ring on the machinery housing. This steel ring is machined so as to be a true plane perpendicular to the axis of the pivot shaft. Thus the movable leaf may be lowered to the service bearings at any point on the swing arc.

The operating time to open or close the bridge (exclusive of setting traffic lights, gates and clearing the bridge of traffic) is 120 seconds.

Vertical stability in the open position is maintained by two sets of guide bearings, one at the roof level of the machinery housing and one at the machinery floor level. These bearings have bronze bearing surfaces backed by a reinforced elastomer and a wedge pair for fine adjustment. There are 8 bearings at each level. The bearings bear against turned bearing rings on the pivot shaft.

Rotational torque is applied to the pivot shaft by a pair of push-pull slewing cylinders. Each cylinder is 560 mm (22 inch) diameter bore by 2.13 m (84 inch) stroke and has a 254 mm (10 inch) diameter rod. A single cylinder is capable of operating the bridge at half speed (i.e., 2 times normal operating time). Operating pressures under normal conditions are based on 6.9 MPa (1000 psi).

Lifting of the leaf is accomplished by a lift piston which operates between the bottom of the pivot shaft and a pedestal on the footing. These pistons are 2.74 m (108 inches) in diameter with a normal 25 mm (1 inch) stroke, but with the ability of a total 127 mm (5 inch) stroke for maintenance. Operating pressure for the normal lift is 11.7 MPa (1700 psi).

Hydraulic power for lifting and slewing is provided by three variable flow hydraulic pumps in each machinery housing. Flow rate at normal operating pressure is 7.7 liters per second (122 gpm) in each pump. Normally two of the three pumps are used on an alternating basis with the third pump as a back-up. Dual hydraulic connections are provided to each cylinder for redundancy. The pumps are powered by direct connected 75 kW (100 horse-power) electric motors. A standby diesel driven generator set is provided in each pivot pier with sufficient power for reduced speed operation in the event of a power failure.

The project owner is the City of Seattle with funding assistance to be provided by the Port of Seattle. Design consultants are the West Seattle Bridge 2 Design Team, a joint venture of Andersen-Bjornstad-Kane-Jacobs, Inc., Parsons Brinckerhoff Quade & Douglas, Inc., and Tudor Engineering Company. Contech Consultants assisted in development of the superstructure design. Construction of the project is scheduled for Autumn of 1985.