D. L. & W. Completes Three-Track Lift-Span Bridge

New river crossing in Jersey City, N. J., has modern features of design and operation. Concrete approaches are a feature.

One of the largest railway bridge projects of the year is the new three-track lift-span bridge of the Delaware, Lackawanna & Western over the Hackensack river on its Morristown line, between Jersey City and Kearny, N. J., which was put in full operation early this month. This bridge, which has been under construction since March, 1927, has a total length, including viaduct approach structures, of about 1,500 ft. In addition, the bridge has earth embankment approaches at each end with a combined length of about 6,100 ft., which contain about 500,000 cu. yd. of fill.

The new bridge, which includes a vertical lift span providing a clear channel 150-ft. wide and a minimum vertical under-clearance of 40 ft., replaces an old swing bridge, which provided two clear channels at 65 ft. each, but an under-clearance of only 12 ft. at high tide. With such limited under-clearance, only a small percentage of the river traffic could pass the bridge without its being opened. This resulted in serious interference with the movement of trains, particularly with the commuter service to and from New York City during the morning and evening rush hours. Another important disadvantage in the old bridge was that, owing to the careless or reckless handling of boats in the river, the Lackawanna was in constant danger of having its old bridge damaged or destroyed, with the possibility of putting the entire line out of service. While these serious disadvantages pointed to a new bridge in the near future, the construction of the new bridge at this time was the result of an order by the War Department.

As the result of a careful study of the volume and character of the river traffic, it was evident that about 75 per cent of the vessels passing the bridge were 40 ft. or less in height. This lead to the decision to design the new bridge with an under-clearance of 40 ft. above high tide. As it was necessary to keep the river channel open for the passage of river traffic, and to prevent interference with the operation of the old bridge, the new bridge was constructed directly opposite the old bridge, on a new alignment, 65 ft. south of the old line; the total length of the line changed is about 7,200 ft.

General Description of Bridge

The new bridge includes the lift span, 198 ft. center to center of bearings, two tower spans, each about 85 ft. center to center of bearings, and three other fixed river spans of steel deck girders. All of the river spans, with the exception of the lift span, are provided with a reinforced concrete slab deck, which carries a standard rock ballast section.

The viaduct approaches leading to the spans on each side of the river are entirely of concrete with a girderless flat slab floor structure supported on cylindrical columns. The only exception to this is at a point where Duffield avenue and Meadow street intersect under the east approach. Here, on account of the wide opening necessary, deck plate girders were used instead of flat-slab construction. Beyond the masonry approach structures at each end, earth embankments provide runoff to connections with the old line.

All of the river piers of the bridge are of concrete construction, with a belt course of granite masonry within the tidal range to protect the concrete against the deteriorating action of the tide water in the river, and damage from ice or floating debris. The lift-span and tower piers, which have bearing on solid rock at a depth of about 91 ft. below mean tide level, were founded on pneumatic caissons, while all of the other river piers were constructed within open cofferdams and seated on timber piling driven to refusal. No particular difficulties were encountered in this work, although extreme care had to be exercised in the sinking of the lift-span and
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tower pier caissons to avoid disturbing the foundations of the old bridge.

Lift Span Has Many Interesting Features

The lift span of the new bridge, which was designed for Cooper's E-65 loading, consists essentially of two riveted Parker trusses with vertical hanger members at each end. These trusses have a maximum depth of 48 ft. at the center and a span of 198 ft. center to center of bearings. In order to minimize their weight, all of the chord and main web members of the trusses were fabricated from silicon steel and proportioned for a basic unit stress of 22,500 lb. per sq. in. The trusses are spaced 45 ft. center to center, which provides for three tracks on 13-ft. centers, and a side clearance of 8 ft. between the center-lines of the outside tracks and the inside faces of the truss members.

The deck of the lift span, which is of the ordinary floor-beam and stringer type, with three lines of 10-in. by 10-in. bridge ties, has a maximum depth of eight feet from the base of rail to under-clearance. This type of deck was adopted in order to minimize the weight of the lift span, and for this same reason, all of the floor beams were made of silicon steel.

In its normal seated position, the lift span has a minimum under-clearance of 40 ft. above high tide and 46\(\frac{1}{2}\) ft. above low tide. This permits the unrestricted passage of the larger part of the river traffic, but in order to take care of the larger vessels, a vertical lift of 95 ft. has been provided, which affords a maximum clearance of 135 ft. above high water.

Tower Spans Are 168 Ft. High

The lift span is operated between tower spans having a length of 84 ft. 10 in. center to center of bearings, and a height of tower of 168 ft. above the tops of the river piers. These tower spans are constructed entirely of carbon steel with the exception that the floor beams are of silicon steel. The deck of these spans, above the steel floor system, is a 12-in. slab of concrete. The front legs of the towers, which rise in a vertical plane and carry the greater part of the dead load of the lift span, have direct bearing on the channel piers through cast steel pedestals, while the rear legs, which are relatively light members, have a graceful curve extending from the tops of the towers to the bearing shoes on the river piers next to the channel piers.

The moveable span is balanced by means of two concrete counterweights which have direct connection with the span through a series of cables passing over sheaves at the tops of the towers. These counterweights, which operate within the steel-work of the towers, are monolithic concrete structures, rectilinear in shape, poured within steel box forms made up of steel plates with suitable diaphragms and cross bracing. In constructing the counterweights, each was designed to counterbalance one-half of the total dead weight of the lift span, or normally about 1,250,000 lb. The final balance of the weights was accomplished by the addition of precast concrete blocks, each containing about one cubic foot of concrete, which were placed within the two covered wells provided in each counterweight.

The counterweights are connected to the span by means of eight groups of eight two-inch cables, two groups being located at each corner of the span and passing over separate sheaves at the tops of the towers. In other words, eight sheaves, two on each side of each tower, equally share the total weight of the span and the counterweights. These sheaves have a pitch diameter of
13 ft. and, together with their shafts and bearings, have a total weight of about 230,000 lb. Each of the sheaves carries a load of about 300 tons. In providing two sheaves on each side of the towers, the sheaves were equipped with separate bearings, one set of bearings being located to the rear and outside of the other set of bearings for structural convenience. This necessitated an offset in the position of the groups of cable hitches at the counterweights, and also at the lift span, so that the cables in each group fall in a practically vertical plane. The cable connections at the span are made to the webs of a double-webbed transverse lifting girder, the spacing between the webs being equal to the longitudinal offset of the sheave bearings. All of the cable hitches to the span are effected through sockets and adjustable eye-bolts.

While there will be little occasion for slacking the counterweight cables in order to make sheave or cable adjustments or repairs, provision has been made for this emergency through special hanging and jacking frames, provided at the top of each of the towers. Through this arrangement the counterweights can be raised and hung above their highest normal position, slacking the cables for such purpose as may be necessary.

Special Arrangement Compensates

Shifting Cable Weight

The weight of the main cables rolling over the sheaves from the span side to the counterweight side and vice versa, is compensated by a special type of equalizing arrangement. This consists of a 56-ft., A-frame rocker bent mounted, by means of trunnions and bearings, on top of the lift span at the center, which is held in an up-right position by four one-inch cables which loop around an anchor drum at the top of the bent and extend to a point near the top of each tower. At the east end, the cables have fixed connections, but at the west end they pass over a sheave and have connection with an auxiliary counterweight which operates in a vertical plane against guides. Through this arrangement, all of the various degrees of unbalance between the counterweights and the counterweight side of the tower sheaves, the action is reversed and the downward vertical component of the force exerted by the equalizing arrangement tends to add to the weight of the span.

Span Operation Has Four Sources of Power

Power for the operation of the lift span is supplied from four independent sources, which make a complete power failure of the bridge almost an impossibility. Three power units are installed on the bridge. These consist of a motor-generator set and a gasoline engine-generator set, both of which drive two span-operating motors, and a gasoline engine, mechanical-drive auxiliary unit, which is entirely independent of the electrical equipment. Both generator sets are located in the bridge operator's house in the east tower, while the span motors and the gasoline engine auxiliary unit are located in a machinery house on the lift span.

The motor-generator set consists of a 300-hp., 3-phase, 60-cycle, 440-volt, squirrel cage a. c. motor with a full load speed of 1,160 r.p.m., which is direct-connected to a self and separately-excited, 200-kw., 500-volt differentially compound-wound generator. Electric current for the operation of the motor-generator set and for bridge
lighting is supplied over two independent power lines, both delivering 3-phase, 60-cycle current at 6,900 volts. These power service lines are brought in from opposite ends of the bridge and both extend directly into the operator's house in the east tower.

In the present power arrangement, the line from the east end is utilized as the main power feeder, but both this line and the west line have connection within the operator's house with a battery of 100-k.v.a. transformers for reducing the voltage delivered to the motor-generator set. Both lines also have connection with two 5-k.v.a. transformers for furnishing 220 and 110 volts for the bridge lighting circuits. Power cables to the motors and lighting circuits on the lift span are carried on the rocker bent cables, then down the rocker bent and into the machinery house. Through this arrangement, the conductors are kept taut in all positions of the span.

Motors ordinarily work together in series, but they are so arranged that in case of emergency, either motor may be cut out of service and the span operated by the other motor alone. Both of the driving motors are directly-connected through a train of gears to a single drive shaft which extends across the lift span. At each end, the drive shaft is gear-connected to two winding drums which actuate the up-haul and down-haul ropes in raising and lowering the span. Each of these drums carries two one-inch up-haul and two one-inch down-haul cables leading to the towers, one set of ropes winding in the grooves of the drums while the other set is unwinding. Steel plate wind guards on each side of the hauling ropes, as they extend vertically up the front legs of the towers, have been provided to prevent the humming and clapping of the ropes together.

The third means provided for operating the lift span in

The General Plan and Elevation of the Lift Span

The gasoline engine-generator set, which is provided for use in case of a complete power line failure, is capable of delivering only one-half the output of the motor-generator set, and, therefore, operates the bridge at about one-half the speed attained with the motor-generator set. This unit consists of a Sterling water-cooled, tractor-type, eight-cylinder gasoline engine, capable of developing 240 b. h.p. at 1,200 r.p.m., which is direct-connected to a 100-kw., 300-volt, differentially compound-wound, direct-current generator. While only half the capacity of the main generator, this unit, like the motor-generator, is capable of operating the lift span by either one or both of the driving motors.

The main driving units of the lift span are two 150-hp., d.c. motors, operated on 230 volts at 475 r.p.m. These case of an electrical failure, is the gasoline engine unit which is located in the machinery house on the lift span. This is a Sterling tractor-type, water-cooled, six-cylinder engine, capable of delivering 180 b. h.p. at 1,200 r.p.m., which is clutch-connected to an arrangement of hoisting machinery, which, in turn, is gear-connected to the main span driving shaft. With this equipment, operation of the span is considerably slower than when the motor-generator is used, but as in the case of electrical operation, the span can be raised or lowered and held in any desired position.

The Machinery and Operating Houses

The machinery house, including the span-driving motors and the gasoline engine unit, is a single-room,
one-story structure, about 18 ft. by 26 ft., located above railway clearance in the middle panel of the lift span. This house, which is of fireproof construction throughout, has a four-inch reinforced concrete floor, and steel side and roof framing which is covered with Johns-Manville 3/4-in. Transite corrugated asbestos board. In addition, the roof is covered with a four-inch course of aerated gypsum, on top of which is built-up asbestos-asphalt roofing. The entire interior of the house is furnished with Transite asbestos board. All doors and window sash in the house are of steel and are glazed with wire glass.

In order to provide for lifting heavy supplies and equipment up to and within the house, both the inside and exterior of the house are served by four-ton Yale & Towne hand-operated hoists. The hoist within the house operates on a bridge crane, while the outside hoist operates on a trolley beam extending around the house. The operator's house, which is located above railway clearance in the east tower, is a one and two-story structure, and, like the machinery house, is entirely of fireproof construction. The two-story section of the house, which is about 15 ft. by 40 ft. in plan, is located directly between the main tower trusses, while an additional section, approximately 18 ft. by 38 ft. and only one story high, located at the first floor level of the main house, extends outside of the north truss of the tower and is carried on cantilever girders. The first floor in the main part of the house is occupied principally by the two generator sets and the transformers, while the upper floor is divided into a relay room, a signal maintainer's room and a toilet. The single story section of the house, extending from the north side of the tower, has one large room in which are all of the bridge controls, an interlocking machine, an illuminated track model, power circuit panels, and a small stove for auxiliary heating purposes. The main heating system of the operator's house is by steam furnished by a small heating plant installed on the east bank of the river under the bridge approach viaduct. The control room was located clear of the tower to give the bridge operator a clearer view of the lift span and the river channel. Like the machinery house, the operator's house is served by a four-ton, hand-operated trolley hoist, operating between the tower trusses, on the east side of the house.

In order to insure the safety of train operation over the bridge, all three of the bridge tracks are protected by color-light signals and split-switch derailed, located about 300 ft. each side of the lift span, the center track being signalled for two-way operation so that it can be used as a second east-bound track during the morning rush hours and as a second west-bound track during the evening rush hours. In addition, the lift span is equipped with rail locks, bridge locks, and circuit controllers, which are so interlocked with the signals and derailed that no movement of the lift span is possible until the signals and derailed are set in the danger position.

Both the rail locks and the bridge locks are of the electro-pneumatic plunger type, similar to a number of other installations made in recent years, including the new four-track double lift-span bridge of the Central of New Jersey over Newark bay, a few miles south of the Lackawanna's new bridge. In this type of locks a plunger is forced through slots provided in the movable and fixed parts of the locks when the lift span is fully seated.

**Safety Equipment Operation**

All of the safety equipment in connection with the bridge is operated by one man through an interlocking machine and a power control bench in the operator's house. The actual raising or lowering of the movable span requires about 1 1/2 minutes. The raising of the lift span can be accomplished only by following a predetermined sequence of operations, each of which is dependent upon the one preceding it. In the first place, all track signals must be set at stop; then the derailed can be opened, following which the operator can release the rail locks and then the bridge locks. These latter operations permit the unlocking of the bridge motor circuit controllers and make it possible for the operator to raise the span. Before rail traffic over the bridge can be restored, all of the various operations mentioned must be performed in the reverse order, the last being the clearing of the track signals. In raising or lowering the span, over-run of the high and low limits of travel is prevented by a series of limit switches in the control circuit, which cut off the power and set the power unit brakes. Further protection in this connection is provided through a lifting leeway of four feet at the top of the towers above the normal maximum opening of the span, and through pneumatic buffers at all four corners of the span, which prevent its being seated with a shock.

While the lift span and the flanking tower spans are...
possibly the most striking parts of the new Hackensack River bridge, these units form only a relatively small part of the entire bridge project, for in addition to these spans, the entire river crossing includes three other river spans, 814 ft. of concrete viaduct and 6,100 ft. of approach embankments. On the east side of the river there is only one fixed river span, 110 ft. in length, while on the west side there are two fixed spans, one, 110 ft., and the other, 75 ft. long. All three of these are structural steel deck girder spans. Like the deck of the tower spans, the deck of the three plate girder river spans consists of a reinforced concrete slab, 12 in. thick, which supports a full-ballasted roadway carrying the tracks.

In general, both viaduct approaches to the river spans are of similar construction, consisting of rectangular slab deck spans, 22 ft. 6 in. in length, supported on bents of three columns each. The concrete deck structure, which consists of regular rectangular panels, continuous between expansion joints, is 46 ft. wide, providing room for three bridge tracks on 13-ft. centers, and ample clearance between the outside tracks and the balustrades which line each side of the deck.

The system of spans from one expansion joint to the next was designed for a loading of two E-65 engines per track, followed by a uniform load of 6,500 lb. per linear foot, the loads being so placed as to give conditions of maximum column reaction and maximum bending moments in the spans. The slabs, which are reinforced longitudinally, transversely and diagonally in both directions, are 22 in. thick, with an additional thickness of 10 in. in the drop panels directly over the bent columns.

The balustrades along each side of the viaduct were formed integral with the deck slabs and were made of sufficient section to form a pleasing appearance, and at the same time, to form a safeguard in the event of a derailment. Within the balustrades, a series of ducts carry all power and signal circuits which lead to the lift span or across the river on the bridge, pull boxes being provided at the signal bridges and in the safety bays provided for the safety of employees.

Drainage of the entire concrete deck, including that over the deck girder river spans and the tower spans, is effected by suitable pitches in the upper surface of the slabs, carrying the water to four-inch openings through the slabs. The entire deck is waterproofed by two-ply asphalt-saturated fabric, which is protected against abrasion and the cutting action of the stone ballast by a course of 8-in. by 4-in. Hastings asphalt blocks, 1¾ in. thick. These blocks were laid in asphalt and then flushed with hot asphalt to seal all joints. At the sides of the slab, the waterproofing is carried up the sides of the balustrades to a height of 20 in., and is protected by a single course of common brick.

The bents of the viaduct consist of three columns, 3 ft. 8 in. in diameter, spaced 18 ft. center to center. These columns, which are reinforced both longitudinally and spirally, range from 36 to 41 ft. in height. Owing to the unstable character of the soil on both sides of the river, unusual precaution had to be taken in the footings for the viaduct bents. In general, therefore, the columns of each bent rest on continuous concrete piers, which, in turn, are supported on either timber or concrete piles. In addition, all of the piers are tied together longitudinally by sub-surface reinforced concrete struts extending in line with the outside rows of columns. Where conditions were most severe, two such lines of struts were provided to prevent any possibility of the shifting of the bent footings.

In the east viaduct, with the exception of the first three bents from the river span abutment, Raymond cast-in-place concrete piles were used, these ranging from 25 to 38 ft. in length. In the case of the first three east viaduct bents, and at all of the bents in the west viaduct where piles exceeding 40 ft. in length were required, untreated timber piles were used.

At the extreme west end of the west viaduct, where the soil was found to be extremely unstable, and where the superimposed load includes both the live and dead loads of the viaduct and the weight of the earth in the high approach fill extending under the viaduct, special foundations were found advisable. At this point, therefore, which includes the four most western bents, the pier at the foot of each bent is a concrete beam, six feet wide by nine feet deep, extending the full width of the bent. This is supported on two concrete shafts, eight feet in diameter, and carried down about 70 ft. to rock. These shafts, which are located at each end of the piers, were constructed by driving steel sheet piling to rock, excavating within the piling with an orange peel bucket, and then filling the excavated area with concrete.

A Cantilever Pier Was Necessary in East Approach

The only exception in the uniformity of the viaduct approaches occurs in the east viaduct where it passes over Duffield avenue at an angle of 78 deg., and at the same point extends over a part of Meadow street, which cuts under the south side of the viaduct and intersects Duffield avenue directly under it. In order to keep both of these streets free from obstruction, a 75-ft. steel deck girder span was constructed over Duffield avenue for all three viaduct tracks, and on the east side, these were joined with a 75-ft. single-track deck girder span carrying the most southerly track, and a three-panel section of the flat slab type of viaduct carrying the two northerly tracks. This arrangement avoided the construction of piers in Duffield Avenue, and necessitated the construction of only one pier which could in any way encroach on Meadow street, this being the east pier at the Duffield avenue crossing.

In order to prevent the encroachment of this pier on Meadow street, a special pier design was developed with a heavy cantilever bracket on the south end of sufficient height to permit the movement of street traffic under it. This cantilever section of the pier supports the abutting 75-ft. girders carrying the most southerly track over Duffield avenue and over the intersecting portion of Meadow street. This cantilever section, which is reinforced to resist a moment of more than 130 million inch pounds,
and a shear of 1 1/3 million pounds, projects 12 ft. 6 in. over the street, is 10 ft. deep at its outer end, 14 ft. deep at its junction with the pier proper, and is 7 ft. 6 in. thick.

The embankment approaches to the viaduct at both ends of the bridge are entirely of earth, and together required the handling of about 500,000 cu. yd. of material. At the west end, the fill is about 4,700 ft. long and about 46 ft. high at its highest point, while at the east end the fill is about 1,400 ft. long and has a maximum height of 42 ft. The embankment on the west side was allowed to take a natural slope throughout its length, but in constructing the east embankment it was necessary to build a high retaining wall, 300 ft. in length, on the south side in order to prevent the encroachment of the fill on Meadow street. Practically all of the grading work in both approaches was carried out with motor trucks, which hauled the filling material direct from numerous construction projects in and about Jersey City.

Few Serious Constructional Difficulties Were Encountered

In constructing the new Hackensack River bridge, a number of interesting, although not particularly serious problems arose. The chief problems were in connection with the viaduct footings in the unstable soil of the Hackensack meadows, and the construction of the lift span so as not to interfere with the operation of the old swing bridge, which when in an open position, fouls the lift span in its lowered position. In this latter work, it was necessary, therefore, either to erect the complete lift span on barges and float it into place, or to erect the span at a point high enough between the towers to permit the end of the old swing bridge to pass under it.

As carried out, a combination of these methods was used. In the first place, about two-thirds of the span was erected from the east tower, at an elevation in the approach and the approach tracks for delivering the steel work with the exception of the concrete piles in the approach footings, which were placed by the Raymond Concrete Pile Company, New York. All of the steel-work of the bridge was fabricated and erected by the American Bridge Company, which also had the contract for installing all of the electrical and control equipment. The electrical equipment was furnished by the Crocker-Wheeler Company, while the bridge control equipment was supplied by the General Electric Company. All of the signal and interlocking equipment in connection with the bridge was furnished by the Union Switch & Signal Company, and was installed by the signal department of the road. The actual construction work on the project was carried out under the general supervision of M. H. Doughty, division engineer, and under the direct supervision of W. H. Speirs, resident engineer, both of the Lackawanna.

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Mountain Type Locomotive on the D. & R. G. W.