Rebound of the bascule bridge
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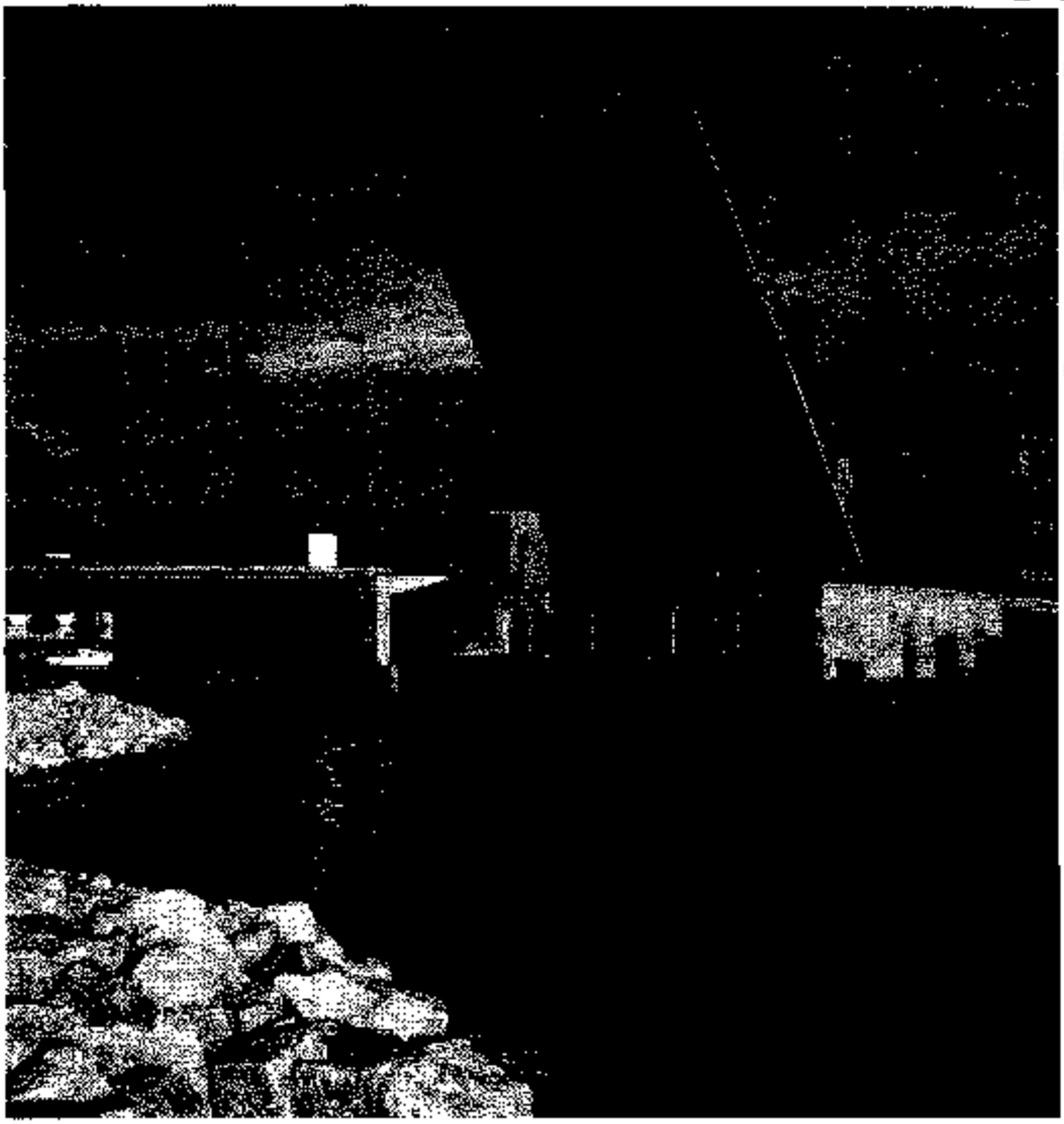

A patented bascule bridge in Sheboygan, Wis. demonstrates design innovations that reduce the cost of bascule construction and minimize maintenance problems.

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The new $7.5 million South Eighth Street Bridge spanning the Sheboygan River in Wisconsin may resemble existing bascule bridges, but it represents a significant departure from traditional bascule design.

The single-leaf, unbalanced bascule bridge incorporates three new design features: a noncounterweighted design, a concrete roadway deck slab and a single structural framing system. These improvements address long-standing cost and durability issues surrounding bascule bridges. The result is a structure that is less expensive than a conventional bascule bridge and nearly as durable as modern fixed bridges.

Designed by Teng & Associates, Inc., Chicago, the bridge is the first unbalanced bascule bridge of this size built in the U.S. and the first operable bascule bridge in the world with a conventionally reinforced concrete deck. The design received the "Most Innovative Structure" award for 1996 from the Structural Engineers Association of Illinois and a national award from the American Consulting Engineers Council.

The new bridge, designed and built under the direction of Wisconsin departments of transportation and natural resources, and

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construction

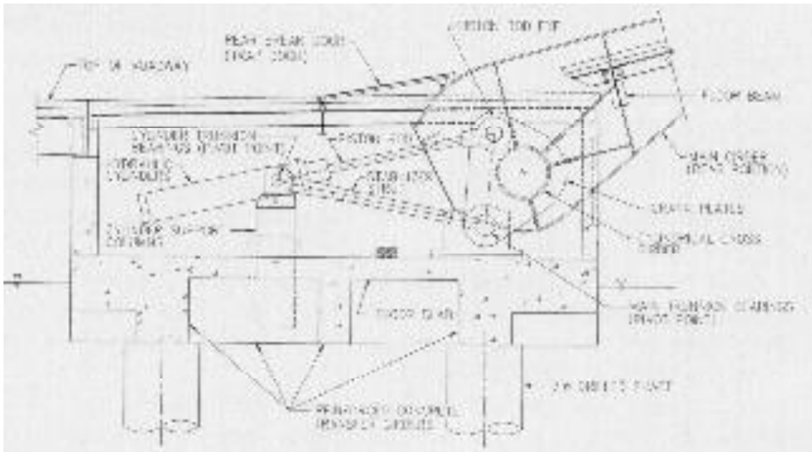

Diagram of the drive mechanism (left). The new bridge's crank plates are shown below.

the city of Sheboygan, and funded in part by the Federal Highway Administration, is the third structure at its location. It replaces a double-leaf balanced bascule bridge built in 1922, which replaced an 1892 swing bridge.

BASCULE PROBLEMS SOLVED

The problems associated with current bascule bridge technology discourage construction of new bridges of this type. Owners of bascule bridges avoid replacing their structures because of high replacement costs and poor maintenance histories.

The city of Chicago has 38 operational bascule bridges with an average age of 63 years. The last new bascule bridges to be built in Chicago were the Columbus Drive Bridge, built in 1982 for $33 million, and the Randolph Street Bridge, built in 1984 for $18 million. The Michigan Avenue Bridge, over the Chicago River, was built in 1920 for $1.8 million and was rehabilitated in 1993 at a cost of $24 million.

Clearly, a demand for new bascule bridges exists. Given the age and replacement costs of the existing bascule bridges, owners will soon be faced with the investment of billions of dollars for bascule bridge rehabilitation and replacement.

NEW BRIDGE

The South Eighth Street Bridge is 68 ft wide and accommodates four 12 ft traffic lanes and two sidewalks. The main bascule span is 90.5 ft from the centerline of the trunnions to the centerline of the bearings at the tip of the main girders. There are approach spans on each side of the bascule span. A main pier supports the pivoted end of the bascule span and houses the drive machinery. The main pier also supports the operator's house. Abutments are founded on steel piling, and piers are supported on reinforced-concrete drilled shafts.

When fully raised, the bridge provides a clear navigational channel that is 75 ft wide. By raising the vertical profile of South Eighth St., we increased the vertical clearance under the bridge in the closed position from 7.5 ft to 13.3 ft, reducing lift frequency.

The bridge is operated through a custom-designed, custom-manufactured computer control system that operates traffic-warning gates and activates the fluid-power system that lifts the bascule leaf. The system includes a data-acquisition feature that logs operating parameters for better maintenance.

Separate electrical services at both ends of the bridge eliminate the need for an underwater cable. Each end of the bridge has an independent power supply.

The movable leaf is mounted on four main trunnions and is raised and lowered by four hydraulic cylinders and pistons powered by eight 150 hp electric motors and hydraulic pumps. The bridge can be operated at reduced speed, for economical or maintenance purposes, using two, four or six motors. The typical time to raise or lower the bridge with all eight motors in operation is 115 s. The Oilgear Co., Milwaukee, performed the detailed design and fabrication of the fluid power and computer control systems.

The designers paid particular attention to the bridge's aesthetics to ensure harmony between the new bridge and adjacent waterfront development and streetscaping projects. All structural steel was painted "Sheboygan blue" to match the city's standard paint color. Ornamental lighting, stainless-steel handrailing, architectural treatment of the operator's house and an extension of the riverfront walkway add aesthetic character to the bridge structure, making it a major element in the overall revitalization plan for downtown Sheboygan and the riverfront.

DESIGN CHALLENGES

Most existing bascule bridges in the U.S. were built in the early 1900s. With the exception of the transition from gear-driven mechanical systems to hydraulic drive systems, designs have advanced little since then.

Most bascule bridges have steel grating or steel plate decks on the span. A steel deck is lighter than a concrete deck and is less susceptible to stress while raising and lowering the bridge, but it has major drawbacks.

Steel grating allows salt-laden drippings from vehicles and adjacent sidewalks to pass through the roadway deck, damaging the land and water below and accelerating corrosion and deterioration of structural elements. Concrete-filled steel grating eliminates the weight benefit of grating, and such decks tend to lengthen due to water infiltration at the steel-concrete interface, causing expansion joint problems.

Steel plate or orthotropic roadway decks, widely used in the 1970s, proved to be extremely labor intensive because they required the installation of extensive structural stiffeners under the plate. Moreover, steel plate decks require the bonding of costly and troublesome wearing surfaces.

In traditional bascule bridge designs, a large pit is excavated below the roadway to accommodate the counterweight as it swings downward when the bridge is raised. The pit is below water level, and requires expensive cofferdam construction.

The Sheboygan bridge design eliminated the need for the pit and the counterweight by using large-scale hydraulic and electrical systems developed for industrial applications. GMP Consulting, Kansas City, Mo., designed the fluid-power system.

In the Sheboygan bridge with all four pistons active, the maximum force in each piston is on the order of 1,000 kips. The large, higher-capacity machinery compensates for the absence of the traditional counterweights of balanced bascule bridges, resulting in reduced overall life-cycle costs, even when greater electricity costs for bridge operation are factored in.

The new bridge has a cast-in-place concrete deck slab that is heavier than a steel deck, but the weight problem is minimized by the use of lightweight aggregate concrete mix. The slab is conventionally reinforced, allowing for the use of conventional maintenance patching methods on the deck. Most important, the concrete deck protects the underlying structural steel framing from corrosion and deterioration due to salt-laden runoff.

The key to the structural framing system of the new bridge is its massive cylindrical cross girder. This steel girder is 5 ft in diameter and runs across the full width of the bridge under the roadway deck, near the hinged end of the structure. The girder provides a rigid spine on which all other primary structural components are mounted.

The main longitudinal girders, one on each side of the bridge, are steel I-sections of varying depth, fastened rigidly to the cross girder. Also mounted rigidly on the cross girder are four pairs of crank plates, one pair on each side of each longitudinal girder. Each pair of crank plates has a trunnion bearing at the bottom and a piston-rod end bearing at the top. The crank plates support the cylindrical cross girder and, when acted on by the pistons, impart torque to the girder to lift the bridge.

The inherent rigidity of the cylindrical cross girder holds all of the bearings in proper alignment, regardless of the flexibility of the longitudinal girders and other superstructure components. Since no bearings are mounted on the longitudinal girders, they do not need special stiffening; I-section girders can be used because the greater torsional and lateral stiffness of a box section is not required.

The low torsional stiffness of the I-sections simplifies floor framing connections by permitting the longitudinal girders to twist freely as the floor beams deflect under load, without inducing the secondary end moments that have caused problems in other bridges. The I-sections are also far more economical to fabricate and are more convenient to inspect, maintain and paint.

The longitudinal girders are 52 ft apart. The roadway floor beams, about 15 ft apart, span between longitudinal girders. Longitudinal stringers, about 4 ft apart, span between the floor beams and support the 9 in. concrete deck. The floor beams are welded plate girders, and the stringers are rolled wide-flange sections. Shear studs allow the floor beams and stringers to act as composite members with the concrete deck slab. Brackets cantilevered on the outside of the longitudinal girders, opposite the floor beams, support the precast concrete sidewalks. Lateral bracing completes the framing system. PDM Bridge, Eau Claire, Wis., fabricated structural steel for the project.

HANDLING STRESSES

We analyzed the structure using the GT STRUDL program. The three-dimensional finite element model we developed helped us to determine the stresses in the main girders, cylindrical cross girder, crank plates and corresponding connections under various loading conditions with the bridge in different positions.

Cantilever action of the main girders just after liftoff controlled the sizes of the webs and flanges in the rear half of the girder. Dead- and live-load forces in the down position controlled the sizes of the flanges and webs in the front half.

The crank plates, hydraulic cylinders and stabilizer struts (which extend from the cylinder support bearings to the trunnion bearings) form the legs of a triangle that internally resolves the primarily horizontal load applied by the hydraulic cylinders into a vertical couple. As a result, the cylinder-support columns and trunnion supports resist only the vertical reactions produced by the weight of the cantilevered bascule leaf.

The floor of the main pier incorporates large reinforced-concrete girders that transfer forces from the main trunnion bearings and the steel columns anchoring the hydraulic cylinders outward to the four main drilled shafts, which transmit the loads down to bedrock about 35 ft below the bottom of the girders. The drilled shafts behave as laterally unsupported concrete columns that are restrained from rotation at the top by the girders and restrained from rotation and translation at the base by the rock.

CONSTRUCTION

The bridge is built on an EPA Superfund site. One of our main concerns about construction activities was the possibility of resuspension and transport of PCB-contaminated sediments in the riverbed. We worked with the contractor and with our environmental engineering consultant, EMI, Inc., Madison, Wis., to minimize channel excavation and disturbance, to reduce the amount of special waste material handled and treated, and to limit the environmental impact.

To control the downstream transport of resuspended sediment, the contractor, Lunda Construction, Black River Falls, Wis., constructed cofferdams around existing substructures and new drilling sites. In addition, the contractor suspended silt curtains from flotation devices around the perimeter of the cofferdams to trap sediment that passed through the cofferdams.

If we had designed a typical balanced bascule bridge for this site, construction of the pit to accommodate the counterweight system would have required excavation in the riverbed and much greater environmental-protection measures.

The Sheboygan bridge demonstrates that innovation in bridge engineering is not necessarily a risk. The project was completed on schedule in September 1995, 18 months after the start of construction, with a total cost of change orders at less than 1% of the original awarded bid price. ▼

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