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Substructure of Michigan Avenue Bascule Bridge, Chicago

Cylinder Piers Sunk to Rock and Hardpan Carry Large Concrete Tailpits for Double-Deck Bridge—Steel Columns Embedded In the Walls Support Girders for Trunnions and Uplift Anchorage

BY HUGH E. YOUNG AND WILLIAM A. MULCAHEY
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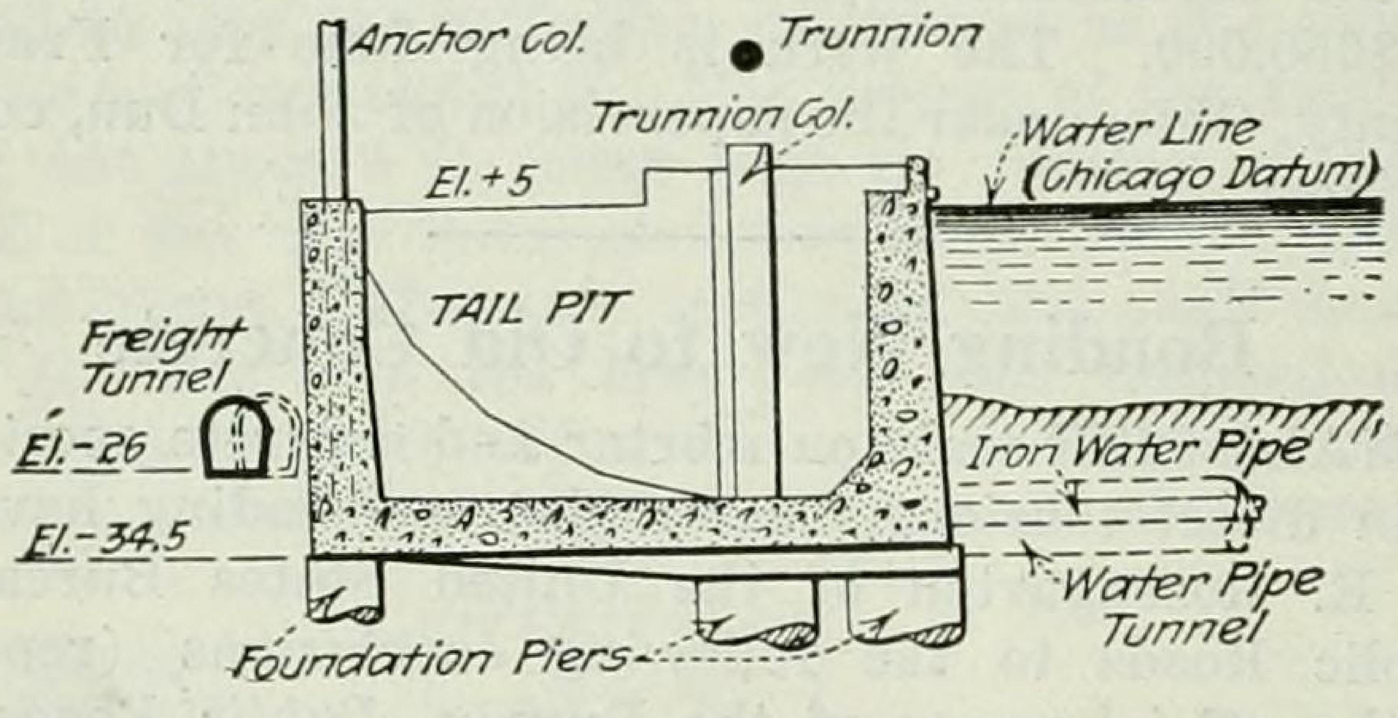
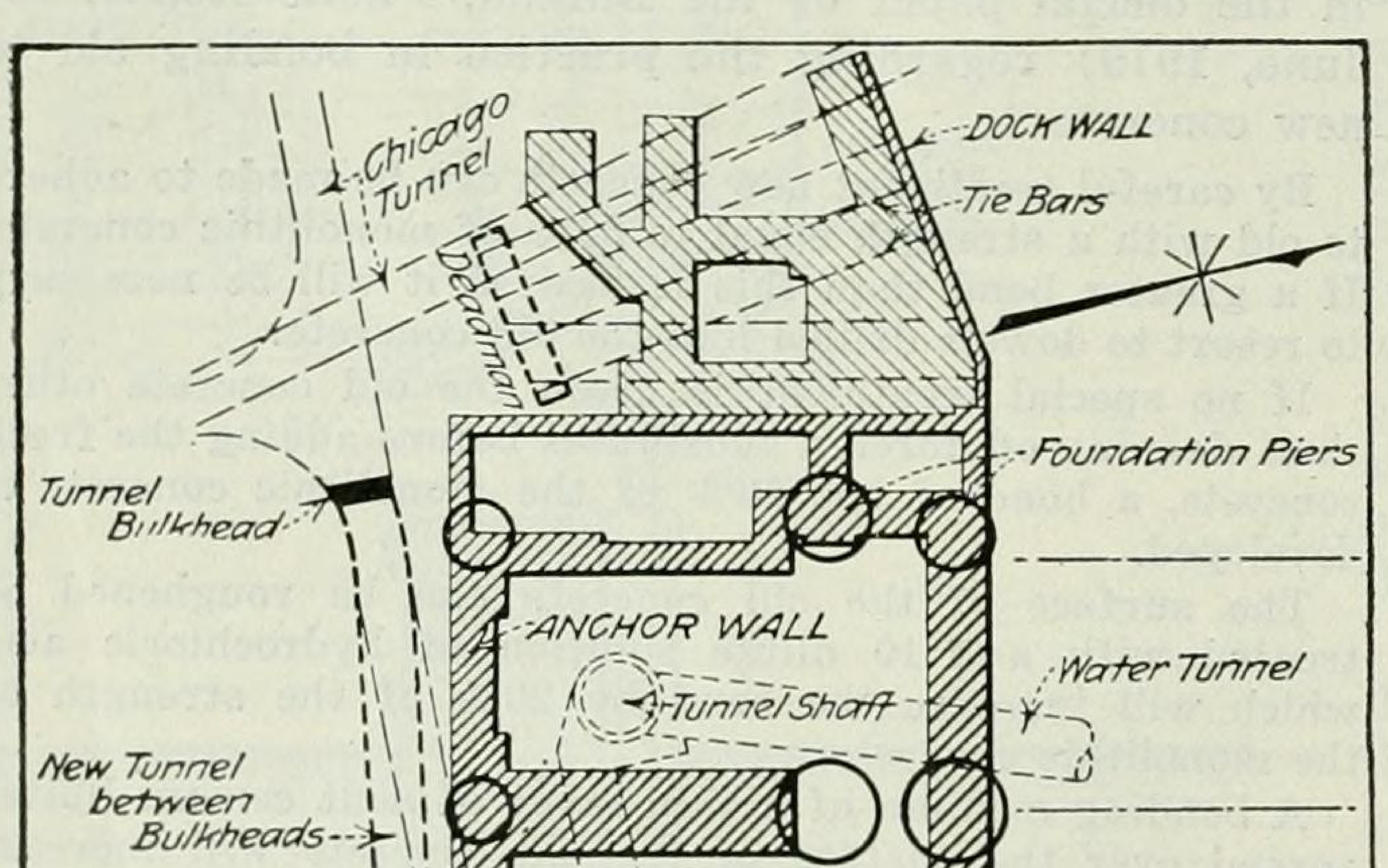
REINFORCED-CONCRETE boxes or tailpits about 95 x 67 ft. in plan over all and 40 ft. deep, with their floors 34½ ft. below water and supported on concrete cylinder piers, form the principal parts of the substructure for the 254-ft. double-deck bascule bridge across the Chicago River at Michigan Ave. Braced cofferdams about 75 x 100 ft. were required, one of these being in 22 ft. of water. Open wells for the piers were sunk after the excavation had been carried down to the floor of the tailpit. Tunnels for water-supply and freight traffic were encountered, and a break in one of these caused the flooding of a cofferdam.

This bridge will be a double-leaf four-truss structure of the trunnion type, with a span of 254 ft. between trunnions and a clear width of 220 ft. between masonry piers. It is a part of the Michigan Ave. improvement to form a new link between the boulevard systems of the north and south sides of the city.

Each pit is a monolithic structure, 52 x 66 ft., inside at the floor level. Its front wall or river pier and its rear wall or anchor pier are each supported on three cylinder piers. In the rear wall are embedded the steel anchor columns carrying girders or floor-beams which serve to take the upward reaction at the bumper blocks due to the live load on the river arm of the bascule leaf.





PLAN OF SUBSTRUCTURE FOR SOUTH PIER SHOWS INTERFERENCE WITH TUNNELS

Transverse beams at the bases of these columns distribute the uplift to the concrete wall. The side walls are supported at their ends by the river and anchor walls and at intermediate points by cylinder piers carrying the girders for the trunnion bearings. At the ends of the side walls are brackets supporting cantilever shelves which form horizontal girders to reinforce the sides against lateral loads. These cantilevers also carry the masonry of the inclosure walls and columns supporting the sidewalks of the two decks on the fixed portion of the bridge.

To carry the trunnion bearings there is a heavy steel cross-girder behind the river wall, its ends resting on the side walls directly above the cylinder piers under these walls. At the center of the girder, where are located the bearings of the two middle trusses, it is supported by a heavy steel column seated on an independent cylinder pier beneath the floor of the pit. This column is braced longitudinally by a steel A-frame which has its toe in the river wall and is incased in concrete.

Of the 18 cylinder piers, nine to each pit, varying from 7½ to 12 ft. in diameter, one is carried to bedrock at a depth of 108 ft. below water line or city datum. This pier is formed with a shallow taper footing. The other piers are carried only to the hardpan, at depths of 80 to 90 ft. below datum. In these the bottoms are belled out for about 6 ft. in height to give a base diameter equal to 1½ times the diameter of the body of the pier. The maximum load per square foot allowed on the base of the footings is 25 tons on rock and eight tons on hardpan.

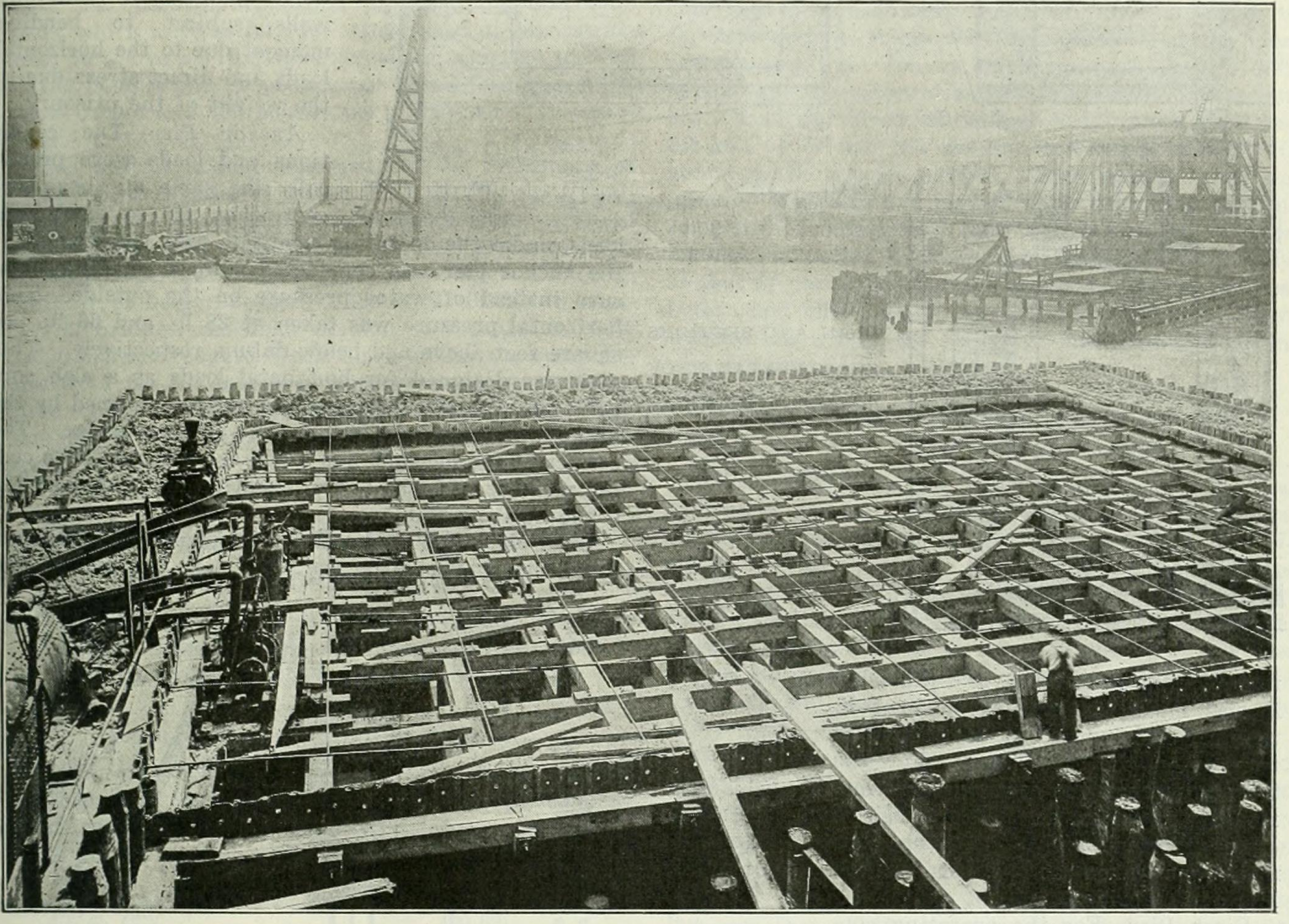
Owing to the great depth to which the tailpit is carried, its base being 34½ ft. below the water line, it was necessary to provide a heavy floor to withstand the upward pressure. This floor is 5 ft. 3 in. thick, including a 6-in. waterproofing course near the middle of its depth. At the center a rib or beam on the underside of the floor-slab is provided to carry part of the floor loads and the reactions developed from lateral loads on the anchor pier.

To provide supports for the rails of the emergency brake system, having toggle-joint brakes which act on the curved heels of the trusses, four concrete walls are built in the pit in line with the ends of the trusses. These are stepped at the top to permit of a good bond with the concrete and grout which will be placed when the brake rails are installed.

A stone concrete of 1:3:5 mix is used throughout, and to all the concrete of the tailpits was added hydrated lime in the proportion of 10 lb. of lime to 94 lb. of cement.

For waterproofing, a 6-in. layer of 1:2 mortar, made of portland cement and fine aggregate, is placed in the floor and on the outside faces of the walls, the thickness being reduced to 4 in. in the upper portion of the latter. This was carried up with the concrete, a 12-in. plate with angles on the inside being placed against the form to insure a uniform thickness of the facing.

The 45-ft. steel column supporting the middle of the trunnion girder is about 51½ x 22½ in. in section, with three 22-in. webs between the 50-in. side plates, as shown in the drawing. This shows also the A-frame brace. Provision is made for placing shim plates at all bearing points of the girder, in order to permit of adjustments in case of any difference in deformation of the sidewalls and the steel column under the dead load of the bridge. As the anchor columns are for tension loads, they are of relatively light construction. Each has two built-up sides of channel section connected by batten plates and lacing. These columns are 60½ ft. long, weighing 10 tons; they were erected complete, requiring a long spliced boom on a floating derrick to lower them vertically through the pockets formed by the bracing of the cofferdam. Between these columns are framed the 52½-in. floor-beams.



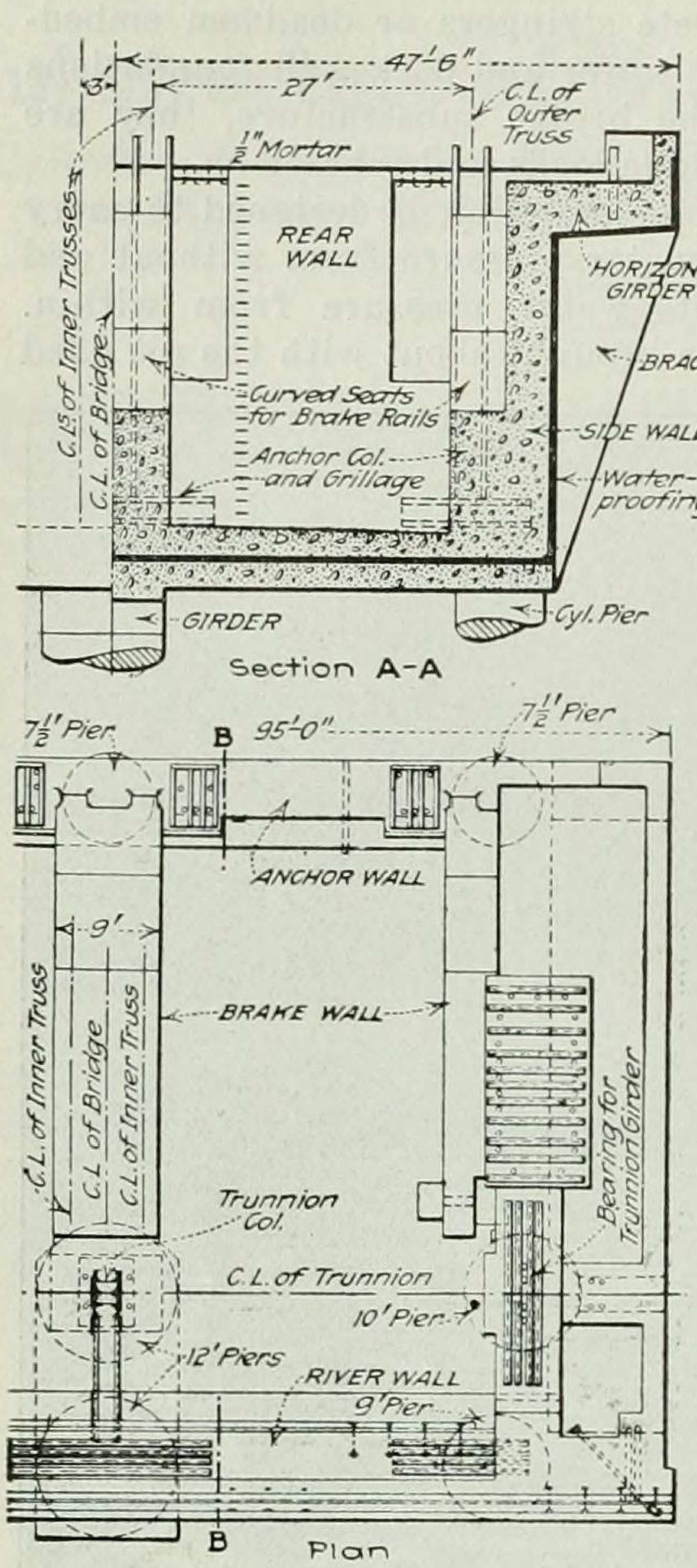
COFFERDAM, 75 X 105 FEET INSIDE, FOR NORTH PIER OF MICHIGAN AVENUE BRIDGE, CHICAGO RIVER

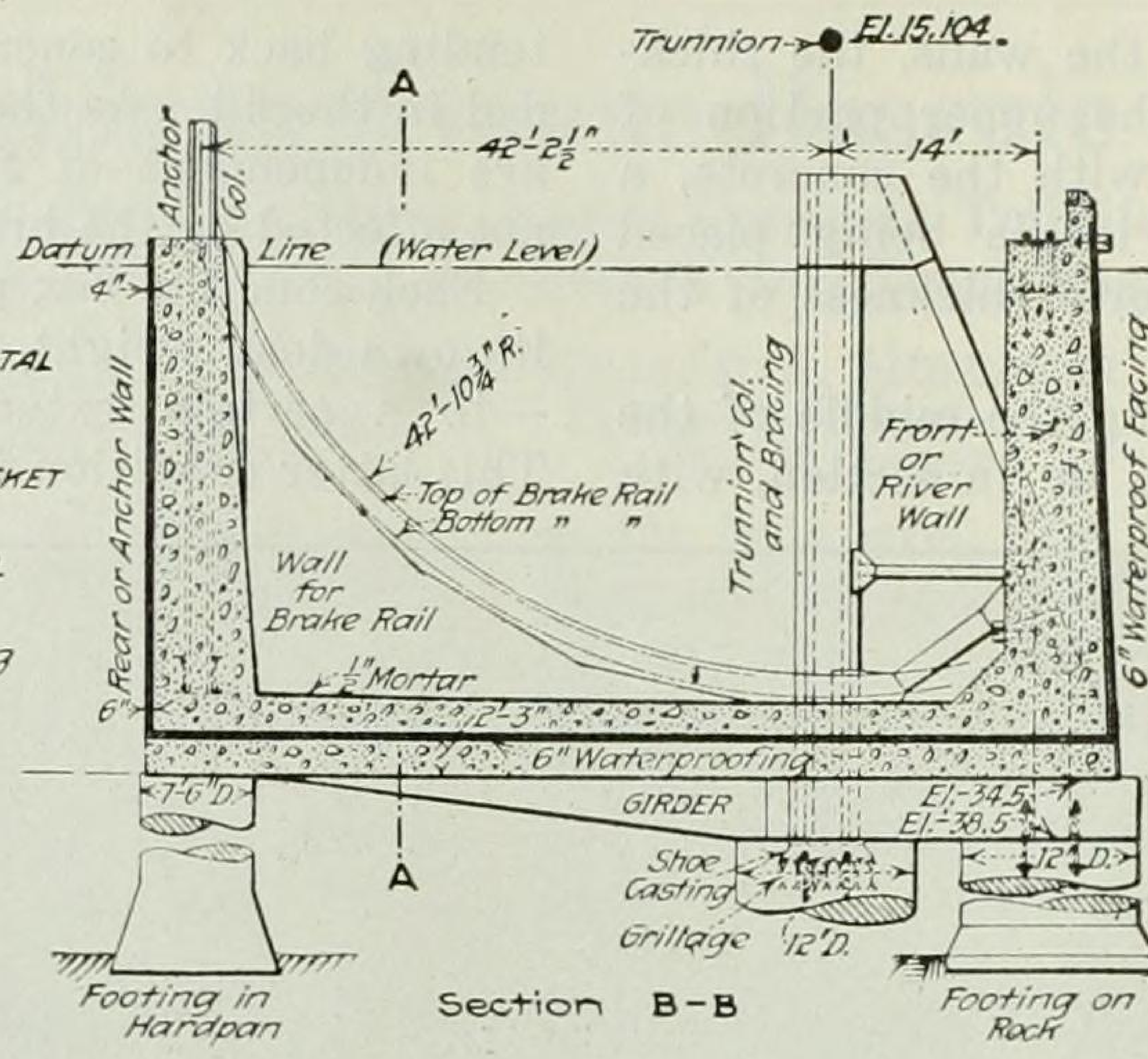
Concrete slab foundations on timber piles having a penetration of 18 to 20 ft. are used for the four operating towers, the spaces between the piles, behind the dock walls, being filled to the level of the base of the buildings. The dock walls are of concrete, supported on a double row of oak piles with a single line of triple-lap wood sheet piling between them. These walls are anchored or tied in place by horizontal bars extending back to concrete stringers or deadmen embedded in the fill. As the tower and dock wall foundations are independent of the bridge substructure, they are not affected by the bridge loads and vibrations.

Each concrete box pier or tailpit is designed to carry its own dead weight, water pressure from without and —to a certain extent—water pressure from within. This latter condition is brought about with the pit filled with water when the final hydrostatic tests are made before the cofferdam is removed. The effect of buoyancy due to the displacement of the pit walls and floor was considered, but the displacement of the pit as a whole was not taken into account either as lessening the dead loads of these parts or as reducing the loads in the subpiers. The loading conditions assumed in the design of the tailpits are given below.

Pit Floor—Two conditions were covered. For the operating condition the pit was assumed to be empty, with water pressure on the under side of the floor equal to 1410 lb. per square foot. For the construction condition the pit was assumed to be 25% filled with water, with the soil offering no support to the floor and pressure taken at 1410 lb. per square foot.

The floor was designed as a slab—reinforced longitudinally and transversely—supported by the sidewalls and pier walls and continuous over the girder along the center line of the bridge for both upward and downward pressures of 1410 lb. per square foot. This load was distributed to the longitudinal and transverse spans in inverse proportion to the fourth power of their span lengths. For the longitudinal span the coefficient for





PLAN AND SECTIONS SHOW DETAILS OF TAILPIT, MICHIGAN AVENUE BASCULE BRIDGE, CHICAGO

was assumed to be filled with water to datum (for testing the pit for leaks) with the cofferdam in place and, therefore, no external pressure. The method used in the design of the river pier for horizontal loads is similar to that applied to retaining walls subject to bending moment due to the horizontal loads and direct stress due to the weight of the masonry.

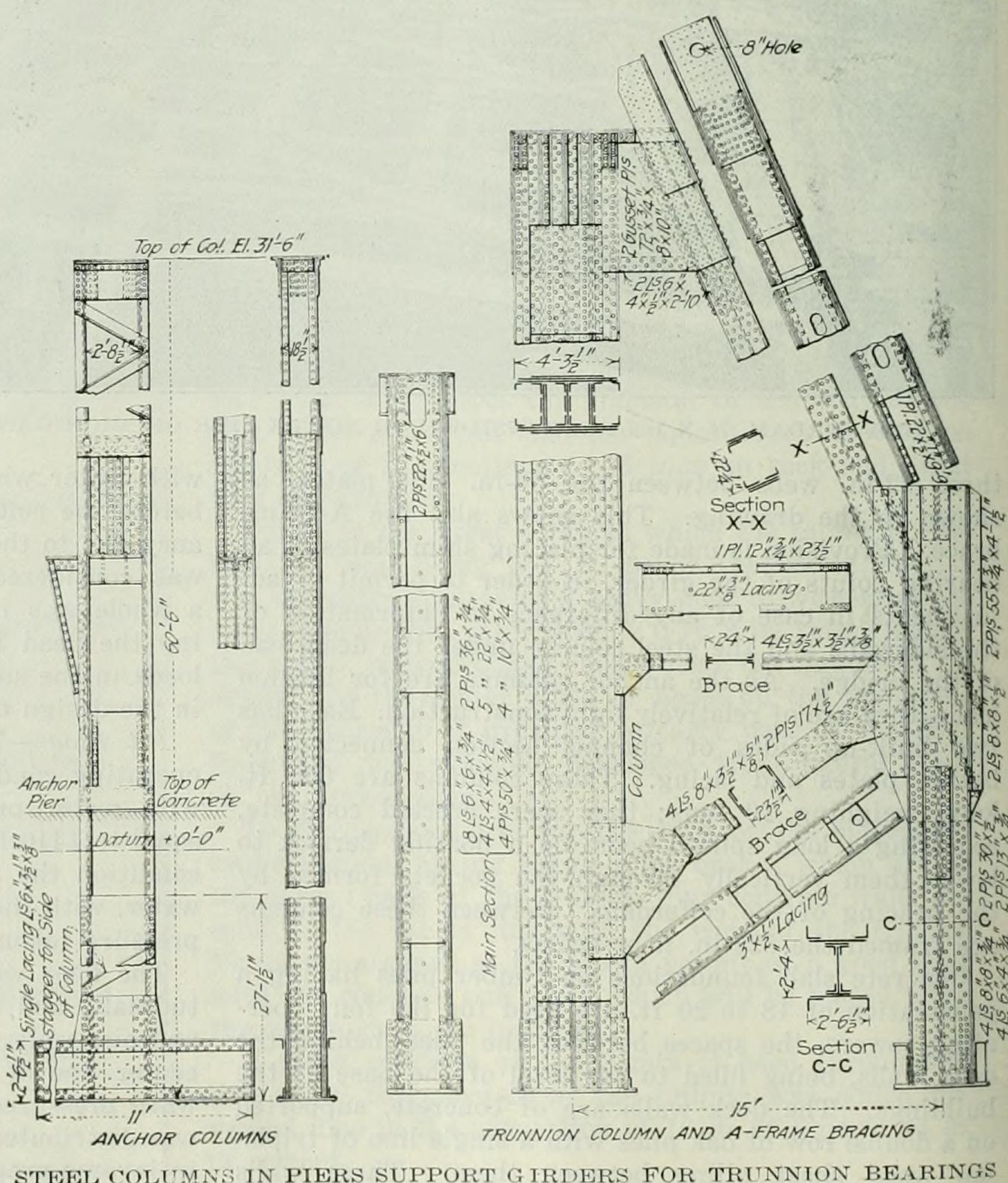
Anchor Pier—The conditions and loads were practically the same as above, except that as to horizontal loads, under the operating condition with the pit empty, the anchor pier was considered subject to earth pressure instead of water pressure on the outside. This horizontal pressure was taken at 28 lb. and 60 lb. per square foot above and below datum, respectively. This pier was designed for horizontal loads as a slab supported by the sidewalls and the buttress formed by the brake wall along the center line of the bridge. The coefficient for moment was taken as $\frac{1}{10}$ for positive center moment and as $\frac{1}{10}$ for negative moment over the brake buttress wall.

Sidewalls—Each sidewall was designed as a continuous beam supported by the river pier, the anchor pier

moment was taken as $\frac{1}{10}$ and provision is also made for bending moment in the floor slab induced by the cantilever moment in the river pier. For the transverse span the coefficient for moment was taken as $\frac{1}{12}$ for positive center moment and $\frac{1}{12}$ for negative ment was taken as $\frac{1}{12}$ for positive line of the bridge.

River Pier—For the operating condition the pit was assumed to be empty and the river wall or pier subject to the vertical loads of the bridge superstructure. For the construction condition the pit was assumed to be 25% filled with water and having a proportional part of this load on the floor carried by the river pier. The loads for these conditions are as follows: Pit empty; dead load of superstructure; 75% live load of superstructure; concrete in pier above datum at 150 lb. per cubic foot; concrete in pier below datum at 90 lb. per cubic foot. Pit 25% full; no superstructure loads; concrete in pier at 150 lb. per cubic foot.

For vertical loads this pier was designed as a beam continuous over the three cylindrical subpiers as supports. For horizontal loads, under the operating condition, the pit was assumed to be empty and the river pier subject to water pressure on the outside, while for the construction condition the pit



STEEL COLUMNS IN PIERS SUPPORT GIRDERS FOR TRUNNION BEARINGS AND UPLIFT ANCHORAGE and the cylindrical subpier for the trunnion. For horizontal loads, under normal operating conditions the pit was assumed to be empty and the wall subject to earth pressure on the outside. For the construction condition the pit was assumed to be filled with water to datum, with the cofferdam in place and, therefore, no external loads.

Cylinder Piers—In the design of the cylindrical subpiers the operating condition produced the maximum loads, which were as follows: Dead load of superstructure, 50% live load of superstructure, concrete of wall at 150 pounds and 90 pounds per cubic foot above and below datum and 150 pounds per cubic foot in the subpiers.

This project is being carried out by the Board of Local Improvements, of which C. D. Hill is chief engineer, but the plans and specifications were prepared in the bridge-designing section of the bureau of engineering, Department of Public Works: Hugh E. Young, engineer of bridge design; Thomas G. Pihlfeldt, engineer of bridges, and John Ericson, city engineer. The Great Lakes Dredge & Dock Co. is doing the substructure work for the bridge and its south approach under three contracts which aggregate $2,350,000. Capt. William Murphy is general superintendent for the company.

Camp Beds and Bedding Service Lower Labor Turnover

Bed Service by Big Lumbering Company Reduces Cost and Retains Men—Old Floaters Rent Beds and Forget To "Roll Up and Move On"

By W. C. Ruegnitz
Bridal Veil Lumbering Co., Portland, Ore.

MEN will cheerfully pay a dollar a week rent for bed and bedding service, and a camp which houses a hundred men for a ten-months' operation can make a profit on the service. Moreover, it is found that the men will stay longer on the job and will work more energetically.

An experience extending over a period long enough to be conclusive has established the truth of these assertions. This experience was gained in a logging camp, but the same results should be as readily obtained in a mining camp or in a construction camp, where similar conditions prevail.

About two years ago an experiment in furnishing bedding was tried by the Bridal Veil Lumbering Co. at one of its logging camps where about one hundred men are employed. Two of the regular bunk houses were especially cleaned, and to the regular equipment of steel bunks and mattresses there were added sheets, pillows, pillow slips, blankets and comforters. All of the bedding was of a good quality and was warm. The beds in these houses were called "special service bunks," and a charge for their use was made at the rate of $1 per week, 25c. for each of the first four nights of each week.

Coupled with this bed service there was a shower-bath house and a drying room. Men coming in from work on wet days could leave their wet clothing in the drying room instead of bringing it into the bunk house. A laundry was established so that the men on coming in from work could have a clean change of clothing after taking their baths. No man was allowed to elect to use this special service unless he had two suits of underwear, a complete change of clothing. This was done to keep the place clean and to improve the sanitary conditions.

Applications for the use of this special service came in slowly at first. Men had been so in the habit of carrying their beds that they paid little attention to the new service; many old-timers sneered at the idea, and continued to "roll up and move on." It was difficult to get the coöperation of the foremen. Occasionally a man was hired who had no bedding. He had lost his roll or he had not worked in a camp before. He accepted the special service. Soon results were apparent. Men who had carried their beds compared the company's bedding with their own. The special-service bed was better; it was clean; it was made up daily, so that at night the men had as good a bed as the best hotel could offer, and it was actually inviting. There was no change in the building, but the environment was different.

Waiting List Soon Established for the Special Service

We soon had a waiting list of men who wanted to use the special service. The following year 50 special-service beds were put in camp. This year we have 75 special-service beds in a camp of 100 men, and a waiting list of 17 men shows the feeling the men have toward this class of service. Many have discarded their blankets, and the labor turnover in our camp has been materially reduced. The men who take the special service invariably stay longer in camp than the men who carry their bundles.

It may be interesting to know how this special service is handled. We do not use the old-fashioned "bull cook" to make the beds. A washing machine and drying room are established in one building. The linen is washed by a woman who has charge of the special-service beds. She not only takes care of the making of the beds, but sees that all the linen is clean and mended. She has as much assistance as may be necessary, according to the number of beds that are used. An enterprising woman in camp can easily work up trade among the men to do their personal laundry and mending. This personal service is one that is greatly appreciated by the men.

The following tabulation of costs will no doubt be quite surprising to many contractors or operators who have considered that it would be impossible to put in bed service with supplies of bedding. First, we will consider costs based on the old practice of supplying beds alone:

One iron bed and spring, first cost, $5; years of life, 5; annual depreciation, $1. One mattress, first cost, $3; years of life, 2; annual depreciation, $1.50. Stove and miscellaneous equipment, first cost, $3; years of life, 3; annual depreciation, $1. Totals, first cost, $11; years of life, 3; annual depreciation, $3.50.

Assuming ten months' operation, the unit cost per man per month are:

Depreciation, $0.35; interest, $0.066; labor (actual costs), $1.00; rent, light, etc., $1.00; total, $2.416.

Since, according to logging-camp practice, nothing is charged for this service, this $2.416 represents the loss per man per month. Now, let us add bedding to the

Chicago Bascule Bridge—Design and Operating Features

Four-Truss Duplex Construction of Double-Deck Bridge—Emergency Grip Brakes—Interlocked Control of Gates, Locks, Safety Devices and Machinery

By Hugh E. Young
Engineer of the Chicago Plan Commission, recently Engineer of Bridge Design for the City of Chicago

To meet severe service requirements many new features of construction were incorporated in the new double-deck double-leaf fixed-counterweight trunnion bascule highway bridge of 256-ft. span over the Chicago River at Michigan Ave., which was opened in May, 1920. They have proved wholly successful, except for the division of the bridge into two separable structures set side by side and coupled together, which arrangement has not yet been put to the test of uncoupling and separate service.

Even apart from its novel design the bridge is noteworthy for its size and the exceptionally heavy traffic which it carries. It is believed to be the only double-deck bridge ever built having highways on both levels in order to provide for a separation of fast and slow traffic. Other double-deck bridges combine railway and highway traffic. A view of the bridge is given in Fig. 1.

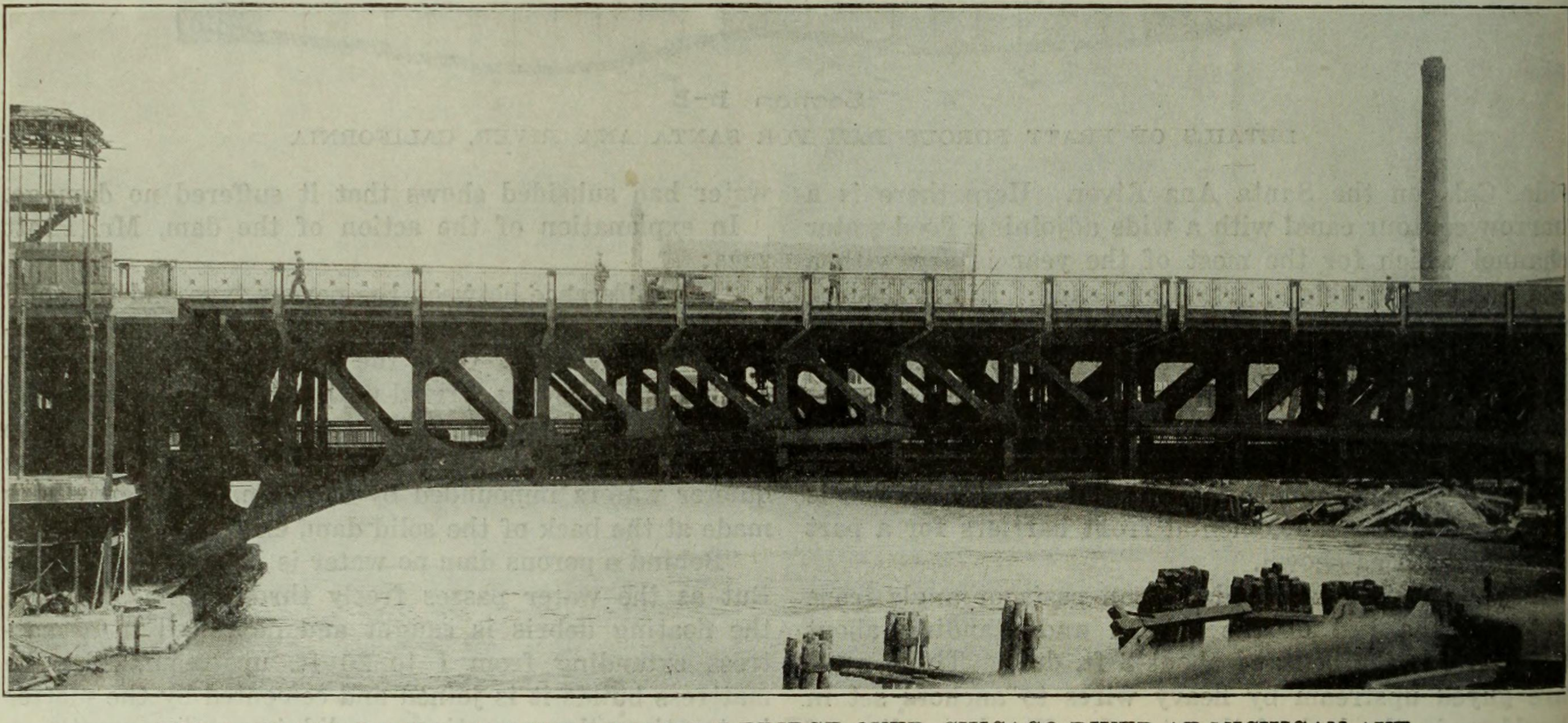


FIG. 1. DOUBLE-DECK HIGHWAY BASCULE BRIDGE OVER CHICAGO RIVER AT MICHIGAN AVE.

This bridge is the most important part of the widening and extension of Michigan Ave. between Randolph St. and Chicago Ave. to afford a wide and direct thoroughfare connecting the business district with the north-side section of the city, an improvement which eliminates the former circuitous and congested route crossing the old Rush St. swingbridge. Viaduct approaches connect the street level of the avenue with the upper roadway of the bridge, the lower roadway being for the slow and heavy traffic between various industries, terminals and steamship docks in the vicinity of the river. At the ends of the bridge the approaches are widened to form broad and ornamental plazas.

With a span of 256 ft. c. to c. of trunnions, the structure provides a clear channel width of 220 ft. Its navigation headroom was required by the War Department to be 16½ ft. from water line (city datum) for 80 per cent of the channel width with the bridge closed, and 120 ft. for the entire width of channel with the bridge open. The lower deck has a traffic clearance height of 13½ ft., while the upper deck is free of overhead obstruction. Both floors are paved with creosoted yellow-pine block paving on transverse planking bolted to the I-beam stringers. Back of the trunnions, however, the lower deck has sandstone block paving on concrete on a buckle-plate floor, in order to add weight to the tail and to give a better footing for teams on the 3 per cent grade from the street.

Provision is made for the future construction of two street-car tracks on the lower deck.

Four trusses were used for each leaf, for reasons noted below. The two inner trusses are spaced 6 ft. c. to c., and the outer trusses 27 ft. On the upper deck there are two 27-ft. roadways between trusses and two 15-ft. sidewalks on cantilever floor beams. On the lower deck are two 18-ft. roadways and two 6 ft. sidewalks, all inside of the trusses. The width over all on the upper deck is 91 ft. 9 in.

Reasons for Four-Truss Construction—Two principal reasons determined the adoption of four-truss in preference to three-truss construction: (1) advantages in design and construction, and (2) the possibility of separating the bridge into two parallel parts in case of emergency. With three trusses the load on the center truss would have been approximately double that on each outside truss, which would have meant double work in designing, detailing and fabricating the trusses. The anchor arm for the center truss would have been so heavy that the shop details would of necessity have differed considerably from those of the outside trusses,

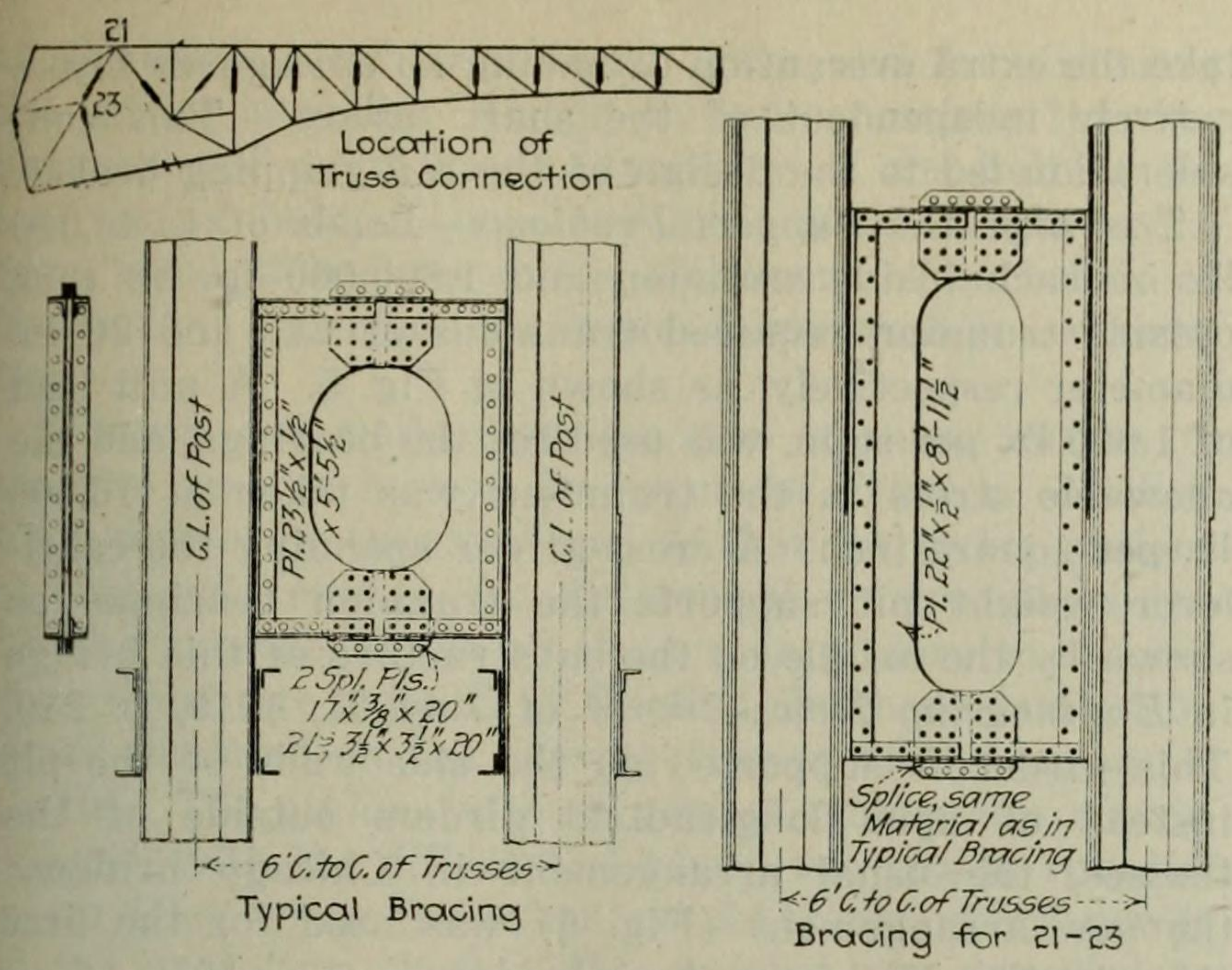


FIG. 2. SEPARABLE DIAPHRAGMS CONNECT INNER TRUSSES OF FOUR-TRUSS BRIDGE

grips of rivets would have been increased and difficulties of detail encountered. The increased weight of the two center trusses over one center truss is slight, being due only to additional structural detail, as the main section of the chord and web members requires the same amount of material in both cases. The increased weight due to truss details and to diaphragms connecting the two parts is offset by cost advantages secured through the shorter floor beams and fewer stringers in the roadways. Erection would have been more difficult with a heavy center truss and light outer trusses.

Again, the trunnions for the four-truss span are all of approximately the same diameter, while the much larger trunnions of a center truss would have involved difficulties and extra cost. Further, there would have been difficulty in arranging the anchor-arm floor members to clear the journal boxes of the larger inner trunnions. The cross-girder supporting the trunnions would have required wider flanges in order to seat the bearings and this, in turn, would have made it difficult to obtain clearance between the lower flanges of the cross-girder and the truss members of the anchor arm.

The Duplex Arrangement—By using four trusses each leaf could be built in two parallel parts so constructed that each part can be operated independently. Bridges over the Chicago River frequently are struck by vessels and damaged to an extent that necessitates raising them to the open position for repairs, interrupting street traffic until these are completed. Experience has shown that in such cases the principal damage done is to the sidewalk construction and to the trusses ahead of the trunnions, and as the parts back of the trunnions are not affected it has been possible to raise the damaged leaves into the open position. If one side of the Michigan Ave. bridge should be struck by a vessel there is no doubt that the shock would be absorbed by one half of the leaf, and that the damage would not prevent the raising of this part of the leaf, leaving the remaining half available for traffic. To provide for such contingencies, therefore, the two halves of the leaves were made independent but connected at the panel joints by diaphragms split at the center and spliced to take shear loads only. These diaphragms (Fig. 2) would buckle under impact before distorting the heavy truss members to which they are connected.

It is estimated that the diaphragms at the 26 panel points could be disconnected in eight hours by a force of twenty men, including the time required to remove bolts from shaft couplings and to place bolts in the differential gears for the purpose of causing this device to act as a unit. The removal of the diaphragm plates is also included in the time given above. If it should become expedient to cut the diaphragm connections by burning it is estimated that eight men with four torches coud accomplish this in four or five hours.

This separable four-truss arrangement was applied years ago in the four-track rolling-lift bascule bridge of the Metropolitan Elevated Ry. at Van Buren St., Chicago. It has never been necessary to disconnect the two parallel parts of that bridge; as it carries only an elevated railway it is considerably higher than the street bridges, and therefore less exposed to damage by vessels. Street bridges are not only lower but also very close together, so that when there is delay in opening a bridge it is difficult to handle a ship so as to avoid striking it. Advantage will be taken of the duplex arrangement, however, in replacing the old Van Buren St. bridge by a new structure: traffic will be maintained over one half of the old bridge during the removal of the other half and the erection of the corresponding half of the new bridge. The Charles River single-leaf bridge of the Boston Elevated Ry. also has the duplex or four-truss arrangement, so as to permit of maintaining traffic on one side if it should become necessary to raise the other part for repairs.

Emergency Brakes of New Type—Electro-pneumatic emergency brakes on the heels of the trusses, which act by gripping rails fastened to concrete supports in the

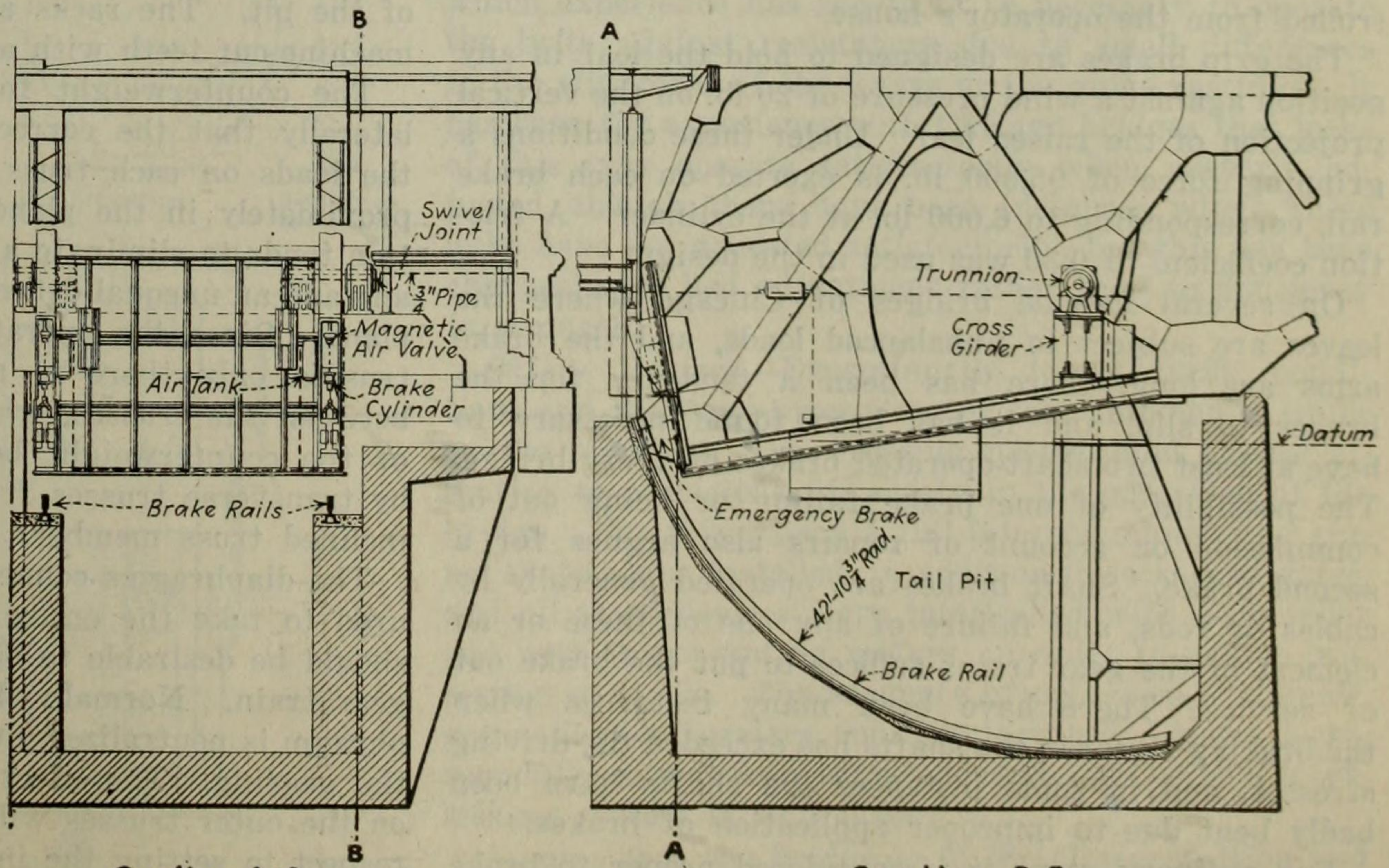


FIG. 3. EMERGENCY GRIP BRAKE ON HEEL OF BASCULE

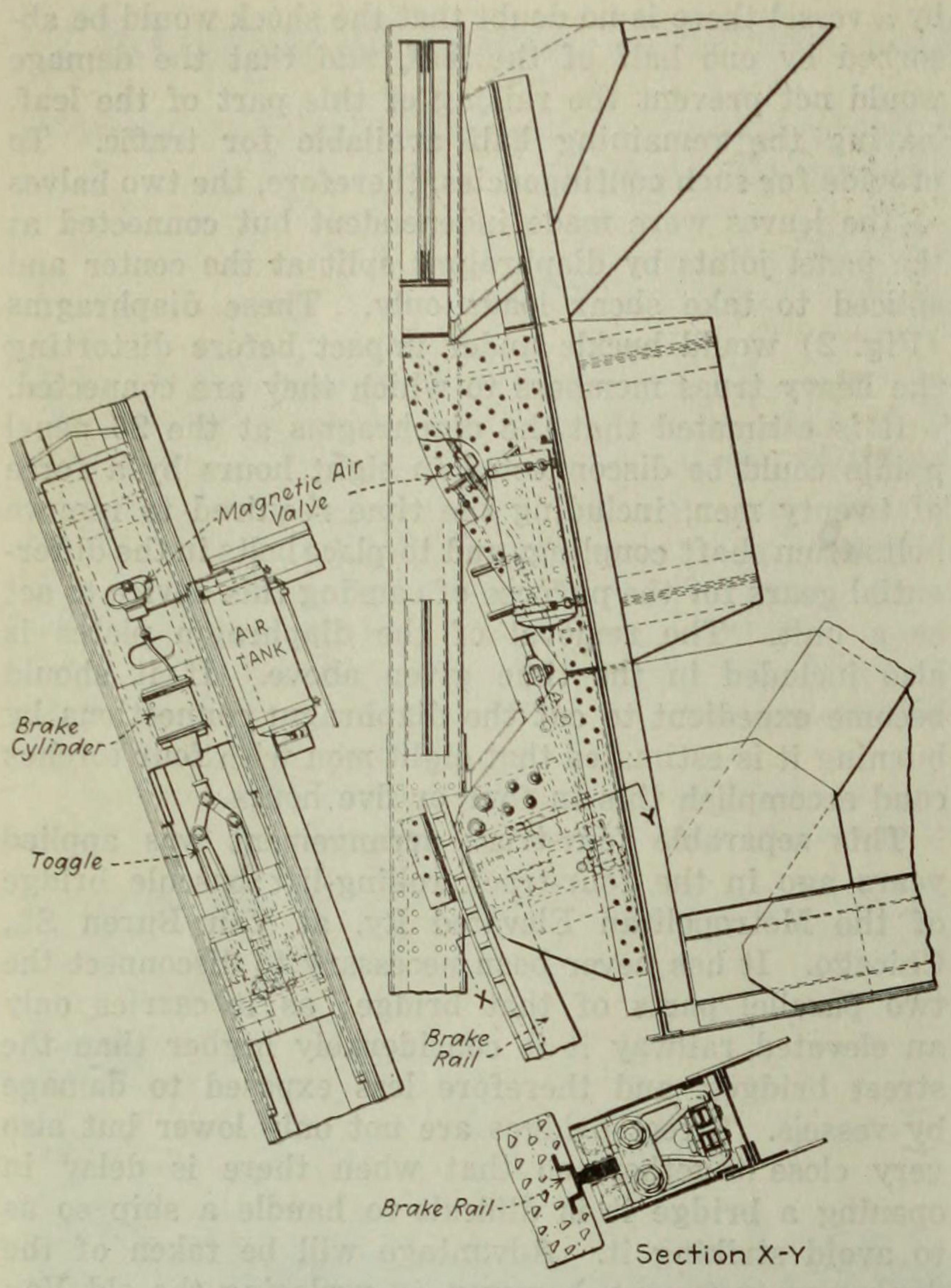


FIG. 4. DETAIL OF EMERGENCY BRAKE

tail pit, have been introduced to supplement the pneumatic and hand brakes which operate through the gear train. This is an innovation in bridge design at Chicago and is for the purpose of holding the bridge in case of accident to the machinery. The construction is shown in Figs. 3 and 4. The four brake rails are curved to the path traveled by the ends of the trusses and each is gripped by shoes operated by toggles through levers from a pneumatic cylinder 10 x 10 in., the air supply to which is regulated by a magnetic air valve controlled from the operator's house.

The grip brakes are designed to hold the leaf in any position against a wind pressure of 20 lb. on the vertical projection of the raised leaf. Under these conditions a gripping force of 95,000 lb. is exerted on each brake rail, corresponding to 6,000 lb. at the cylinder. A friction coefficient of 0.30 was used in the design.

On several bascule bridges of Chicago where the leaves are subject to unbalanced loads, and the brake arms are long, there has been a tendency for the brakes to slip, and it has been found necessary to have at least two shaft-operated brakes on every bridge. The possibility of one brake failing or being out of commission on account of repairs also argues for a second brake. Shaft brakes are operated generally by cables or rods, and failure of any one of these or an element of the gear trains suffices to put the brake out of service. There have been many instances when the braking stress in the shafts has exceeded the driving stresses, and in some instances the shafts have been badly bent due to improper application of brakes.

For ordinary spans it is considered proper to brake through the machinery, but the Michigan Ave. bridge is of such magnitude that it was considered necessary to take the extra precaution of having an emergency brake entirely independent of the shaft brakes. This consideration led to the design of the rail-gripping brakes.

Trunnion and Support Problems—Loads of 1,540,000 lb. on each inside trunnion and 1,800,000 lb. on each outside trunnion required trunnions of 24½ and 26 in. diameter respectively, as shown in Fig. 5. A unit load of 1,800 lb. per sq.in. was used for the bearings, and the allowable stress in the trunnions was taken at 16,000 lb. per square inch. A cross-girder spanning the cantilever weight pit supports the trunnion bearings, as shown by the article on the substructure of this bridge in *Engineering News-Record* of July 31, 1919, p. 210. This girder is supported on the side walls of the pit instead of upon longitudinal girders outside of the trusses, the usual arrangement in Chicago bridges; the new arrangement (Fig. 6) was used for the first time in the Michigan Ave. bridge.

Elimination of the longitudinal girders gives a more efficient way of carrying the loads to the foundations and has proved very satisfactory, but with the trunnion loads carried directly on the side walls of the pits it is necessary to place concrete piers under the walls in addition to those required for the support of the pit proper. Another type of support is to have each trunnion carried by a pair of longitudinal trusses so arranged that they clear the counterweight boxes. Several bridges having the trunnion truss type of support have been built in Chicago, and their operation has been very satisfactory.

Operating Machinery—Each leaf of the bridge is operated by two 100-hp. motors, with two additional motors in reserve. These motors are located in the machinery room under the lower street level just back of the anchor pier, and are arranged both electrically and mechanically so that any two motors can be used for operation. The machinery layout is shown in Fig. 7. In the plane of the chord of each outer truss is a cast-steel internal rack of 19 ft. 9 in. pitch radius, having teeth 22½ in. wide and 7½ in. pitch, as indicated in Fig. 8. This operating scheme requires a gear train at each corner of the bridge, located just outside the outer truss and resting on grillage beams in the walls of the pit. The racks are engaged by pinions having machine-cut teeth with a pitch diameter of 33.4 inches.

The counterweight for each leaf is so distributed laterally that the correct amount required to balance the loads on each truss has its center of gravity approximately in the plane of the truss. This distribution tends to eliminate a deflection of the trusses laterally and an unequal deflection of the trusses in a vertical plane. Since the operating gears lift on the outside trusses only there is a torsional moment developed between the trusses, which is resisted by the girders of the counterweight box back of the trunnions and by transverse trusses framed between the vertical and inclined truss members ahead of the trunnions.

The diaphragms connecting the inner trusses are figured to take the entire load of one pinion in case it should be desirable to operate the entire leaf with one gear train. Normally, however, the shear in the diaphragm is neutralized, due to the action of the differential gearing. The effect of applying the operating load on the outer trusses will, of course, be the same with respect to setting the inner trusses in motion for both the leaves with diaphragms in and with diaphragms out. The diaphragms are of value only when it is necessary to operate the leaf by one gear train, and for stiffening the bridge laterally. Under normal conditions the diaphragms will overcome the tendency of one half of the leaf to lag behind the other half, which might occur from same differences in the alignment of each half of the leaf or imperfections in the workmanship and erection.

Changes are made from the two working motors to the two reserve motors by means of friction clutches. Each pair of motors is placed so that the motor pinions of each pair engage the differential on opposite sides. On the extended hubs of the motor pinions are keyed discs which are gripped by friction clutches operated by levers mounted on the bearing frames of the armature shafts. The pinions of both sets of motors are always in mesh with the differential gears, one pinion running as an idler when the other set is transmitting power to the operating shaft. The clutches are provided to permit easy shifting of the motors, it being considered necessary to alternate the use of the motors from week to week; the particular reason for putting in the clutches was to avoid the necessity of sending to the municipal shops to get the necessary machinist to take out the bolts (in case such mechanical arrangement had been provided), which would cause considerable delay. Bridge operators are not supposed to remove bolts from couplings or any other apparatus.

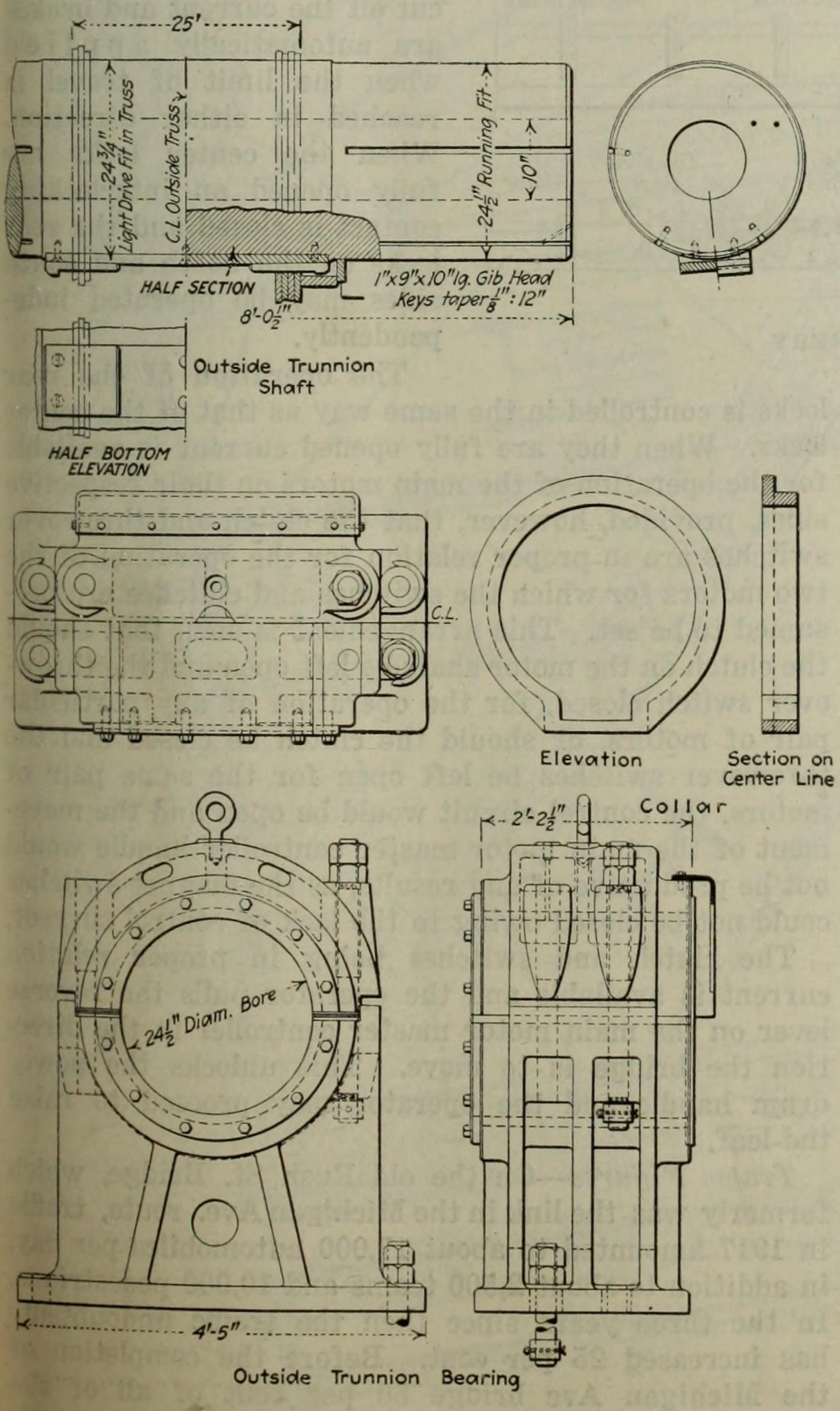


FIG. 5. TRUNNIONS FOR 6,700-TON BASCULE

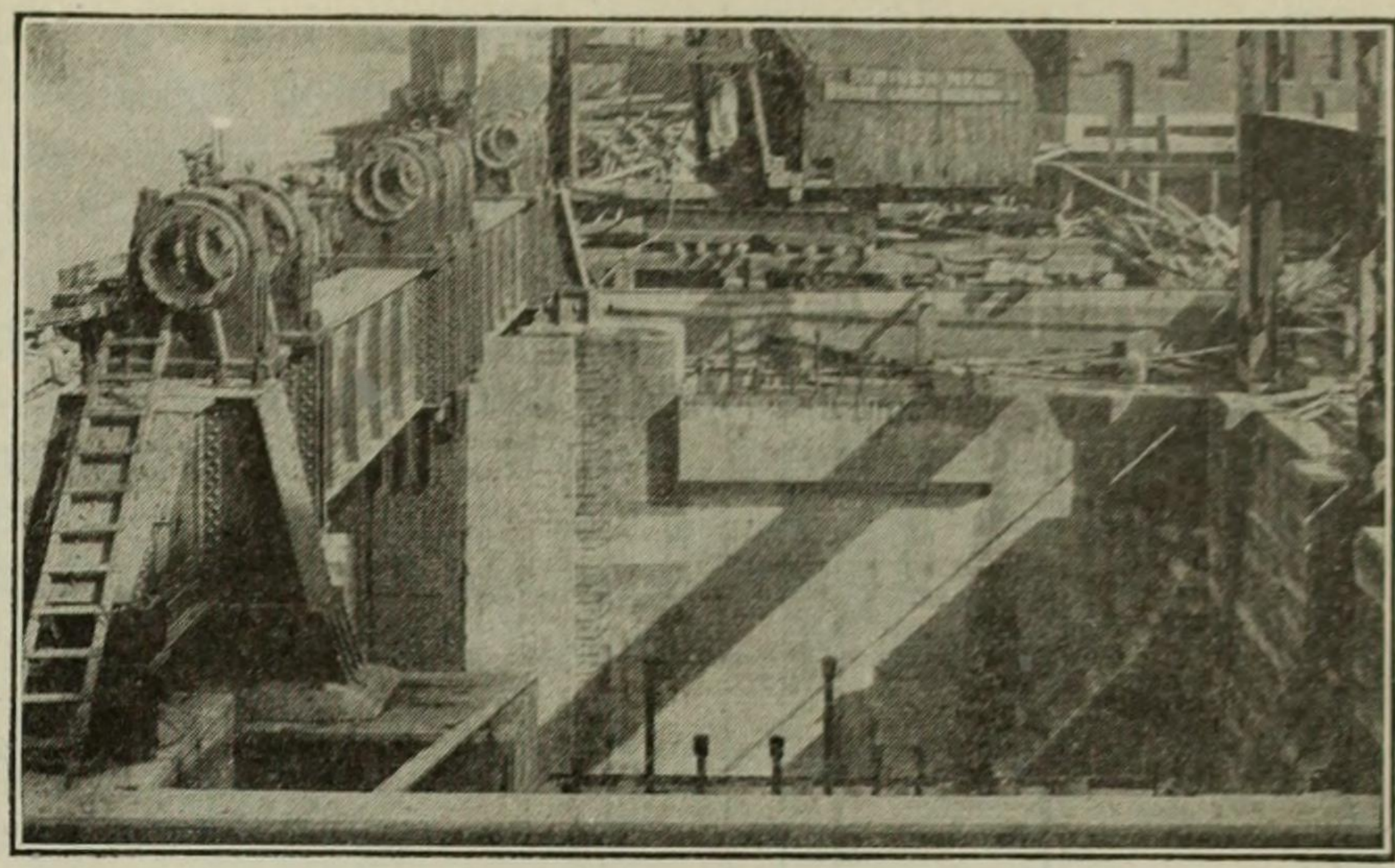


FIG. 6. HEAVY GIRDER CARRIES TRUNNIONS

Heel and End Locks—Heel locks to take the live-load reactions are four in number for each leaf, one lock in the plane of each truss (Fig. 9). These locks are operated through gear trains mounted on the anchor pier and connected with the toggle arm, which engages a casting on the rear girder of the counterweight box. The live load amounts to about 138,000 lb. per lock. What power should be provided for the locks was subject only to arbitrary assumption, but experience has shown that 10-hp. motors are satisfactory. The locks are also required to push the leaf into the final position, which places the heaviest duty on the motors.

Center locks (Fig. 10) are provided to insure that the two leaves of the bridge will deflect equally under live load, to prevent unevenness at the center break in floor. These are bolt locks placed in the bottom chord of each truss and are operated by 5 hp. motors so arranged that the two locks on each side can be operated independently. The machinery for operating the locks is placed below the lower-level floor, and the gearing is connected to rods which operate levers that force the bolts into place.

The locks were designed in accordance with the standard practice of the city of Chicago. They were proportioned for the greatest shear at the end of the arms, which can be definitely determined. The operating mechanism, however, was proportioned for the size of motor which experience has shown to be necessary to operate the bolts against resistances due to small differences in the alignment of the leaves at the guide castings. It has been the experience with Chicago bridges that locks of this type operate satisfactorily when properly adjusted, though there have been instances where these locks have not operated satisfactorily, but this has been chargeable to bad adjustment rather than to deficiency in strength.

Safety Devices—Exceptionally heavy traffic conditions and the large proportion of fast automobile traffic on the Michigan Ave. crossing necessitated special attention to provisions for safety in the operation of the bridge. For this reason a full intercommunicating signal system was installed, in addition to locks and gates, and all these devices were interlocked with each other and with the operating motors, in order to assure protection of traffic. The sequence of operation of signals, gates, flexible barriers (not yet installed), center locks, rear locks and main motors as determined by this interlocking system is as follows:

Assume that the bridge is in the closed position and carrying traffic. The center and rear locks are closed, the roadway and sidewalk gates are raised, the brakes

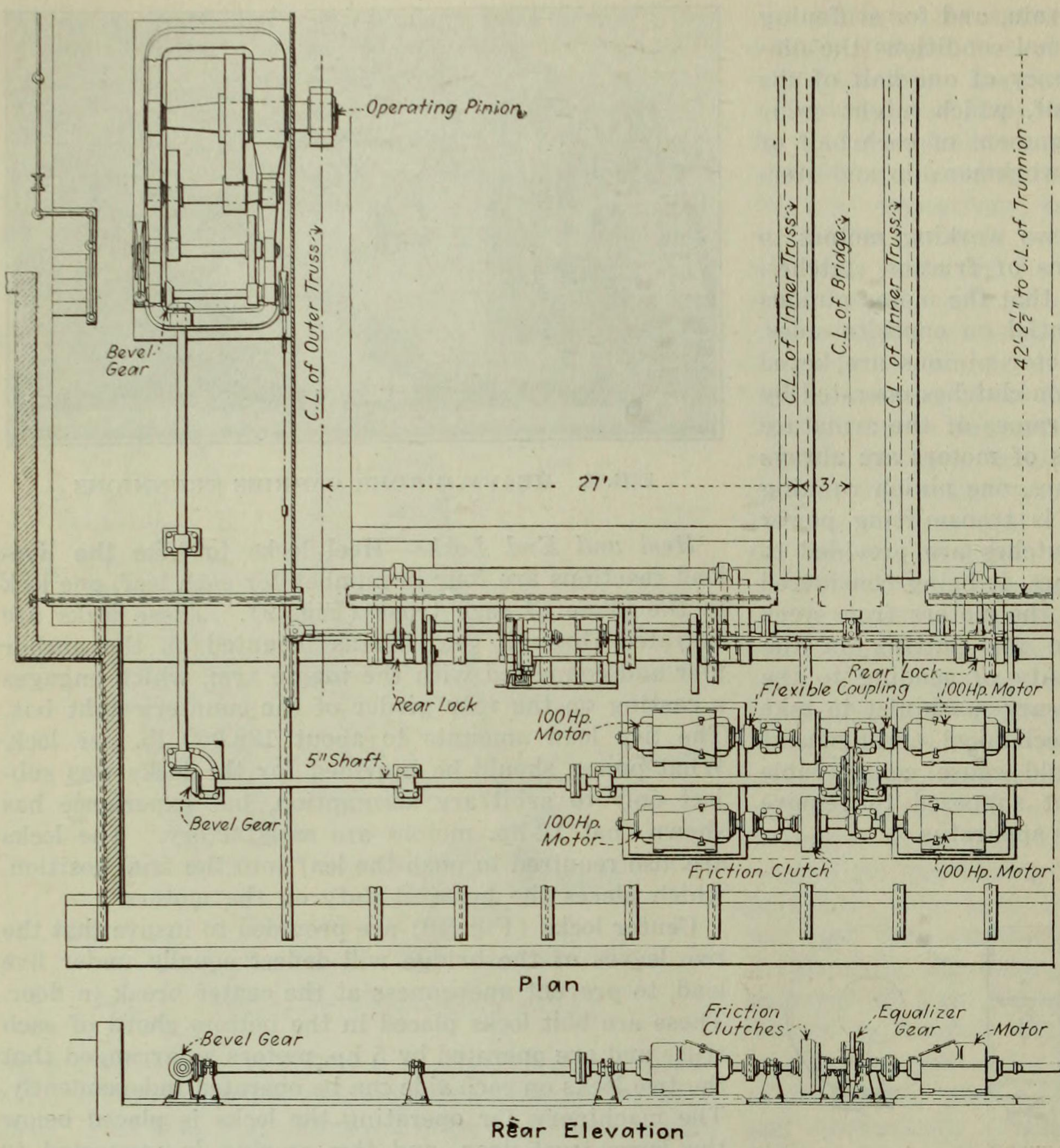


FIG. 7. LAYOUT OF OPERATING MACHINERY

may or may not be set, the magnetic feeder section switch is closed and current is available for the river signals, service and signal lights.

Following the practice as established upon the other city bridges, the operator having the control of the center lock (the north operator in this case) is the one to give the signal for starting the preparation of the bridge for raising, and he also gives the signal for the raising of the leaves. The operators and gatemen exchange signals for the purpose of calling each of the gatemen and the south operator to their posts. This is done by means of vibrating bells in the operator's houses and single stroke bells in the gatemen's and operators' houses. Upon receiving the return signals the north operator again signals as before, and the gatemen and operators each ring the large hand-operated bells and start the warning bells and flasher motors of warning signs by means of a snap switch located near the gate controllers. When these switches are closed current is available for the operation of the gates closing that section of the roadway at which the signals are displayed.

The roadway gates against traffic approaching the bridge are stopped when they reach the fully lowered position, and at the same time they automatically close switches in the gate posts and current is available for the operation of the flexible barrier at that section of the roadway closed by the gates. The barrier is then lowered, a limit switch cutting off the current and applying a brake when it is down. The sidewalk gates are now lowered. When traffic has cleared the bridge the exit gates and barriers are operated in the same sequence. When all the barriers are down the interlocking switches at each barrier are closed automatically and the first section of the interlocking is completed.

The centerlocks may be operated at any time in the opening, the object of this being to permit of the opening of the center locks by the operator while waiting for the traffic to clear. In closing, however, the center locks cannot be closed until the rear locks are closed. The operation of the center locks is controlled by a master controller and the necessary magnet switches for accelerating and reversing; limit switches cut off the current and brakes are automatically applied when the limit of travel is reached in either direction. When the center locks are fully opened an interlocking contact is closed and the rear locks on the north and south sides may be operated independently.

The operation of the rear locks is controlled in the same way as that of the center locks. When they are fully opened current is available for the operation of the main motors on their respective sides, provided, however, that the clutch and throwover switches are in proper relation for the operation of the two motors for which the switches and clutches are presumed to be set. This arrangement is such that should the clutch on the motor shaft be left open and the throwover switch closed, for the operation of any particular pair of motors, or should the clutch be closed and the throwover switches be left open for the same pair of motors, the control circuit would be open and the movement of the main motor master controller handle would not be productive of any results, as the magnet switches could not be closed owing to the lack of control current.

The clutch and switches being in proper relation current is available and the operator pulls the reverse lever on the main motor master controller in the direction the bridge is to move. This unlocks the power drum handle and the operator may proceed to raise the leaf.

Traffic Figures—On the old Rush St. Bridge, which formerly was the link in the Michigan Ave. route, traffic in 1917 amounted to about 17,000 automobiles per day, in addition to about 2,500 teams and 10,000 pedestrians. In the three years since then the traffic undoubtedly has increased 25 per cent. Before the completion of the Michigan Ave bridge 50 per cent of all of the automobile traffic from the north side to the loop took the Rush St. bridge, the remainder being distributed over the north-south crossings. Much of the latter traffic now goes to the Michigan Ave. bridge, and its total automobile traffic is approximately 30,000 per day. The lower level of the bridge, not yet opened to team traffic, accommodating two lines of trucks in each direction, probably will carry about 6,000 teams per day.

Weights and Stresses—The weight of the Michigan Ave. bridge, both leaves included, is about 13,400,000 lb., there being an average load on each trunnion of 1,675,000 lb. Thus the new bridge is the heaviest in Chicago, and probably it is heavier than any other double-leaf double-deck bridge of its kind in the world. The weight of the new Wells St. bridge, which will be its nearest competitor in Chicago, will be 9,600,000 lb. for both leaves, and this bridge will carry an elevated railway on the upper deck. The single-leaf double-deck bridge of the Canadian Pacific Ry. over the Kaministiquia River at Fort William, Ont., weighs 9,800,000 lb. It has a double-track railway on the lower deck and a 29-ft. roadway on the upper deck.

In determining the stresses for the truss chords of

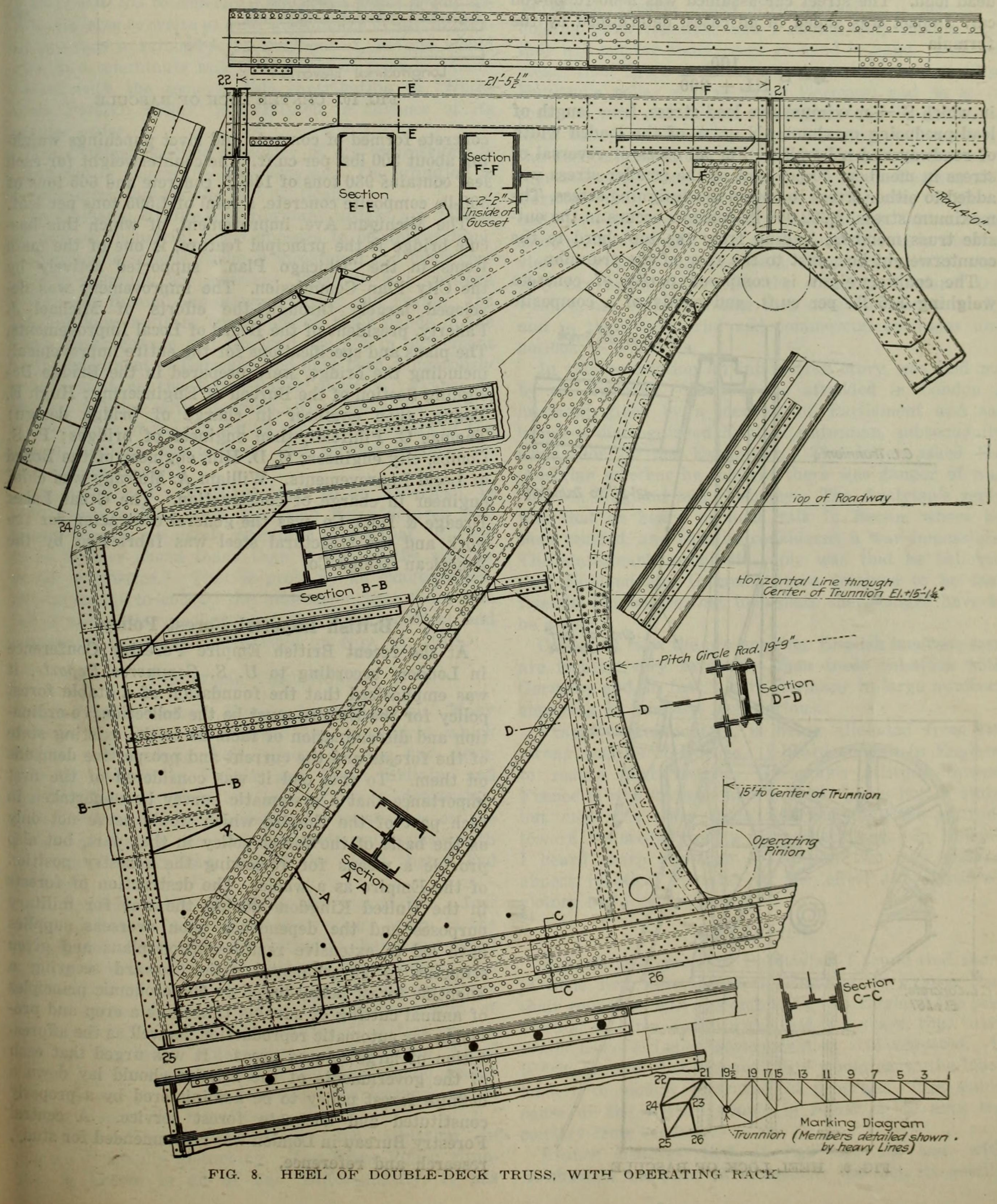


FIG. 8. HEEL OF DOUBLE-DECK TRUSS, WITH OPERATING RACK

the Michigan Ave. bridge the live load assumed was 100 lb. per square foot over roadways and sidewalks for the upper deck, and for the lower deck 2,000 lb. per lineal foot of street-car track distributed over a 10-ft. width, and 100 lb. per square foot over the remaining area, plus the actual dead load of the structure. For the design of the floor beams and stringers of the upper deck, and that part of the lower deck not occupied by street cars, the assumption was a live load of 24,000 lb. on two axles spaced 10 ft., and 100 lb. per square foot over the area not occupied by this load, plus the actual dead load. The street car assumed was a 50-ft. 50-ton car. Impact was added in all cases, determined by the formula

$$I = S \frac{100}{NL + 300}$$

in which S = maximum live load stress, L = length of load producing maximum, N = $\frac{1}{10}$ of the loaded width of roadway and sidewalks. For all cases of reversal of stress in members 50 per cent of the smaller stress was added to either stress to obtain the designing stress. The maximum stress, 2,692,000 lb. tension, occurs in the outside truss members leading from the top chord to the counterweight box, just to the rear of the trunnion.

The counterweight is composed partly of concrete weighing 145 lb. per cu.ft. and partly of a composite concrete formed of concrete and rivet punchings weighing about 300 lbs. per cu.ft. The counterweight for each leaf contains 930 tons of 145-lb. concrete and 665 tons of 300-lb. composite concrete, a total of 1,595 tons per leaf.

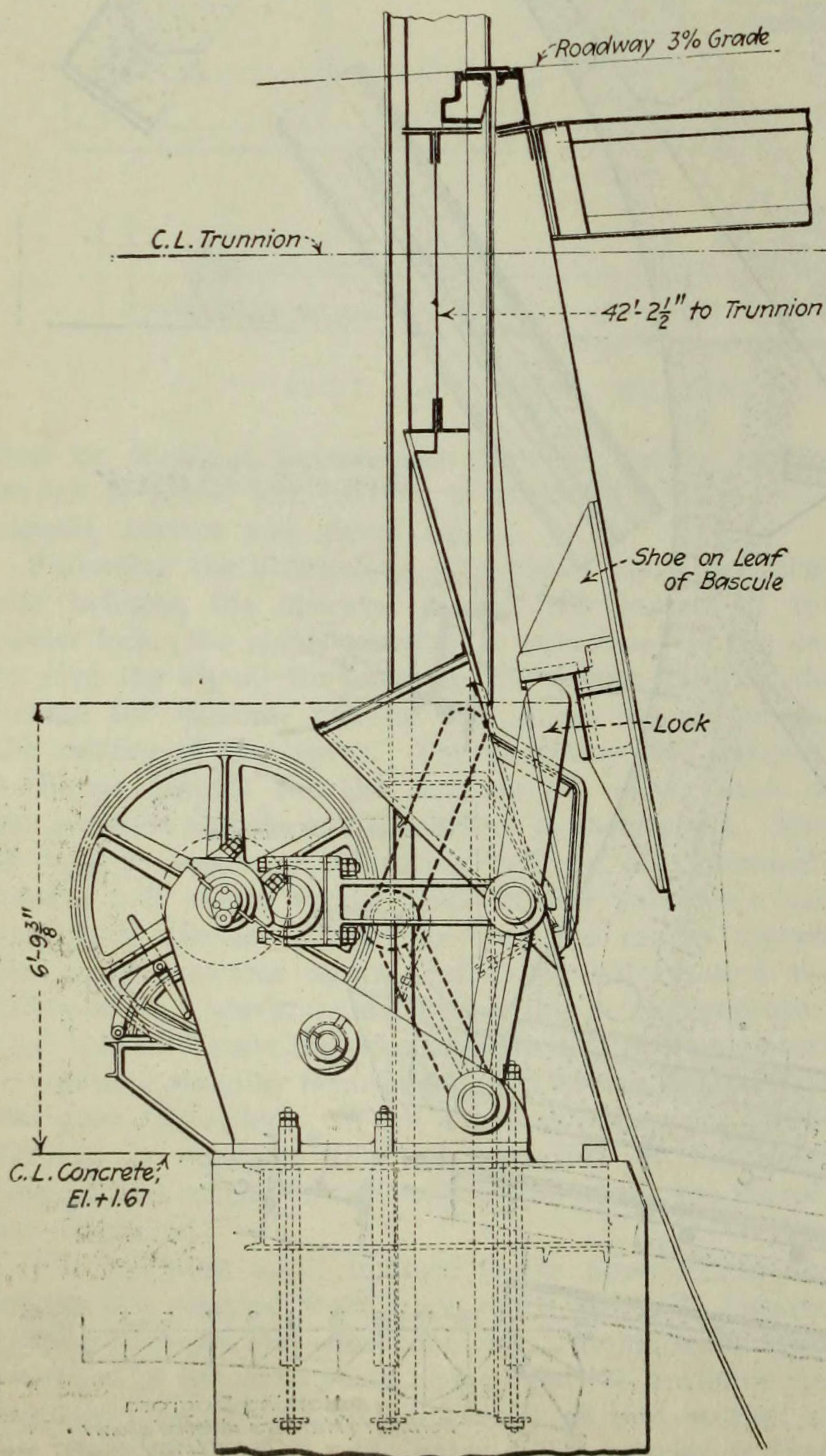


FIG. 9. HEEL LOCK OF BASCULE

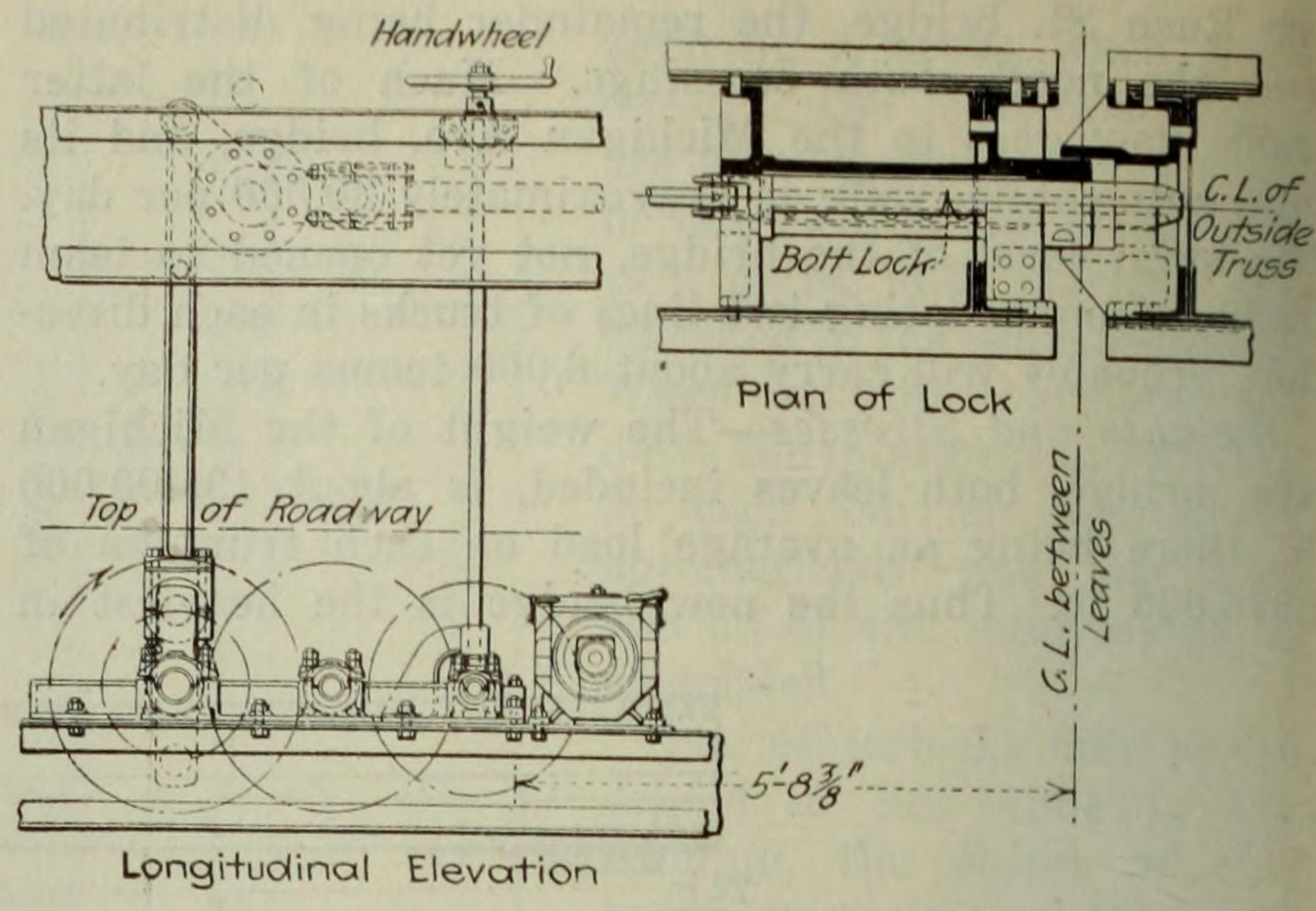


FIG. 10. CENTER LOCK OF BASCULE

The Michigan Ave. improvement, of which this bascule bridge is the principal feature, is one of the main items in the "Chicago Plan," supported actively by the City Plan Commission. The improvement was developed largely through the efforts of Michael J. Faherty, president of the Board of Local Improvements. The plans and specifications for the entire improvement, including the bridge, were prepared in the Bridge Designing Section of the Bureau of Engineering; Hugh E. Young, then engineer in charge of bridge design; Thomas G. Pihlfeldt, then engineer of bridges; P. S. Combs, city engineer; C. D. Hill, engineer of the Board of Local Improvements. William A. Mulcahy was chief engineer in charge of construction. The Great Lakes Dredge & Dock Co. was the general contractor for the work and the structural steel was fabricated by the American Bridge Co.

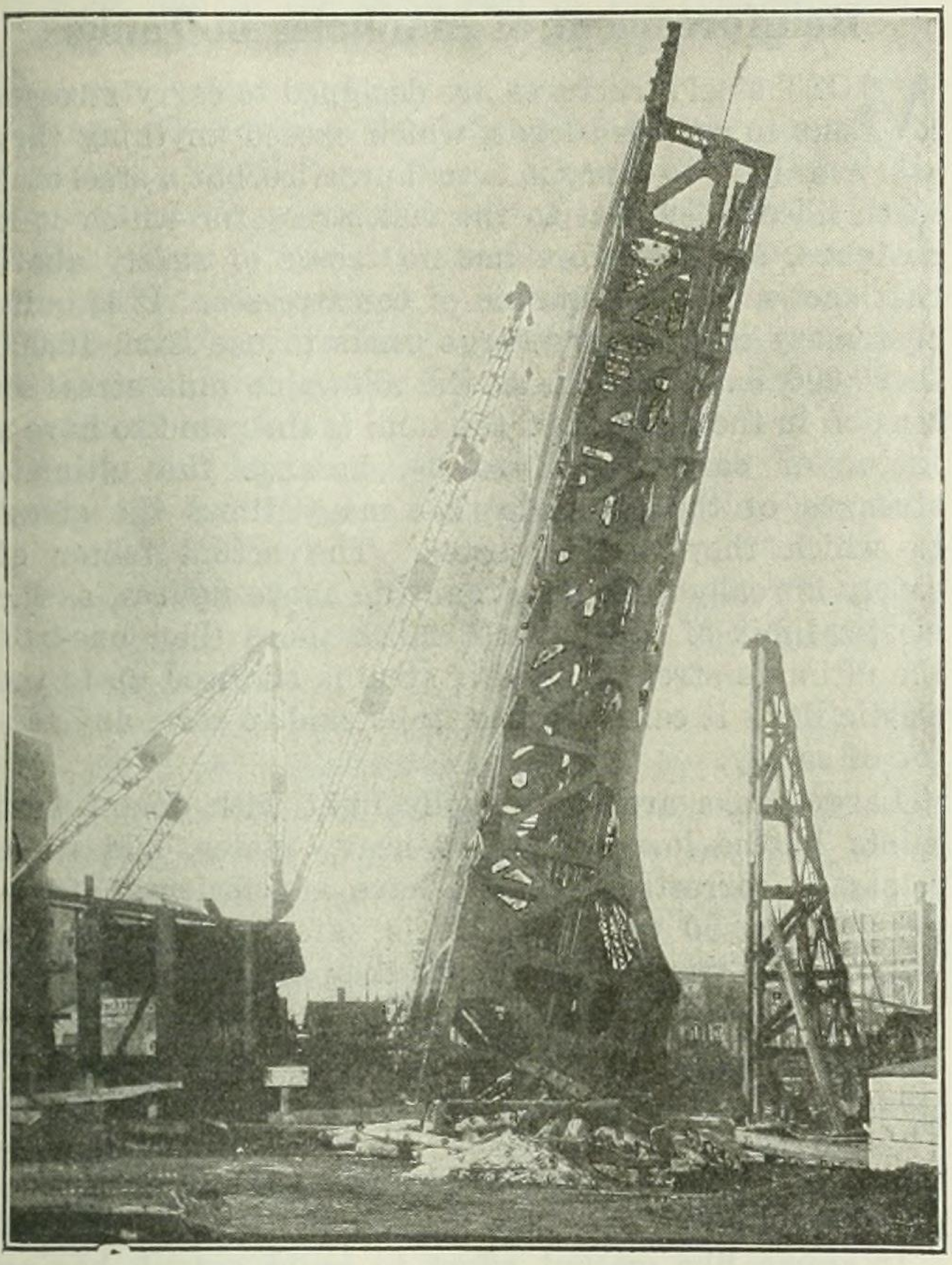
British Imperial Forest Policy

At the recent British Empire Forestry Conference in London, according to *U. S. Commerce Reports*, it was emphasized that the foundation of a stable forest policy for the Empire must be the collection, co-ordination and dissemination of facts as to the existing state of the forests and the current and prospective demands on them. To this end it was considered of the first importance that a systematic survey be undertaken in each part of the Empire which would serve not only as the basis of the forest policy in that part, but also provide a means for reviewing the forestry position of the Empire as a whole. The destruction of forests in the United Kingdom during the war for military purposes and the dependence upon overseas supplies have led to extensive reafforestation plans and given stimulus to governmental action toward securing a scientific forest policy based on the economic principles of annual cutting of surplus timber as a crop and provision for automatic reproduction, as well as the afforestation of large unused areas. It was urged that each of the governments of the Empire should lay down a definite forest policy to be administered by a properly constituted and adequate forest service. A central Forestry Bureau in London was recommended for study, research and reference.

New Chicago Double-Deck Bascule Highway Bridge

A NEW double-leaf double-deck highway trunnion bascule bridge of 256-ft. span and 6,700 tons weight, scheduled to be put in service on May 14, over the Chicago River at Michigan Ave., is the main feature in the widening and extension of Michigan Ave. to connect the boulevard systems north and south of the river.

The bridge is of the trunnion type developed for the city's bridges in 1898 by the engineering bureau of the Department of Public Works, under John Ericson as city engineer. It has four lines of trusses, forming practically two separate bridges, the inner trusses being connected by bolted diaphragms which can be disconnected if necessary, as in case of damage to one part of the bridge by a vessel. The lower deck is for trucks and wagons and the upper deck for automobiles and pleasure traffic, the latter reaching the upper elevation by inclined viaduct approaches. On the upper deck are two 27-ft. roadways with 15-ft. sidewalks on cantilever brackets, making a total width of 91 ft. 9 in. On the lower deck are two 18-ft. roadways and 6-ft. sidewalks, all between the trusses.



SOUTH LEAF OF DOUBLE-DECK BASCULE BRIDGE AT CHICAGO

Each leaf weighs 3,350 tons, with 1,595 tons of counterweight, and is operated by pinions gearing with concave racks in the heels of the outer trusses. For each leaf there are four electric motors of 100 hp., two being for reserve. A description of the substructure, with deep foundation piers carrying concrete boxes for the tail pits, was given in *Engineering News-Record,* Dec. 25, 1919, p. 1056. Another double-deck trunnion bascule bridge of the same type, but of 245-ft. span, carries Lake St. and the elevated railway across the Chicago River. In span, but not in weight, the Michigan Ave. bridge is surpassed by two other bascules of different types: the 336-ft., 3,750-ton Strauss trunnion bascule of the Canadian Pacific Ry. over the ship canal at Sault Ste. Marie, Mich., and the 310-ft., 4,500-ton Scherzer rolling-lift bascule over the Tennessee River at Market St., Chattanooga, Tenn.

Plans for the Michigan Ave. bridge were prepared in the city's bureau of engineering under the direction of Hugh E. Young, engineer of bridge design; Thomas G. Pihlfeldt, engineer of bridges; P. S. Combs, city engineer, and C. D. Hill, chief engineer of the Board of Local Improvements. William A. Mulcahy was chief engineer in charge of construction. The general contract was taken by the Great Lakes Dredge & Dock Co., which did the substructure work and steel erection, the steel being fabricated by the American Bridge Co. Erection was commenced Sept. 22, 1919, and completed Jan. 15, 1920.

Building Trades Receive Flat Increase of One Dollar Per Day

Acting upon a request from the Building Trades Council, New York City, for an increase in wages for all trades, the Executive Committee of the Board of Governors of the Building Trades Employers' Association has granted a flat increase, effective May 1 of $1 per day. Thereby modifying the wage scale fixed November 20, 1919. The new scale and the trades affected are given herewith:

	Per Day, Eight Hr.
Art Glass Workers	$8.00
Asbestos Workers and Insulators	9.00
Blue Stone Cutters	9.00
Carpenters	9.00
Dockbuilders, House Shorers and Sheathpilers	9.00
Cement and Concrete Workers (Laborers)	6.50
Composition Roofers and Waterproofers	8.00
Composition Roofers and Waterproofers (Foremen)	8.50
Electrical Workers	9.00
Electrical Workers' Helpers	5.50
Elevator Constructors	9.00
Elevator Constructors' Helpers	7.00
Hoisting Engineers, by the Week	52.25
Hoisting Engineers, by the Day	10.00
Hoisting Engineers, Running Compressors, extra per Week	7.00
Housesmiths and Bridgemen, Local No. 40	9.00
Housesmiths' Finishers, Local No. 52	9.00
Housesmiths' Helpers	7.00
Marble Cutters and Setters	9.00
Marble Carvers	10.00
Marble Polishers, Bed Rubbers and Sawyers	8.50
Marble Cutters' Helpers, Riggers, Crane and Derrick men	7.00
Mosaic and Terrazzo Workers	8.00
Mosaic and Terrazzo Workers' Helpers	6.50
Metallic Lathers	9.00
Plasterers	9.50
Plasterers' Laborers	7.00
Plumbers and Gasfitters	9.00
Roofers and Sheet Metal Workers	9.00
Riggers and Machinery Movers	9.00
Steam and Hot Water Fitters	9.00
Steam and Hot Water Fitters' Helpers	7.00
Stone Derrickmen	8.00
Tile Layers	9.00
Tile Layers' Helpers	7.00
Wood Lathers	9.00

Alaska Lignite Compares Favorably With That of North Dakota

Steaming tests on the relative value of Alaska lignite and spruce carried out by the Alaska station of the Bureau of Mines indicate substantially the same behavior as that of North Dakota lignite. From 3 to 4 lb. of water were evaporated in a 125-hp. water tube boiler with lignite obtained near the surface and therefore not considered of the highest quality available. The spruce evaporated 3.7 lb. After 14 months the loss of weight due to weathering of the lignite was 6.1 per cent.