A Record Size Bascule

Outer Drive crossing of Chicago River is a double leaf structure, 264 ft. between trunnions and 108 ft. wide, designed for double-deck service

FIG. 1—TEST OPERATION of the double-leaf bascule on the new Outer Drive link in Chicago. The tower framing at the four corners will be enclosed in limestone to form decorative pylons, which will also contain the operators' houses.

THE KEY STRUCTURE of the Outer Drive link that is being built in Chicago to join the south and north side lakefront boulevard systems is a double-leaf bascule over the mouth of the Chicago River. If a lower deck, for which provision has been made in the design, is added at some future time, each leaf will weigh 6,240 tons and be heavier than any bascule now in existence. As initially built, with only an upper deck, the leaf weight is 4,364 tons, which is less than the double-deck Michigan Ave. bridge upstream from it. At the same time the Outer Drive Bridge is 108 ft. wide and 264 ft. long between trunnions, which causes it to rival, if not exceed in these respects, any bascule bridge in the world. In both its design and construction it is a notable structure.

The general features of the Outer Drive link and its importance in helping to solve Chicago's traffic problem were outlined by Hugh E. Young, chief engineer of the Chicago Plan Commission in *ENR* April 15, 1936, p. 546. It will be recalled that it provides a long-planned connection between the south side lakefront boulevards which terminate in Grant Park and the north side boulevards that traverse Lincoln Park, and which now are joined only by the Michigan Ave. bridge. On the south side of the river a steel viaduct, 2500 ft. long, serves as an approach to the bascule, and in addition there is a 1500 ft. viaduct connection to Michigan Ave. along Randolph St. The north side approach is also viaduct, 1200 ft. long, supplemented by a 100-ft. single-leaf bascule over the Michigan Canal. These viaducts are 140 ft. wide, and provide a 100-ft. roadway and wide sidewalks. Some of the interesting phases of this approach work, such as the special methods used in sinking the circular piers 85 to 100 ft. to rock and the design and construction of viaducts, which are two-story rigid-frame three-column bents, will be covered in subsequent articles.

The history of the bascule bridge dates back to July 25, 1929, when a contract was let for its design to the Strauss Engineering Corp. Foundations were built and the steel fabricated before the depression caused the work to be shut down. In 1935, work was begun on the delayed erection contract, and the bridge is now practically complete, furnishing two 38-ft. roadways and two 24-ft. sidewalks. The navigation clearance in closed position is 24 ft., and the clear span between counterweight pits is 220 ft.

The Outer Drive Bridge is of the so-called fixed-counterweight type. Each leaf consists of four parallel trusses, 28½ ft. on centers, located entirely below the upper-level roadway. Each truss (Fig. 2) is made up of 7 panels, 15 ft. 10 in. in length, and one panel adjacent to the trunnion of 18 ft. 2 in. Behind the trunnion are three panels of irregular length which support the counterweights beneath the deck. The upper deck floorbeams, built-up members 32 in. deep, connect the trusses at the panel points along the upper chord. Stringers spanning between the floorbeams, with upper flanges flush, are spaced 2 ft. 8½ in. apart. The trusses are held rigid by an upper and lower lateral bracing system. The deck is made up of steel-grid units filled with light-weight concrete and welded to the deck framing.

Each of the four trusses of a leaf is supported on a steel shaft, operating in a pair of trunnion bearings. These in turn are carried on two 80-ton cross girders spanning between pedestals on the walls of the counterweight pit and steel columns under the inside trusses (Fig. 4). Each column extends through the pit floor to a bearing on an 11-ft. diameter caisson, while a 12-ft. diameter caisson is used beneath each sidewall under the pedestals. Silicon steel is used for the trusses, the supporting cross girders and the trunnion posts. The floor system is carbon steel.

Foundations

The counterweight pits themselves are structures of considerable magnitude, and their location in 25 ft. of water complicated design and construction. Each pit (Figs. 2 and 5) is a concrete box 104½ x 68 ft. and 40 ft.

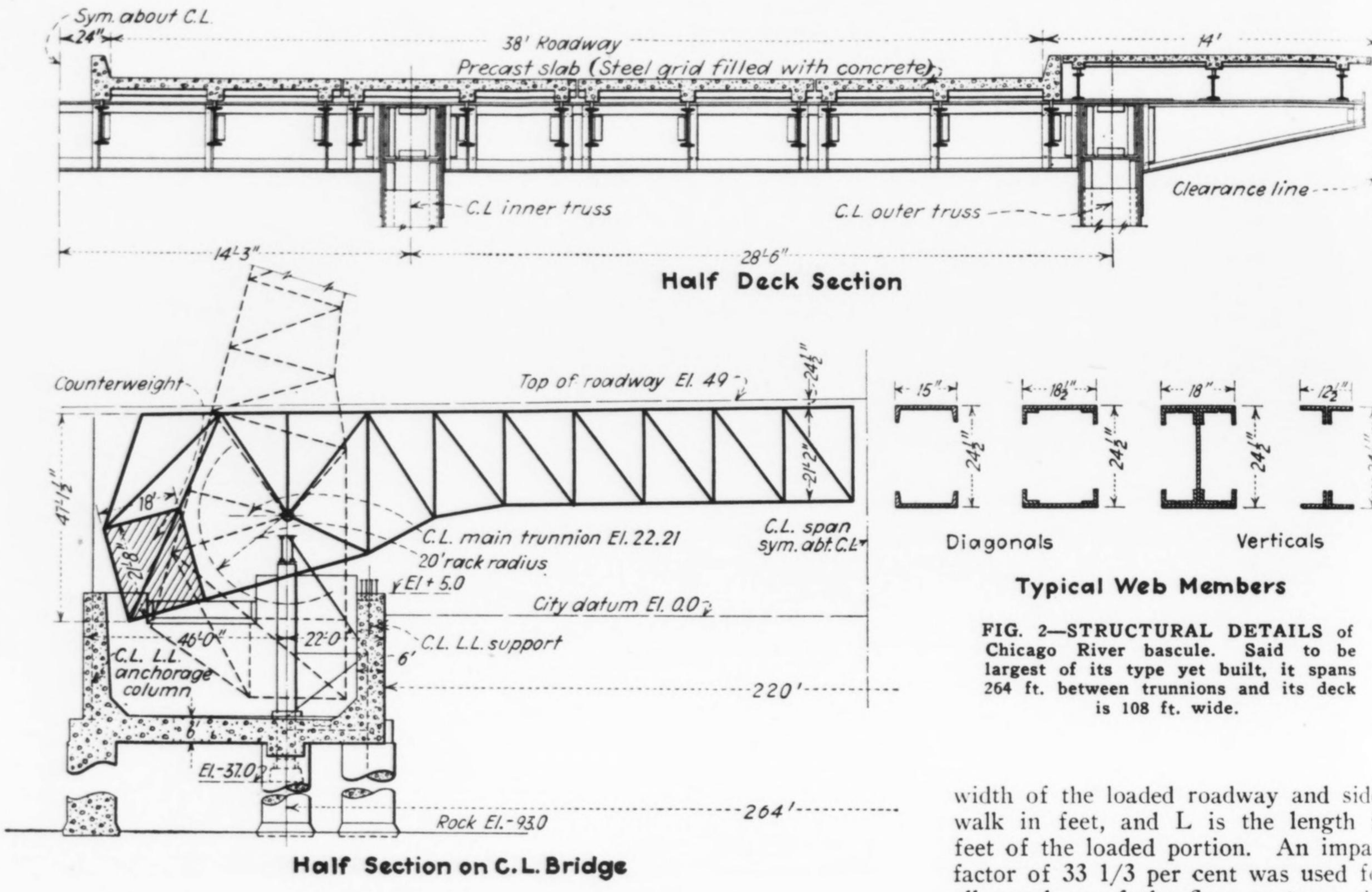

FIG. 2—STRUCTURAL DETAILS of Chicago River bascule. Said to be largest of its type yet built, it spans 264 ft. between trunnions and its deck is 108 ft. wide.

deep, supported by three circular piers along its back edge and by four circular piers along its front edge. In addition the four piers, which are set 22 ft. shoreward of the front face of the pit and serve as foundations for the trunnion girders, also aid in supporting the box. The piers range in diameter from 4½ to 12 ft. and are founded on rock at depths of 60 to 70 ft. below the bottom of the pits.

The several parts of the counterweight pit are designed for a variety of conditions of horizontal and vertical loading. Thus, the river wall is designed to resist full hydrostatic head on the river side and a 560,000 lb. collision load from a boat. Full hydrostatic head on the inside of the wall only was also considered for conditions during construction. The several combinations of vertical loads include buoyancy on the pit floor.

The river wall was designed both as a continuous beam over four supports and as a vertical cantilever beam for bending due to horizontal loads. Similar design was used for the rear wall (except that it is continuous over three instead of four supports). The side walls were designed as beams with ends fixed at the river and rear walls, as beams continuous over three supports and as vertical cantilevers fixed at the pit floor. The pit floor was designed as a slab continuous over three supports—the river wall, the transverse girder on the centerline of the main trunnion sub-piers and the rear wall. The sub-piers were designed as fixed in the clay at El. —58.5 and at the floor. For load combinations including wind and also water inside of the pit, 25 per cent increase in the unit stresses was allowed, while for the load combination including boat collision, the increase was 50 per cent. The allowable unit stresses were 16,000 lb. per sq.in. for steel and 750 lb. per sq.in. for concrete ($n = 15$).

The counterweight pit and its supporting piers were built in an open cofferdam of single-wall type made of deep-arch, interlocking steel sheetpiles, and with internal timber bracing supported vertically by timber piles as well as by vertical and diagonal bracing between the various tiers. The concrete pit floor, involving 1500 cu.yd. of concrete, was placed in a single continuous operation covering 68 hr.

Bascule bridge design

In designing the bascule leaves the dead loads considered included a lightweight slab on the upper roadway and sidewalk deck, and timber roadway and sidewalks on the future lower level. Live loads used in the design were 125 lb. per sq.ft. on all roadway areas; 100 lb. per sq.ft. on all sidewalk areas; 4000 lb. per lin. ft. of street car track on the lower deck; a concentrated load of two 24-ton trucks abreast for the upper deck; a 50-ton trailer truck as an alternate to the two 24-ton trucks on the lower deck roadway in the center and west bays and a 105-ton rail car in the east bay.

The impact coefficient for the trusses was determined by the formula $100 \div (NL + 300)$ where N is 1/10 the width of the loaded roadway and sidewalk in feet, and L is the length in feet of the loaded portion. An impact factor of 33 1/3 per cent was used for all members of the floor system, with the following exceptions made when the wheels are at the roadway breaks: railroad stringers, 100 per cent; roadway stringers, 75 per cent; floorbeams 50 per cent.

In addition to the above dead and live loads, vibration and lateral and longitudinal forces were considered. To provide for the effects of vibration when the bridge is open, the stresses in the members due to the dead loads of the movable leaf were increased 20 per cent; the masonry substructure and the members completely imbedded in it were not subject to this provision. The lateral force was assumed to result from a moving uniform load of 150 lb. per lin. ft. applied at the floor level, plus a moving load of 25 lb. per sq.ft. on the full vertical projection of the floor and one truss, and on 50 per cent of the vertical projection of the three remaining trusses; or an alternate concentrated load of 240,000 lb. applied at the second panel point forward of the river pier bearing. With the bridge open, a longitudinal wind force of 20 lb. per sq.ft. on the vertical projection of the exposed area was considered. With the bridge closed, a longitudinal traction force was used consisting of 10 per cent of the live load on the structure, taken as acting at 4 ft. above the floor.

In the design of the trusses, upper and lower deck loads were considered simultaneous, and both outside trusses were made alike and both inside trusses made alike, despite the disparity in loads. The truss reactions were determined for five different conditions of loading: dead

Chicago Aerial Survey Photo

FIG. 3—KEY STRUCTURE in the Outer Drive improvement is the bridge over the mouth of the Chicago River. In the foreground of this air view the filled approach rises from Grant Park to the Field Blvd. viaduct which connects at the riverbank with the Wacker Drive viaduct at right angles to it. North of the river is the Michigan Canal crossed by a single-leaf bascule and then the viaduct cuts through an existing building. In the left foreground the Randolph St. viaduct provides a connection with Michigan Ave.

loads only, bridge closed; live loads only, bridge closed; dead and live loads, bridge closed; dead load, bridge open; and wind load, bridge open. Design stresses in the trusses due to these several loading conditions were then determined for the bridge in both the open and closed positions. The maximum stress in the closed position was determined by a combination of dead load, live load, impact and reversal; in the open position, by combining dead load, vibration, wind, and reversal. Where wind was considered, the allowable stresses were increased 25 per cent. The fact that the maximum stress in a member may occur at any point of partial opening of the bridge was also taken into account in the design. In the specifications "Reversal" is covered by the following:

Whenever the live and dead load stresses are of opposite sign, only two-thirds of the dead load stress is considered to be effective in counteracting the live load stress. When reversal occurs during the passage of loads, the net tensile and compressive stresses are determined in accordance with the above provisions. Each of these, then, is increased by 50 per cent of the smaller. When reversal occurs during the operation of the bridge, 25 per cent is used instead of 50 per cent. Connections in all cases are proportioned for the sum of the net tensile and compressive stresses.

Machinery for bridge operation

The operating equipment for the Outer Drive bascule is in keeping with the size and importance of the structure. Safety and dependability were first considerations, and brakes, locks and current supply were planned with these objectives in mind. Direct current at 550 volts for bridge operation will be supplied from the cables feeding the Michigan Ave. bridge upstream. Submarine cables will be installed to connect the two ends of the bridge. Alternating current for street lighting will come from two separate sources. Operators will be stationed in stone-faced bridge houses, 24 x 28 ft. in plan, located at each corner of the bridge.

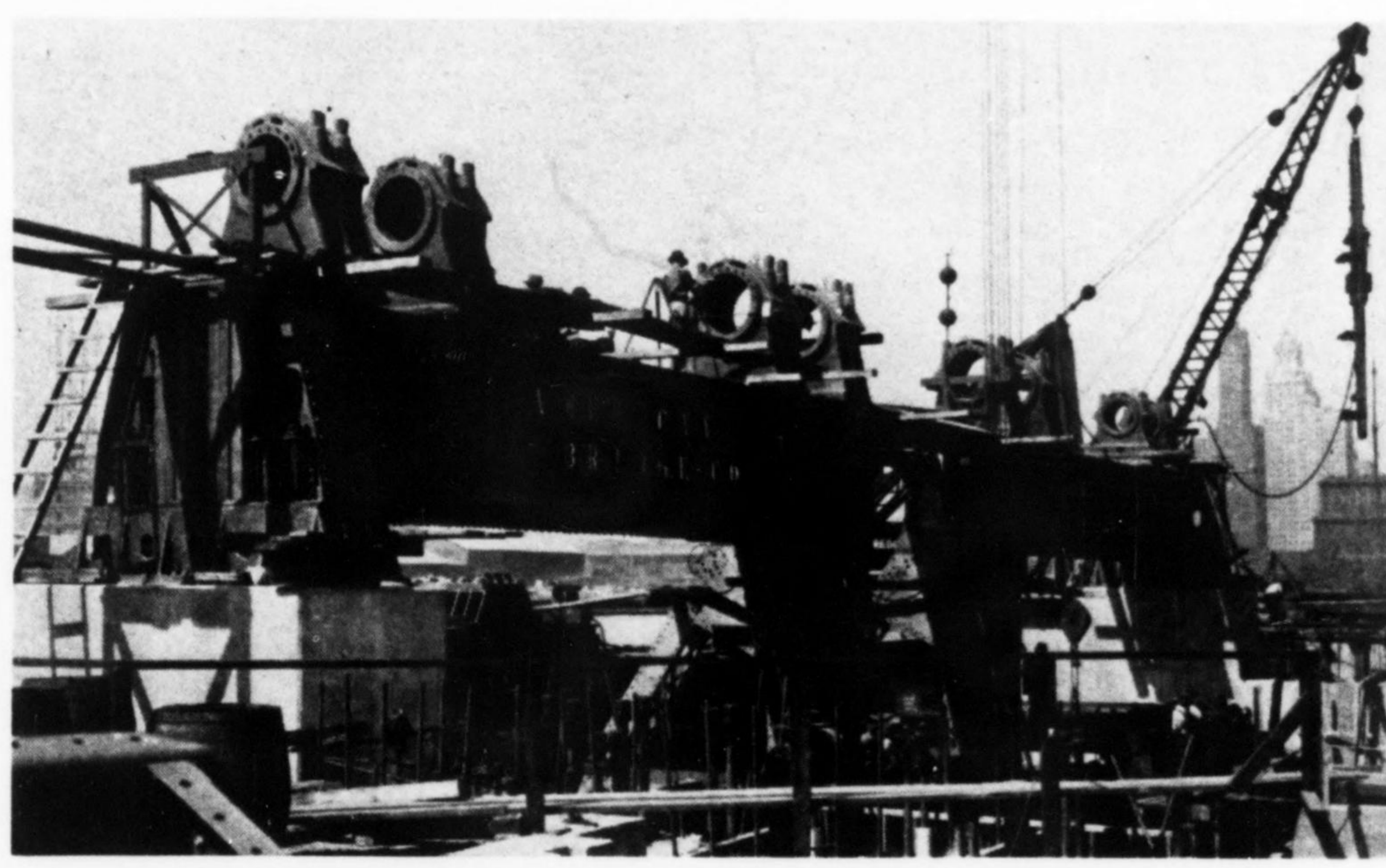

FIG. 4—SETTING TRUNNION BEARINGS for one of the bascule leaves. The two trunnion girders each weigh 80 tons and span between the walls of the counterweight pit and columns under the inside trusses.

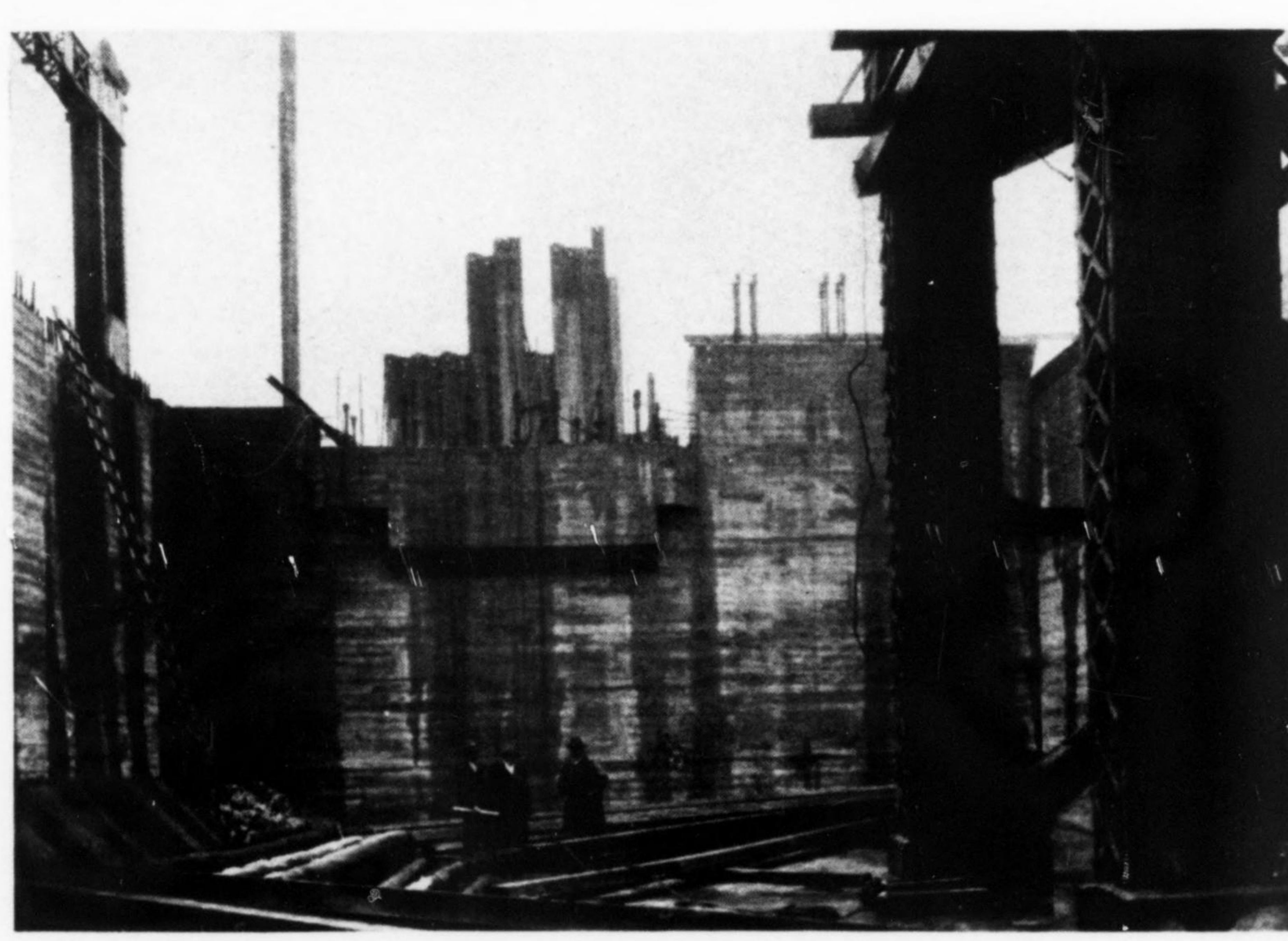

FIG. 5—HUGE PIT for south counterweight of Chicago River bascule. It is supported on eleven circular piers and, being located offshore, is designed against full hydrostatic head and uplift.

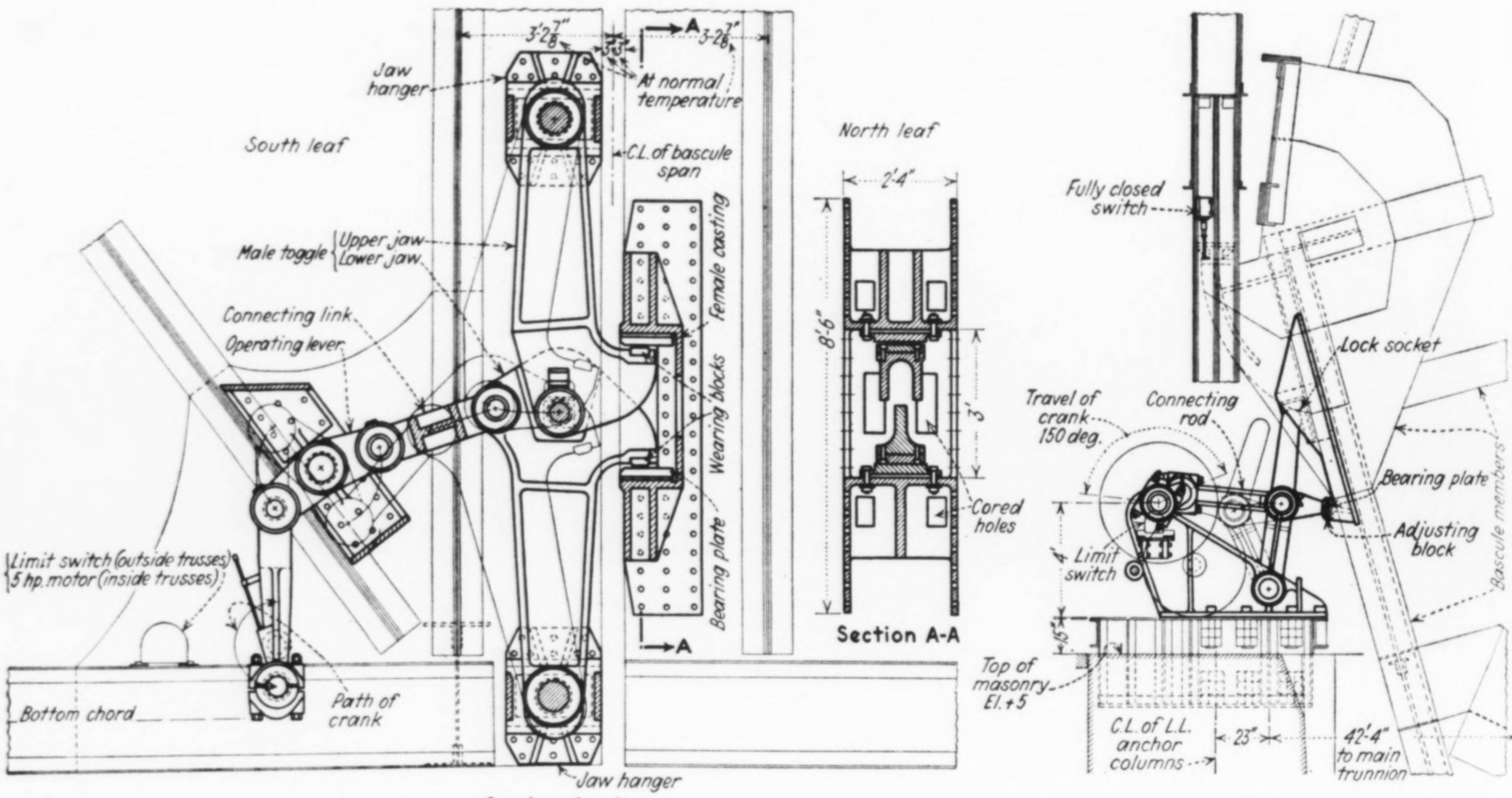

FIG. 6—LOCK DETAILS used at the center and rear of the leaves of the Outer Drive bascule.

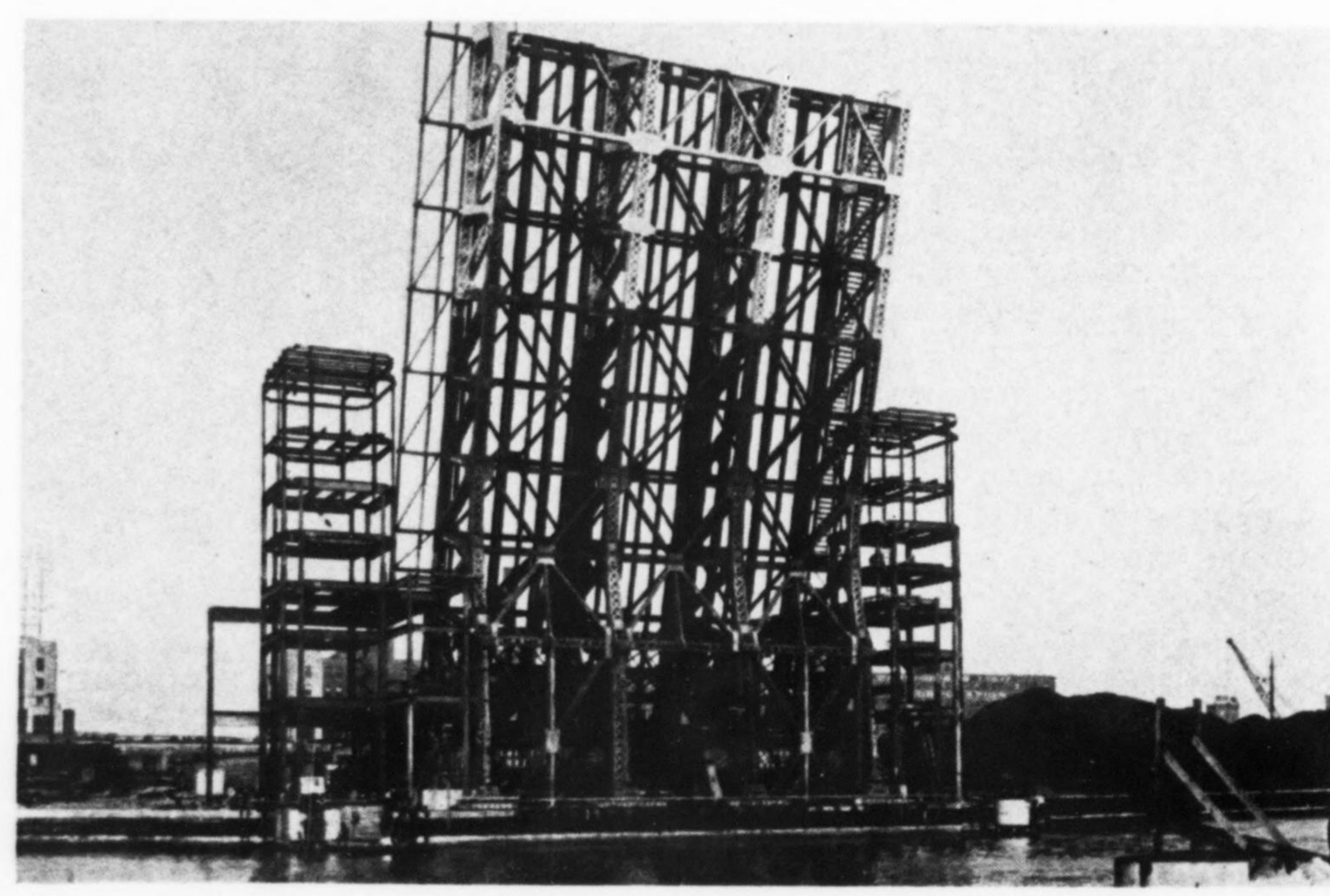

FIG. 7—PAINTING A LEAF of the Outer bascule following the topping-out of the steel which was erected with the leaf in the open position.

Each leaf is to be operated by two sets of gear trains, consisting of four sets of gear reductions. Each gear train is connected to two 100-hp. main operating motors, only one of which is to be used at a time. The time required for opening or closing the bridge against a 28-m.p.h. wind is stated to be 57.6 sec., of which 10 sec. is for acceleration and 2.86 sec. for deceleration. The main operating racks are bolted to the underside of the outside trusses, the pitch radius being 20 ft. The operating pinion, with a pitch diameter of 40 in., is mounted on a shaft of the gear train.

The four trunnions are of drop-forged steel and have a 10-in. dia. hole bored the entire length. The inside trunnions are 34 in. in diameter at the bearings and carry a load of 4,411,000 lb. each, of which 3,673,000 lb. is dead load, 734,000 lb. is vibration or impact (20 per cent of the dead load) and 185,000 lb. is the load from a 20-lb. wind. The unit stress is 11,100 lb. per sq.in. under combined load. The outside trunnions, 27½ in. in dia., carry a load of 3,337,000 lb., and are subjected to a unit stress of 15,800 lb. per sq.in.

Heavy locking devices are provided at the center of the bridge and at the heel of each leaf, to hold the bridge rigid in its closed position (Fig. 6). The center lock in addition to holding the leaves together in their closed position, also transmits live load shear from one leaf to the other. This center lock consists of a set of four female castings bolted to the river end of one leaf, and a second set of four male units bolted to the river end of the other leaf, all castings being on the centerlines of the trusses. The male unit consists of two castings forming a toggle. Fingers, cast integral with the toggle castings at the center, engage the female casting and, since the loads are on dead center, the device is self-locking. The four male units are connected by shafting, and are operated by 5-hp. motors set on the bottom chords of the inner trusses.

Heel or rear locks are necessary to prevent the leaves from opening when live loads pass over the part of the bridge between the trunnions and the rear break in the floor. Each leaf is provided with two pairs of rear locks, each pair being placed between the inside and outside trusses. The four locks of a leaf are connected by shafting, and operation is by means of two 15-hp. motors set either side of the centerline of the bridge.

Erecting the bascule

Interest in the erection operations on the Chicago River bascule span centers principally in the equipment layout used by the contractor, Ketler-Elliott Co. Each leaf was assembled in its open position, so that the erection operations on each side of the river were entirely separate. Main items of equipment for each set-up were an unusually heavy and long-boom stiffleg derrick and an

FIG. 8—THE LIGHT WEIGHT DECK is made up of steel grid units filled with concrete at a nearby plant and welded to the floorbeams and stringers.

electrically-operated concrete mixer. In addition a derrick on a reinforced concrete scow was used to transfer materials and equipment across the river, while on either side a 50-ton locomotive crane was used to unload material and move it within reach of the stiff-legs. The compressor—a 300-cu.ft. unit driven by a 75-hp. motor—was located on the south side of the river, and connected with north side operations by submarine cables.

The stifflegs used were among the largest in the Chicago region. Reeved with 7/8-in cable, they were required to lift loads as heavy as 80 tons, which is the weight of each of the four trunnion girders. The boom lengths were varied from 80 to 160 ft. during the progress of the work. Both derricks were supported on piling, that for the south derrick being originally located in 30 ft. of water. This derrick was anchored against uplift by lashing it to the piling while the north derrick was held down by precast concrete blocks later used to adjust the bridge counterweights.

As steel erection progressed, the counterweight was poured to maintain balance. Two types of concrete were used, one a conventional product weighing 143 to 150 lb. per cu.ft. and the other a mixture of plain concrete and steel punchings weighing 225 lb. per cu.ft. All material going into the mixers was carefully weighed.

After the leaves were topped out, they were lowered, in order that the deck units—steel grids filled with concrete—could be set by the derrick scow. These units were welded to the floor steel. Installation of deck alternated with pouring of additional concrete in the counterweights, to keep the leaves balanced. In the alternating operations an attempt was made to limit the overload to an amount indicated by a 350 amp. reading at 550 volts in operating the leaf.

Personnel

The layout of the Outer Drive Improvement was developed by the Chicago Plan Commission. Subsequently, Hugh E. Young, chief engineer of the Chicago Plan Commission served as consulting engineer for the former Lincoln Park Commissioners on the work north of the Chicago River, and for the South Park Commissioners on the bascule bridge over the river. The initial design work south of the river, except for the Randolph St. viaduct, was carried out under the direction of George T. Donoghue, general superintendent, and Linn White, chief engineer, South Park Commissioners. The bascule bridges and bridge plazas were designed by the Strauss Engineering Corp., Chicago.

The final revision of the plans and the preparation of specifications for the river dock, south approach, Field Blvd. viaduct and the Wacker Drive viaduct, as well as all construction operations that have gone on since 1934 have been under the general direction of George T. Donoghue, general superintendent, Ralph H. Burke, chief engineer, W. I. Bell, asst. general superintendent and Robert A. Black, asst. chief engineer, of the Chicago Park District. The Randolph St. viaduct was designed by the Illinois Central R.R. and the Michigan Central R.R. Frank A. Randall, consulting bridge engineer, is in charge of construction operations in the field for the Chicago Park District. D. R. Kennicott, state director, and G. L. Rounds, state engineer inspector, represent the Public Works Administration on the project.

Folding Ladder Inside Pipe Holds Scaffold for Welders

LARGE STEEL PIPE which has to be welded on the inside while the pipe is in the trench, requires some means for making the seams conveniently accessible to the welder. This problem has been solved on the 11½-ft. distribution system pipes laid by the Metropolitan Water District of Southern California, by the use of folding ladders which open up into semi-circular shape of a diameter just fitting the pipe interior. Planks are laid transverse to the pipe, resting on rungs of opposite sides of the ladder. Thus convenient supports are provided which can be moved horizontally within the limits of the rung length. On these supports the welder can sit or stand as may be best suited to his work.

There are five segments of the ladder connected by hinges and when the planks are lifted off preparatory to moving, the sections are folded up one upon another and in the collapsed condition can be carried ahead conveniently to the next joint. The upright post has nothing to do with the scaffolding; it is a strut which holds the sections in the desired shape at the joint after jacks are used to force the section into circular shape.

A COLLAPSIBLE LADDER serves as a convenient support for welders in an 11½-ft. steel pipe.