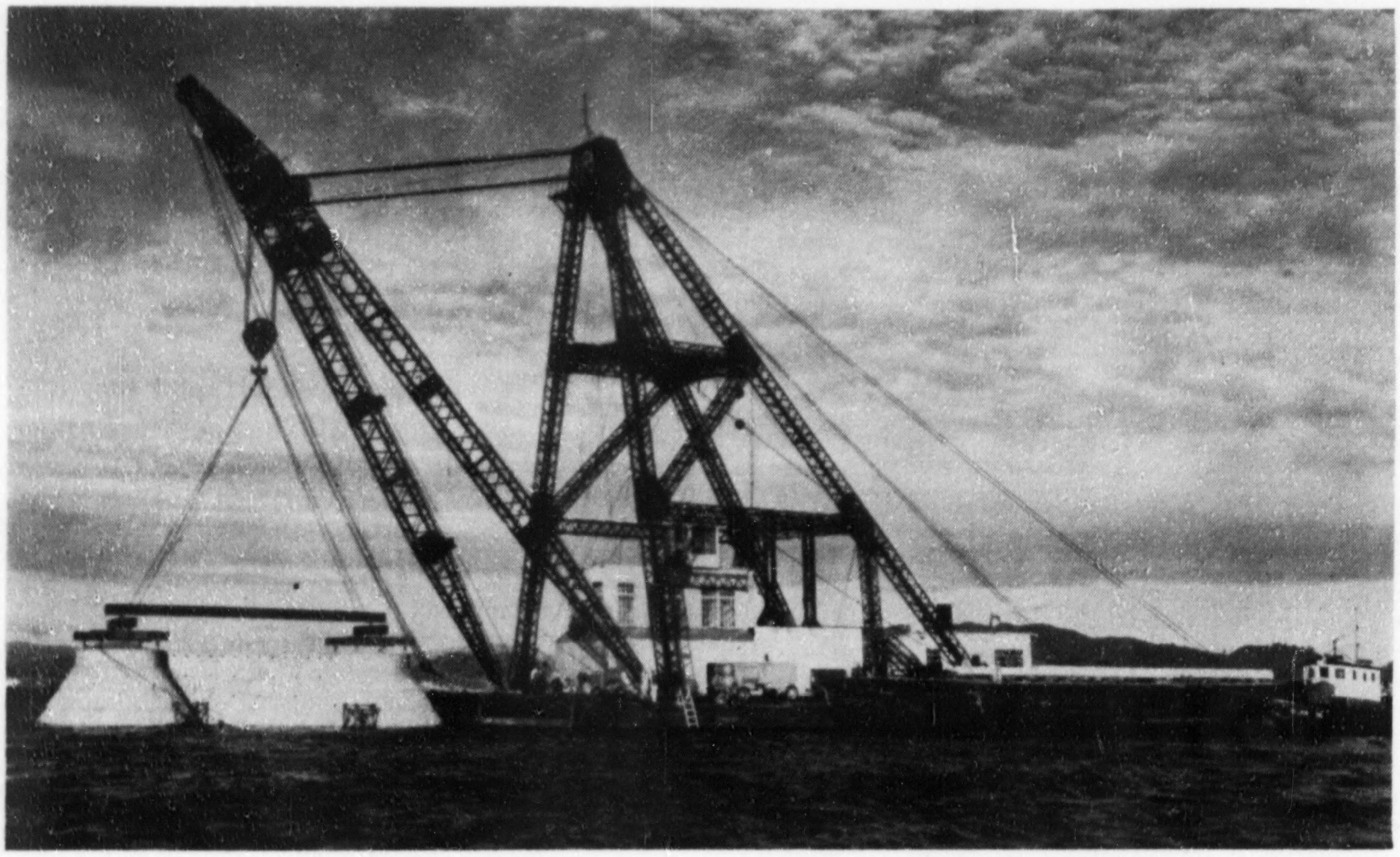

DOUBLE CONE SHELL is set for Richmond-San Rafael Bridge pier by 150-ton floating derrick. These cones rest on top of cylindrical shells already in place and marked by steel towers shown protruding from the water.

Deep piers formed with huge precast units

Bridge marks first use of precast concrete for big bell-bottom pier bases and requires derrick lifts up to 105 tons

Deep-water piers for the Richmond-San Rafael Bridge are being built of precast concrete shells assembled under water. The reinforced-concrete shell units serve as outside forms for filling with tremie concrete to make a solid pier structure.

The four-mile vehicular bridge is being constructed across the north arm of San Francisco Bay under a $62-million financing that is officially called the Richmond-San Rafael Bridge Toll Bridge Revenue Bond issue. The structure will have two 36-ft decks, each with three traffic lanes. It crosses two 1,00-ft wide ship channels, spanning each with a steel cantilever structure with 537-ft anchor arms. The bridge also will have 36 truss spans, each 289 ft long, and 36 girder spans, each 100 ft long. This requires 79 piers, 62 of which are of the deep-water bell-bottom type. The remainder are cofferdam and land piers.

• Departure from ordinary—The concrete-shell method is a departure from recent practice in construction of bell-bottom piers. For example, at the Chesapeake Bay Bridge, non-reusable steel forms held the underwater concrete. And, as a matter of fact, at Richmond-San Rafael there are nine of the larger piers where such steel forms are used for part of the structures. But 53 of the deep-water piers are formed almost entirely of concrete shells.

Credit for development of the concrete shell procedure is due the contractors on the substructure work—a joint venture of Ben C. Gerwick, Inc., and Peter Kiewit Sons Co., holders of a $14-million contract. Experience gained by Gerwick, in using similar methods on construction of piers for a San Francisco Bay crossing of a Pacific Gas & Electric Co. transmission line (ENR March 5, 1953, p 30) convinced both contractors and state officials of the feasibility of the concrete shell method, and that smaller job gave valuable experience to contractor personnel who are now working on the bridge job.

Plans, drawn by the Division of S. F. Bay Toll Crossings of the California Department of Public Works, called for bell-bottom piers. But the plans did not give detailed instruction on construction methods. Thus, the contractor was able to develop new methods for bridge pier construction, subject, of course, to approval and suggestion by state engineers. Other recent bridge jobs not only called for a definite type of bell-bottom pier but gave detailed instructions on methods of construction.

The bell-bottom pier with concrete placed under water was adopted by the state only after several different caisson and cofferdam designs were considered. State engineers estimate the bell-bottom design saved about $1 million over the next cheapest.

• Piles driven first—Profile of the bay bottom varies widely in the four-mile length of the bridge. At some points, rock is very near the surface, but, generally, the mudline is at a 40 to 50-ft depth, and rock (or in some instances a firm sedimentary stratum) is 140 to 150 ft below that. This means that all the deep-water piers must be pile-supported. And the plans require that the piles be driven through a template to assure proper positioning.

The contractor elected to use a concrete template, rather than the more common timber. The concrete is heavily reinforced, is 12-in. thick, and has H-slots in it for pile positioning. It serves a triple purpose, being also used as a bottom form for the tremie concrete that forms the bulk of the pier, and as a seat for the lower shell sections.

First construction step is to excavate a 12-ft depth of mud, then drive timber falsework piles to support the concrete grids. The piles are cut off to proper elevation by an underwater saw operating from telescopic pile driver leads.

The grids are set in pairs, connected by a steel spreader truss. Mounted on each grid is a steel pipe cage with a centering mast for the precise alignment of the units. These towers are removed before pile driving begins.

Since the 62 deep-water piers vary greatly in size because of difference in weight that they must support, the number of piles for each bell differs considerably. They range from 14 to 34 ft in diameter and from 15 to 77 piles per bell (14-in., 89-lb H-sections calculated to support a 60-ton normal load in hard strata or 100 tons under earthquake load). Both plumb and batter piles are used. The batter is 2 in. 12 for interior piles and 3 in 12 on the outer circumference. Number of plumb piles varies from 40 to 70% of the total under each pier leg.

The vertical piles are driven first to anchor the grids in place and also to establish the length of other piles. Then tremie grout is introduced into the space between the pile and the H-slots in the grid. The purpose is to provide bond between pile and grid as well as to retain the tremie concrete. This gives support to the structure above in addition to that provided by the timber falsework piles. And it is a safety factor in case

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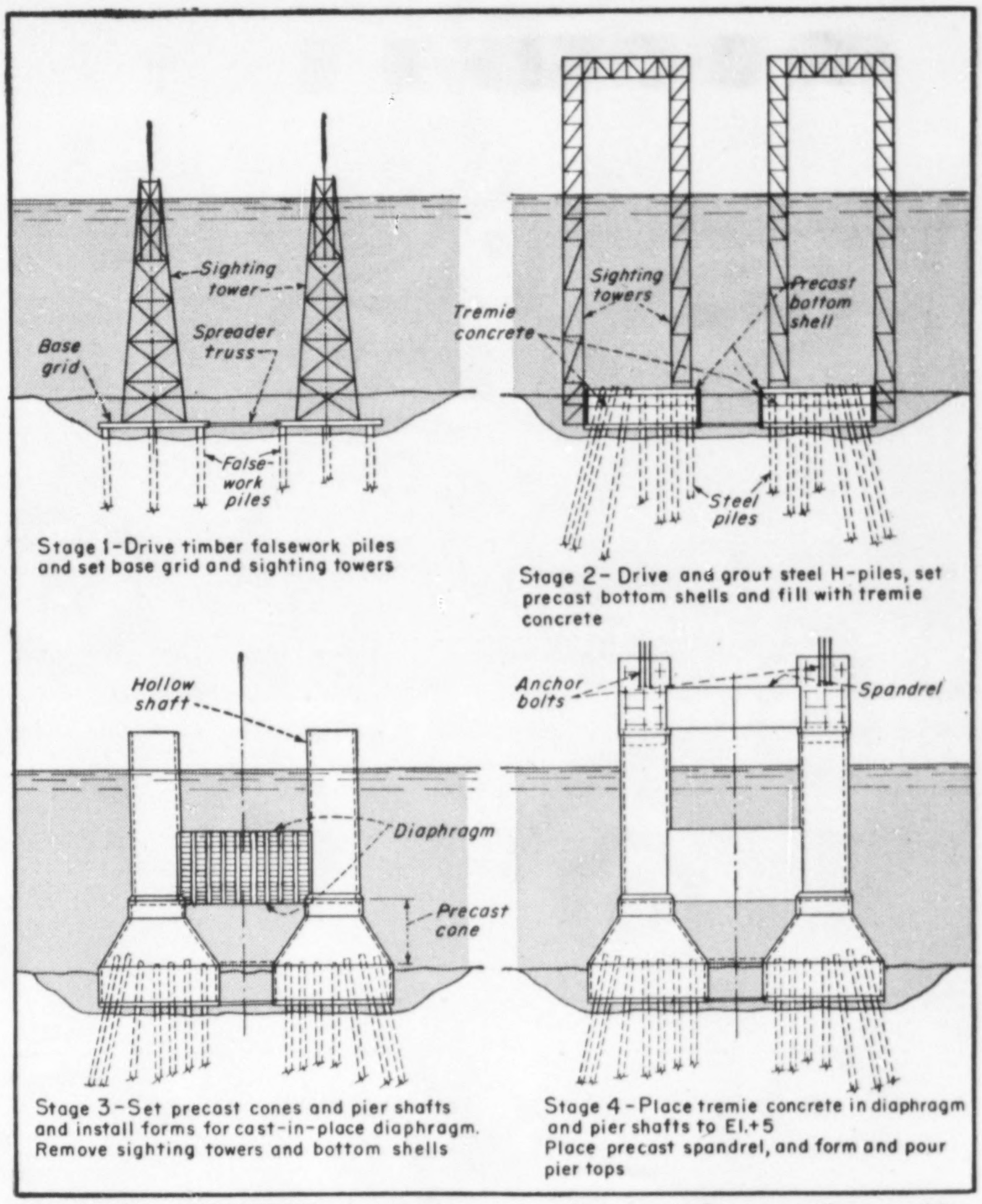
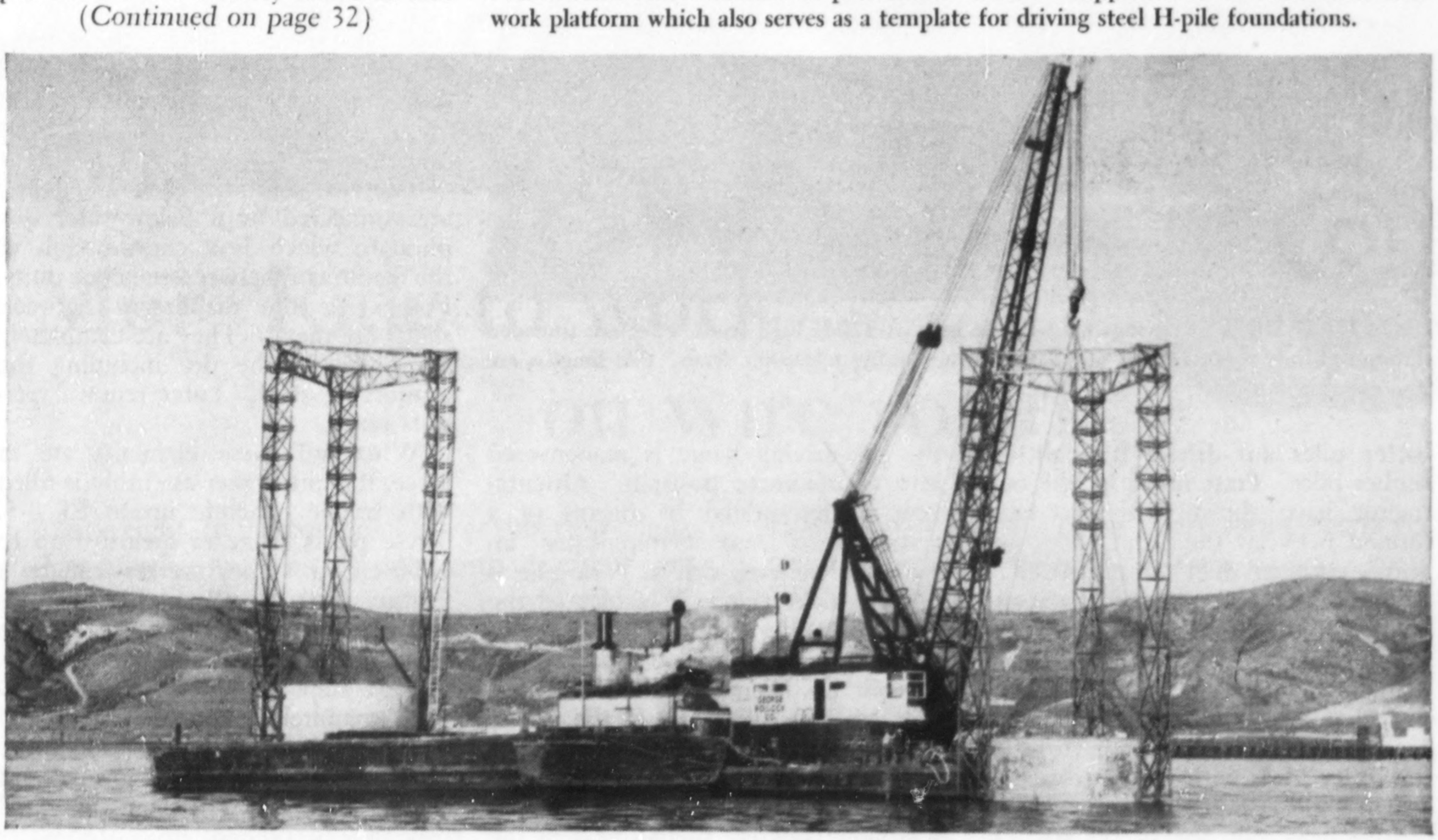
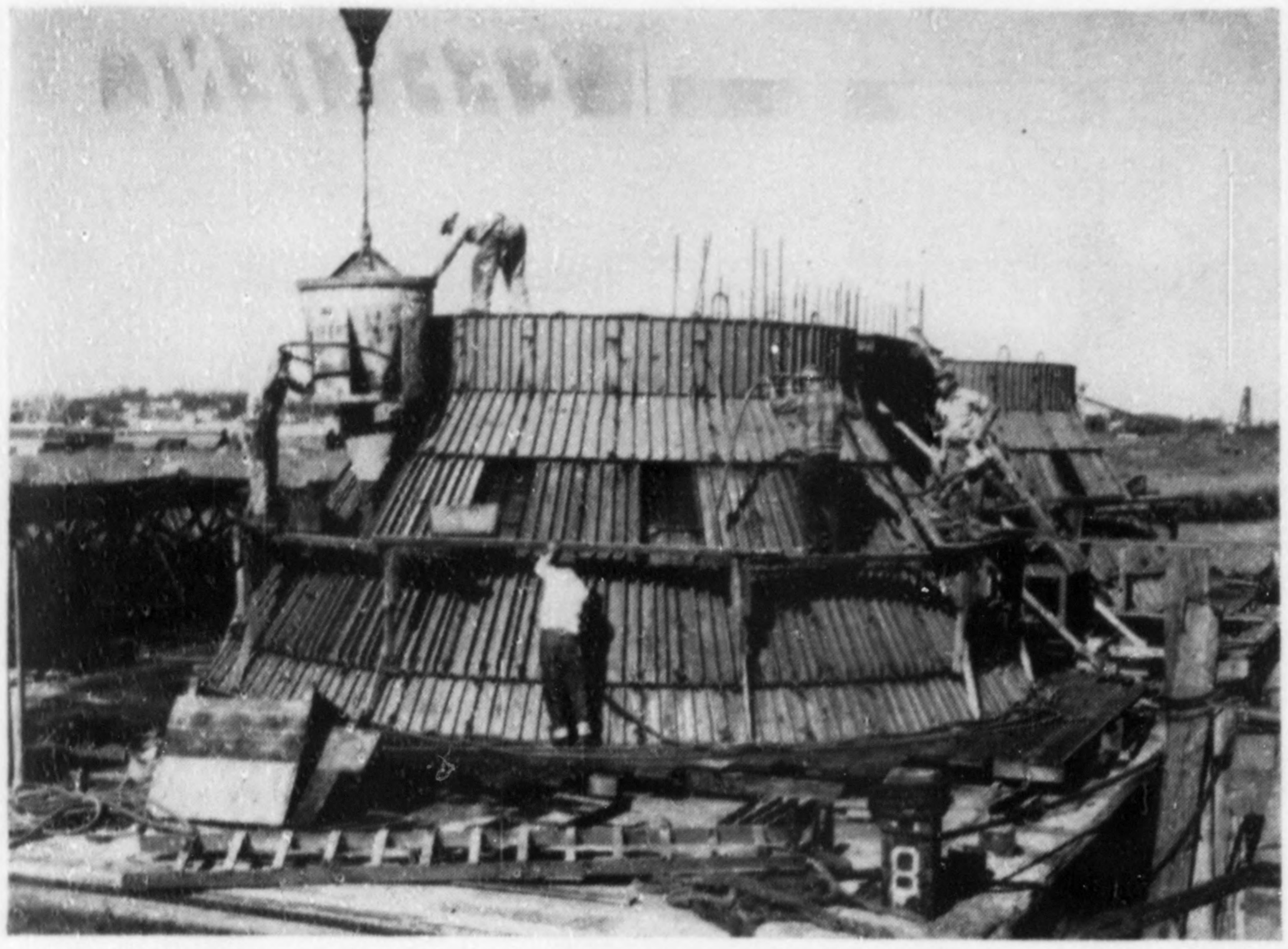


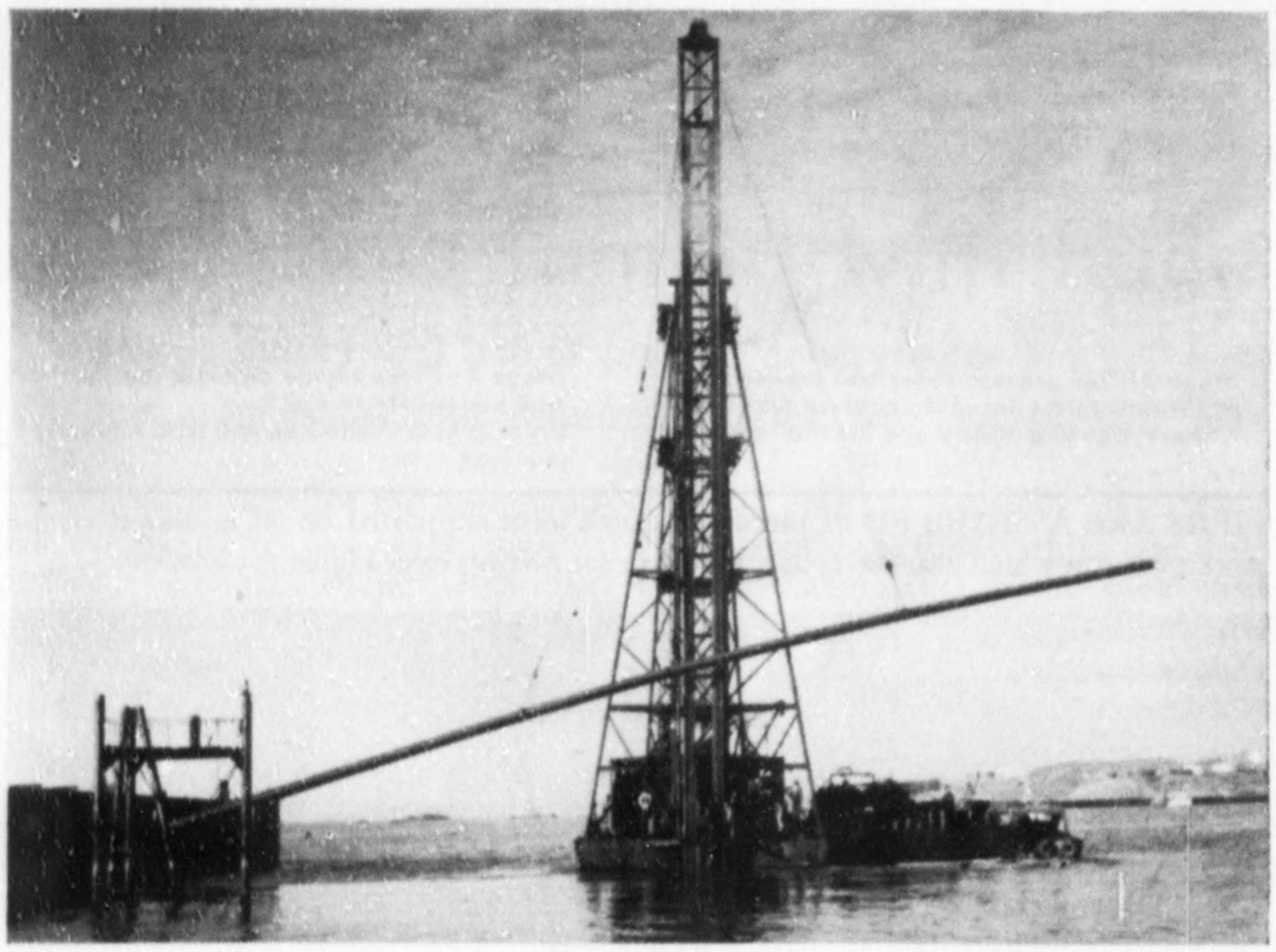
PIERS ARE ASSEMBLED of precast concrete units supported on an underwater falsework platform which also serves as a template for driving steel H-pile foundations.



FLOATING CRANE SETS a bottom shell for one of the Richmond-San Rafael Bridge piers. Steel towers attached to the precast concrete shell will guide additional pier elements into position. Mate to shell being placed waits on barge.



POURING PRECAST UNITS is accomplished at yard some 20 miles from bridge site. Using specially-designed forms, cone and diaphragm shells are cast on barges to eliminate one lift of the units weighing in excess of 100 tons.



FLOATING DRIVER swings long H-pile into its 120-ft high leads. Piles are threaded through H-slots concrete grid 60 ft under water using telescopic leads. Pile lengths are as great as 200 ft.

batter piles are driven through the timber piles. Tests made by the contractor have shown that the bond formed between the grout, piles and grid is stronger than the grid itself.

Next, the batter piles are driven and grouted for additional support and an added safety factor.

Piles are delivered to the work on a surplus LSM converted into a barge. The two drivers on the job have 120-ft stationary leads with 120-ft telescopic leads. They are said to be the largest floating drivers on the West Coast.

Piles are picked up from the LSM barge and, by means of anchor lines, the pile-driving barge is maneuvered into approximate position. Orientation is determined by means of a gyro-compass and gyro-repeater installation on each driver. The pile is lowered to within a few feet of the grid and a diver sent down to "talk" the barge into exact position. Once the pile has been introduced into the slot the diver surfaces and the pile is driven. From 15 to 40 minutes is required to drive each pile.

• Hollow concrete shells—Next in the pier construction sequence are the hollow concrete bottom shells. The 9 ft high shells are positioned by guide plates cast in the grids; however, a diver checks exact position as the units are lowered.

Each bottom shell is handled by 3 tubular steel towers extending above water. These towers are also used to position and brace following concrete elements. The steel towers also support tremie pipes for concrete placing.

After the bottom shells are in position, a 5-ft thick lift of tremie concrete is placed. This bonds the structure to the H-piles for positive support of the rest of the pier as it is built.

Heaviest lift comes next. It comprises a pair of twin truncated cones connected by a concrete diaphragm shell and weighs up to 105 tons. The cone units fit over reinforcing steel extending up from the previously set bottom shells so that, when the tremie concrete core of the pier is placed, the reinforcing provides positive bond between bottom section and cone.

(Fifty-three of the deep water piers are "2-belled" piers and nine are "4-belled" piers. From the cone section on up, the 4-belled piers are formed with steel shells. These shells are light enough to be handled by the contractors' derrick barge whereas concrete 4-belled shells would be prohibitively heavy. These 4-belled piers are required for the main towers on the cantilever portion of the bridge and for anchor piers.)

Next comes concrete shafts weighing up to 101 tons each that take the pier structure above water line. These shafts are positioned by the tabular towers attached to the bottom shell. A turnbuckle arrangement holds them in place until tremie concrete can be poured.

The two shafts in each 2-bell pier are connected by a below-water diaphragm, which is a continuation of the diaphragm between the cone units. Forms for the diaphragm between shafts are metal. They are completely assembled in the dry including the reinforcing steel. Later removal permits reuse.

When all these elements are in place, the entire pier assembly is filled with tremie concrete up to El +5. These pours range in quantity up to 1000 cu yd. They are serviced by a floating concrete plant. The plant is supplied by aggregate barges and a converted LSM carrying bulk cement.

Next step is to place precast concrete spandrel beams on top of and between the shaft units. Then the pier top up to El +13 is formed and anchor bolts set. When this final concrete is poured, the deep-water piers are finished except for form

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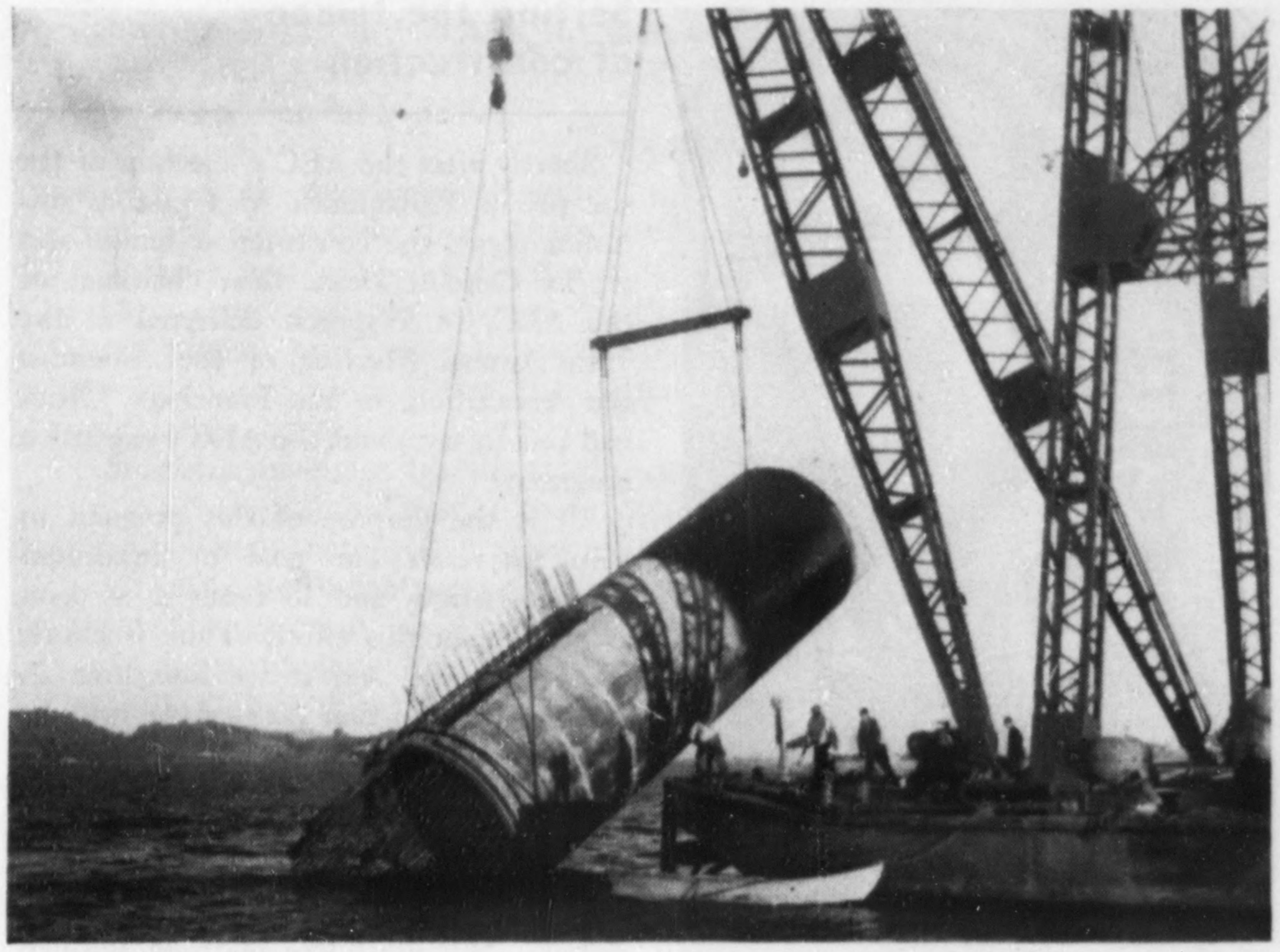

HOLLOW SHAFT goes into the water. Note opening in shaft for diaphragm connecting it with adjacent shaft. Concrete is coated with protective compound in area subject to alternate wetting and drying.

CONCRETE from a floating plant is placed through long tremie pipes. Plant is serviced by aggregate barge placed on one side and cement barge feeding from the other side.

stripping and removal of the steel towers.

• Rigorous time schedule—The substructure contractor is required to deliver piers for steel erection in accordance with a tight time schedule. Each of the 62 deep-water piers is scheduled for an individual completion date ranging from early in 1954 to mid-1955. A liquidated damage penalty equaling the bond interest per day will be assessed when any one of the piers is late. So far the substructure contractor is on schedule. Completion of the bridge, including steel superstructure and approaches under separate contracts, is expected by October, 1956.

The project was designed and construction is being supervised by the Division of S.F. Bay Toll Crossings, California State Department of Public Works. Norman C. Raab is projects engineer, Ben Balala resident engineer.

The Gerwick-Kiewit joint venture is under the general direction of Ben C. Gerwick, Jr., vice-president of Ben C. Gerwick, Inc. Don Weaver is project manager, Wm. Talbot is project engineer and John Ford is project superintendent.

NOVEMBER 4, 1954

ENGINEERING NEWS-RECORD

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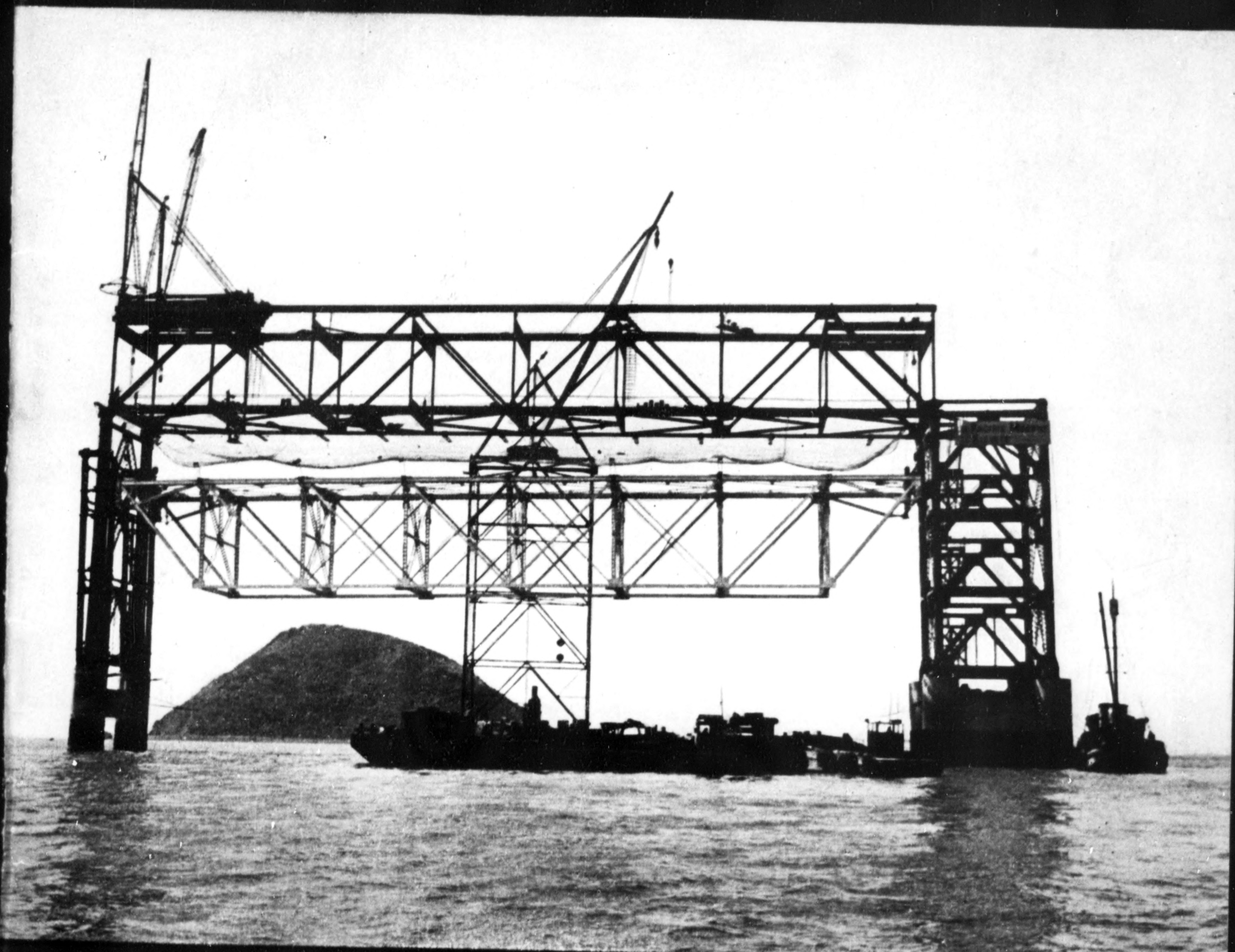
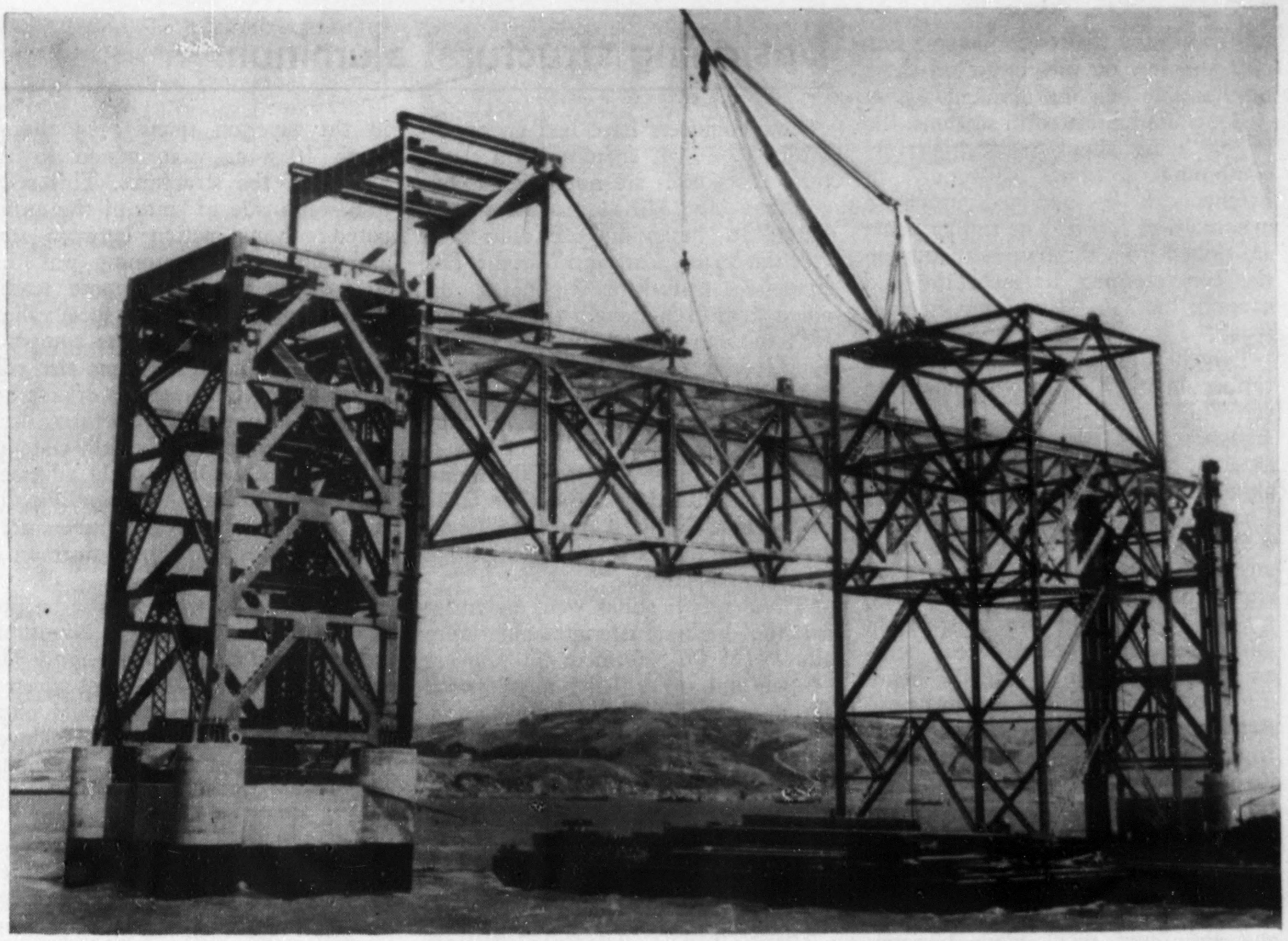


Something new in bridge erection—Aluminum truss span forms work platform

★ Stress losses in prestressed concrete p. 37

★ Astronomers' "eye" is tough construction job

A McGRAW-HILL PUBLICATION



STEEL TRUSS SPAN for California bridge is assembled in place on aluminum erection span. Derrick barge services the steel work; later spans will be erected by a traveler riding the steel work. Aluminum span is supported by timber bents bolted to the towers.

Aluminum spans, 280 ft long, speed bridge truss erection

An innovation in bridge building practice has been developed by contractors who are erecting the superstructure of the Richmond-San Rafael Bridge across the north arm of San Francisco Bay (ENR March 4, 1954, p. 30).

Steel truss spans, 289 ft long, are being erected in place on work platforms formed by 280-ft long aluminum truss spans. The procedure promises greater safety in deep-water operations and speed at least equal to conventional methods.

Traditionally, two methods of truss span erection have been followed: Assembly in place on some sort of falsework platform, or pre-assembly and floating into position.

Falsework has been constructed in some instances on temporary pile bents, but for Richmond-San Rafael, pile lengths would have to be too great for this procedure to be economical. In other cases, steel trusses to be used elsewhere on the job have been used temporarily as erection spans. This was ruled out by Judson-Pacific-Murphy Corp., and Peter Kiewit Sons Co., contractors, because of the weight of the steel spans—in excess of 400 tons.

Floating the spans into place was also ruled out: the steel truss assemblies are too heavy for economical hoisting operations; floating in at a high level was considered too risky since some spans are as much as 170 ft above mean sea level, and the site is subject to treacherous tidal currents and high winds.

However, eight smaller spans—of the total of 36 truss spans—are to be floated in place. These are located near the shore—seven on the Richmond side and one on the San Rafael side—where land masses provide wind and tide protection. They will be set at a relatively low elevation—so low that the aluminum erection spans would have been partially submerged. Electrolytic corrosion of the aluminum in salt water was a contributing factor in the decision to float the low level spans.

Credit for developing the aluminum erection-span method belongs to J. Philip Murphy, president of J P-M, which is acting as job sponsor for the joint venture.

Advantages attributed to the method by Murphy are: A solid working surface is made available; the 117-ton weight of the aluminum spans can be hoisted into position with equipment required for other phases of the erection work; no heavy spans are transported at high level with danger of tipping. And the procedure eliminates the use as falsework of permanent steel intended for use elsewhere on the job.

• **Two spans used**—Two aluminum erection spans were fabricated, at a cost of $150,000 each.

A span is made up of two trusses framed together by top and bottom lateral systems. Truss depth is 36 ft, center-to-center of top and bottom chords. The trusses are spaced on 42-ft centers which is the same as the permanent steel spans. Erection truss panels are 36 ft wide—identical with the steel truss panel width.

The erection spans are supported on timber bents resting on the concrete bridge piers. The bents provide vertical support only; they are clamped

(*Continued on page 34*)

to the bridge towers for lateral support and rest on pin-connected shoes to eliminate bending moment.

Bents are fabricated in sections, the largest being about 30 ft high. By combining sections, a variety of heights can be obtained up to a maximum of 150 ft. The timber bents are sloped from the base that rests on the concrete pier to meet the end shoes of the 280-ft aluminum erection spans.

Largely due to the slope of the timber bents, they are designed to carry no lateral load. Such loads are transferred to the steel bents by shear lock beams at the level of the aluminum truss upper chord.

• Start at a fixed pier—Truss span erection starts at one of five fixed anchor piers and moves, span by span, to one of the split tower expansion joint piers. Intermediate steel bents are flexible enough to take the bending necessary to pull them into position to pin to the permanent steel trusses. Making this connection is, perhaps, the trickiest part of the erection sequence, since it requires both a vertical movement of the truss and a horizontal movement of the bent.

Complicating the erection procedure is the fact that both the steel and aluminum spans move horizontally and vertically between the unloaded condition and the loaded condition. For example, the bottom chord of steel trusses are longer when supporting the dead weight of the steel trusses than when being supported by the aluminum erection span. There is also a difference in area of the steel spans depending on location in the series of spans.

• Erection sequence—First step in the actual erection sequence is to position the supporting bents.

Next step is to lift the aluminum span into position. For the first span of a series, this is accomplished by floating equipment. For subsequent spans, lifting power at one end is provided by a traveler that rides on the top floor beams of the erected steel spans. Floating equipment lifts the other end.

The aluminum erection span must be lifted at an angle with the center line of the bridge in order to clear the timber bents. After it is above the bents, the derrick barge swings the span over its seat.

To facilitate the setting of the aluminum truss, the end shoes have conical bottoms that engage similar sockets in the seat. The cones allow a 3-in. leeway in entering the seat. Thus, precise accuracy in setting the aluminum erection span is not required as the nesting action of the cones force the assembly into proper position.

In addition to the cone-shaped seats, a toggle device that can move the end member 5 in. in either direction is at one end of the erection span. This toggle is adjusted until the span shoes fit into the seats. But some bents are such that the 5-in. leeway is not sufficient. These towers are flexible enough to be pulled with cables to provide the additional movement. After the erection span is seated, the erection span toggles are adjusted to the neutral position so they can be used later in seating the steel span.

• Steel erection—Normal procedure in steel erection will be to erect the first few members in a series of spans by use of a floating derrick. Then a traveler equipped with two 35-ton capacity stiff-leg derricks will be mounted on the erected steel to hoist the remaining steel. The traveler—designed for the job by American Hoist and Derrick Co.—moves on skid beams mounted on the upper floor beams of the steel truss system.

However, for the first steel span erected on the aluminum falsework, all handling was accomplished by a floating derrick as the work could be done faster that way. But when more steel erection is under way, the floating derrick will be needed for other tasks and truss steel will be almost entirely placed by the traveler.

By the time all the steel is in place, more than 90% of the bottom chord rivets have been driven. All other joints are bolted and pinned with 50% to 75% of the holes filled depending on the importance of the connection.

Designing structural aluminum

Few engineers have had an opportunity to design an aluminum structure. Procedures are not much different than steel but controlling factors differ. In designing the aluminum erection spans, Earl and Wright, San Francisco consulting engineers, decided that, even though the spans are for temporary construction use, design considerations should be nearly the same as for a first class permanent structure. They followed closely the "Specifications For Heavy Duty Structures of High-Strength Aluminum Alloy" published as Paper No. 2532 in Volume 117 (1952) of the Transactions of the American Society of Civil Engineers.

These specifications were drawn up for the highest strength aluminum alloy (14S-T6), formed by alloying copper and other light metals with aluminum followed by heat-treating. According to these specs, the following factors in structural aluminum design are important.

Basic allowable tensile working stress is 22,000 psi based on minimum yield strength of 53,000 psi and minimum tensile strength of 60,000 psi.

Modulus of elasticity in tension and compression is 10,600,000 psi (this compares with 30,000,000 psi for steel).

Coefficient of expansion is 0.000012 per degree (double the 0.0000065 per degree F. of steel).

Weight is .10 pci (steel is .28 pci).

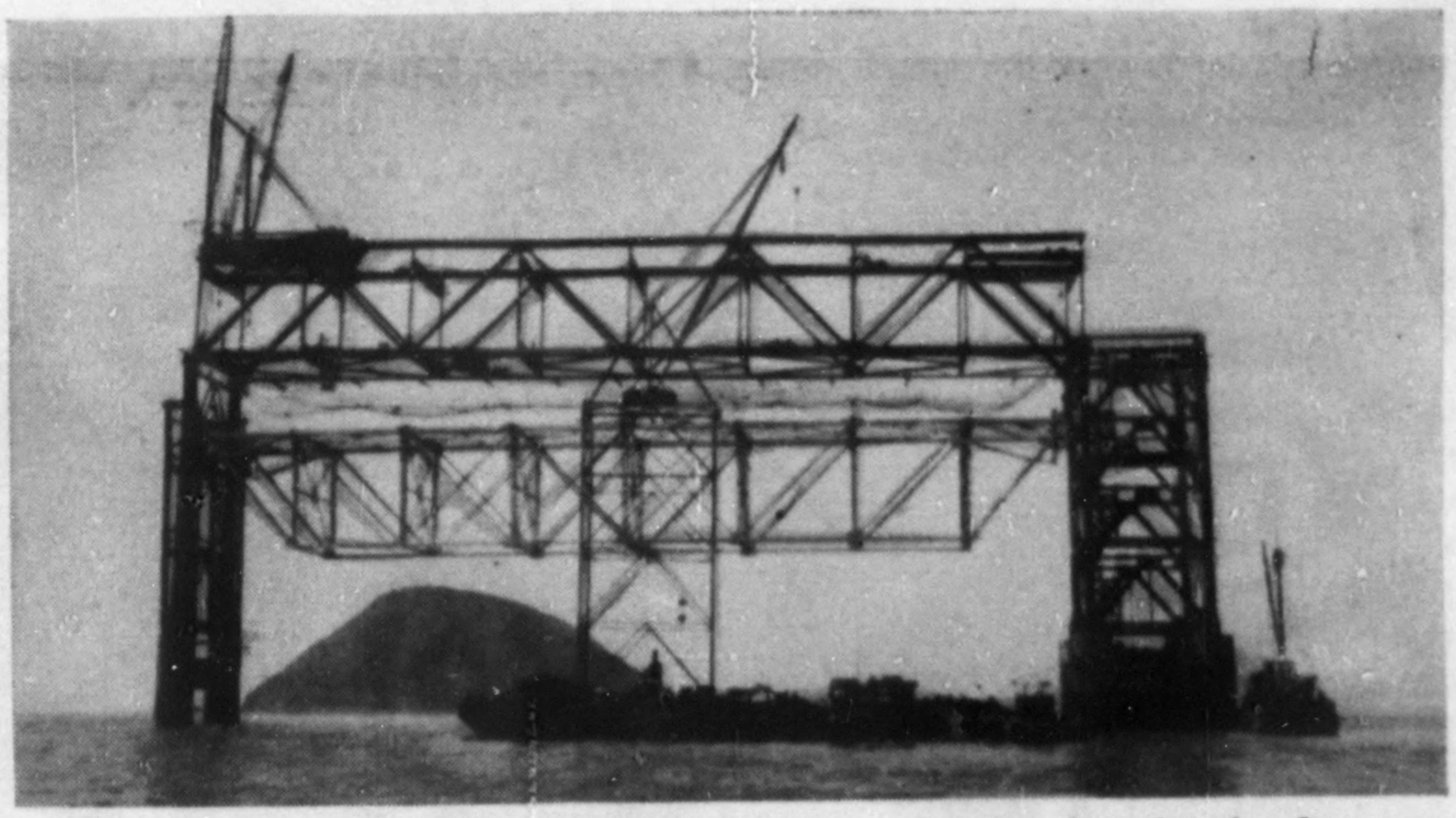
Rivet design in aluminum structures differs from steel practice. Steel rather than aluminum rivets were used in the erection spans even though some 10 tons were added to the weight of the structures. This selection was made in spite of the anticipated galvanic action between steel and aluminum. Reasoning was that steel rivets are much more readily available and have greater shear values: 9,020 lb for $\frac{7}{8}$-in. rivets as compared with 6,240 lb for the same size cold driven aluminum rivets. In driving hot rivets in aluminum structures, heat transference must be carefully watched as too much heating would adversely affect the temper of the alloy. Finally, stitch rivets in built-up members must be spaced closer in aluminum than in steel.

Aluminum structures must be protected by paint. Alloying aluminum reduces resistance to corrosion. The fabricated members are first given a thorough cleaning with a mild phosphoric acid solution. This is followed by a prime coat of zinc chromate. Finish coat for the erection spans is an aluminum pigmented paint.

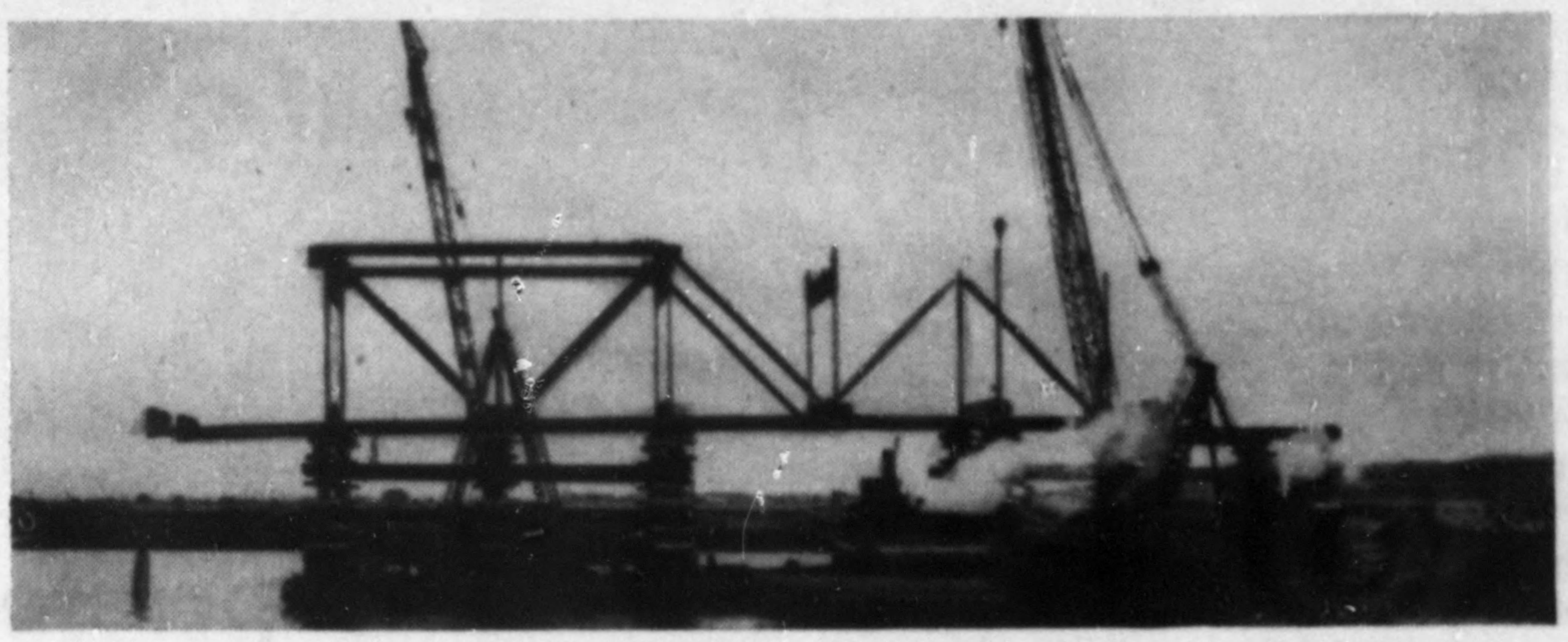
All of the aluminum was provided by the Aluminum Company of America whose engineers assisted in design of the erection spans. The heavier structural channels and angles for the erection spans came from Alcoa's Massena, N. Y., mill—the only mill in the world rolling heavy aluminum shapes. And as demand for heavy aluminum shapes is not very great, all of the heavier members were of necessity rolled to order. Pricing schedule is such that the smaller the order of a specific size, the greater per pound cost. Result is that use of standard member sizes reduces costs.

Next follow the intricate operations of making the pin connection and swinging the steel span—that is permitting it to carry its own weight. The steel truss is moved vertically in these two operations by jacks provided between the aluminum and steel spans at three of the seven panel points. These jacks are 150-ton capacity, are mounted on rollers permitting 6-in. horizontal movement, and have an 18-in. rise.

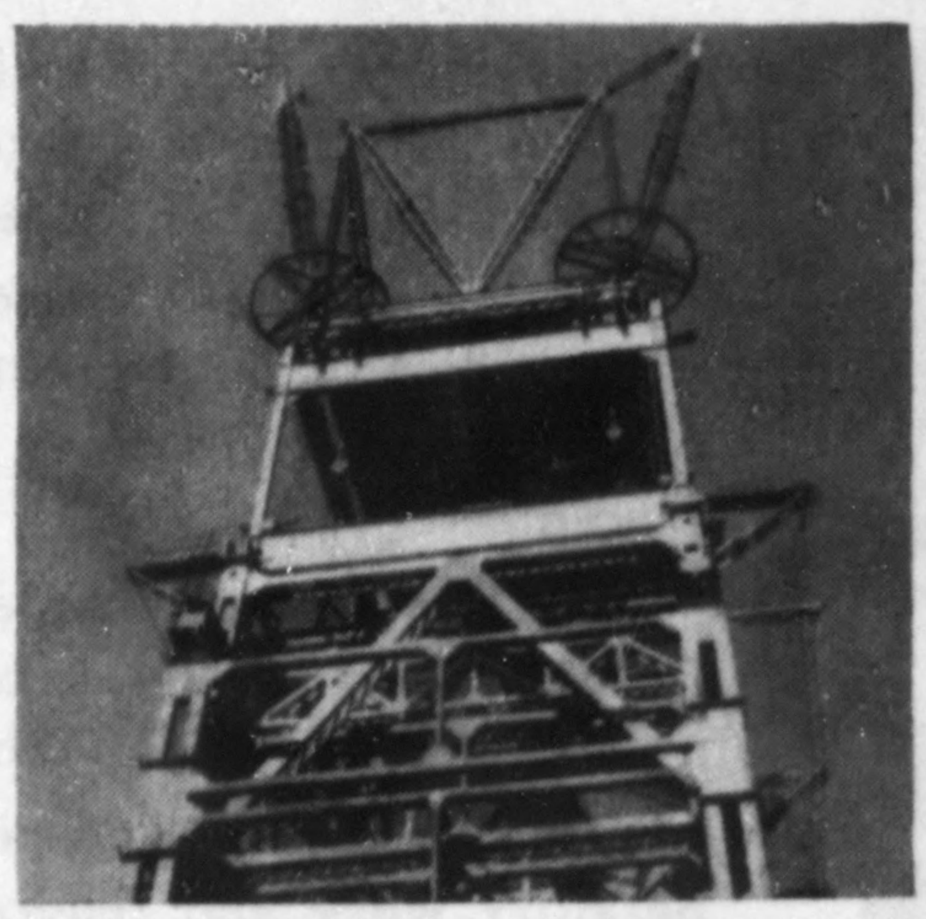
Horizontal adjustment for making the pin connection is accomplished by the toggles on the aluminum erection span. Maximum possible movement is plus or minus 5 in. The toggles working through the wooden bents that are bolted to the steel towers actually pull or push the tower into proper position.



DOWN GOES THE ERECTION SPAN after steel is in place for the first span. Traveler mounted on the steel span (left) controls the movement with its two 35-ton hoists. Barge will move span to new location.



BARGE SUPPORTS STEEL WORK for one of the eight spans to be floated in place. These spans are nearer shore and are lower than the 28 spans to be built on the aluminum falsework system.



DOUBLE boomed traveler mounted on top of steel span will handle most erection. Timber bent to support erection span is in place in front of tower.

STEEL RIVETS make joints for the aluminum trusses. Steel rather than aluminum rivets were used because of higher shear strength and greater availability.

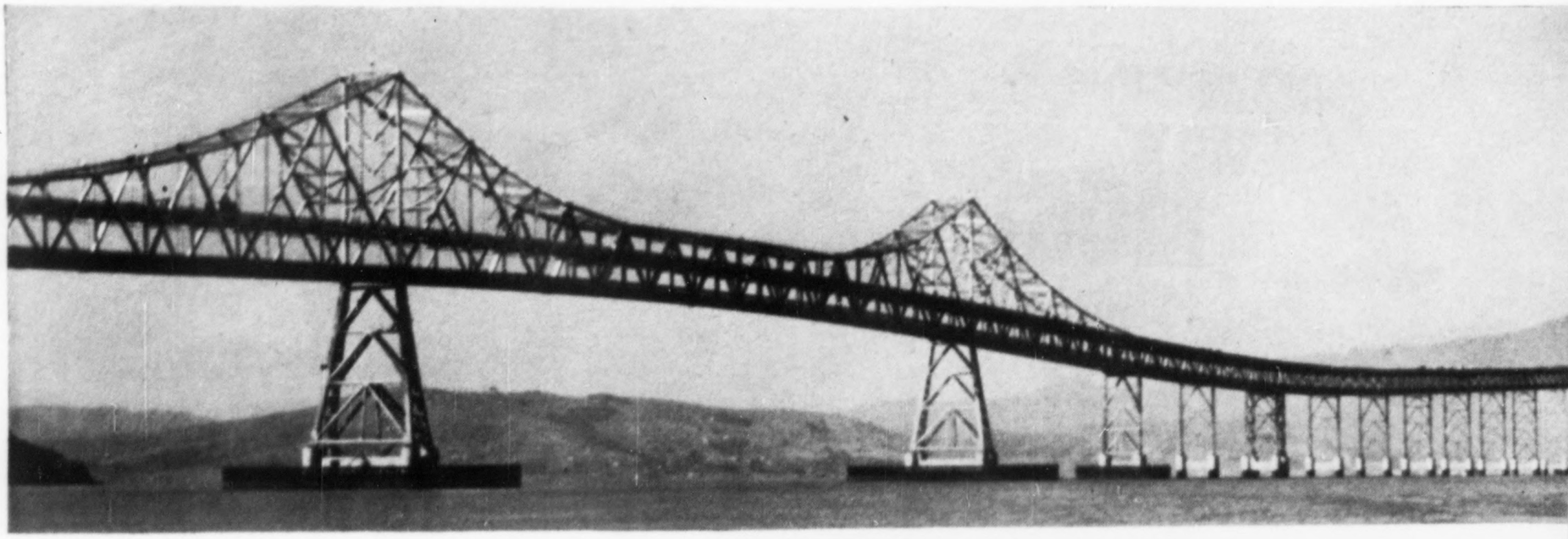
• **Swinging the span**—After the pin connection is made, the toggle is broken and control of the steel bent is taken over by the steel span. Then the jacks are slowly relieved resulting in the swinging of the steel span. In the process of relieving the jacks, the erection span moves up $1\frac{1}{2}$ in. at mid point to its unloaded camber. The upward movement of the aluminum span is accompanied by a top chord shortening of 3 in. And as load is picked up by the steel span, it deflects downward 2 in. at mid point.

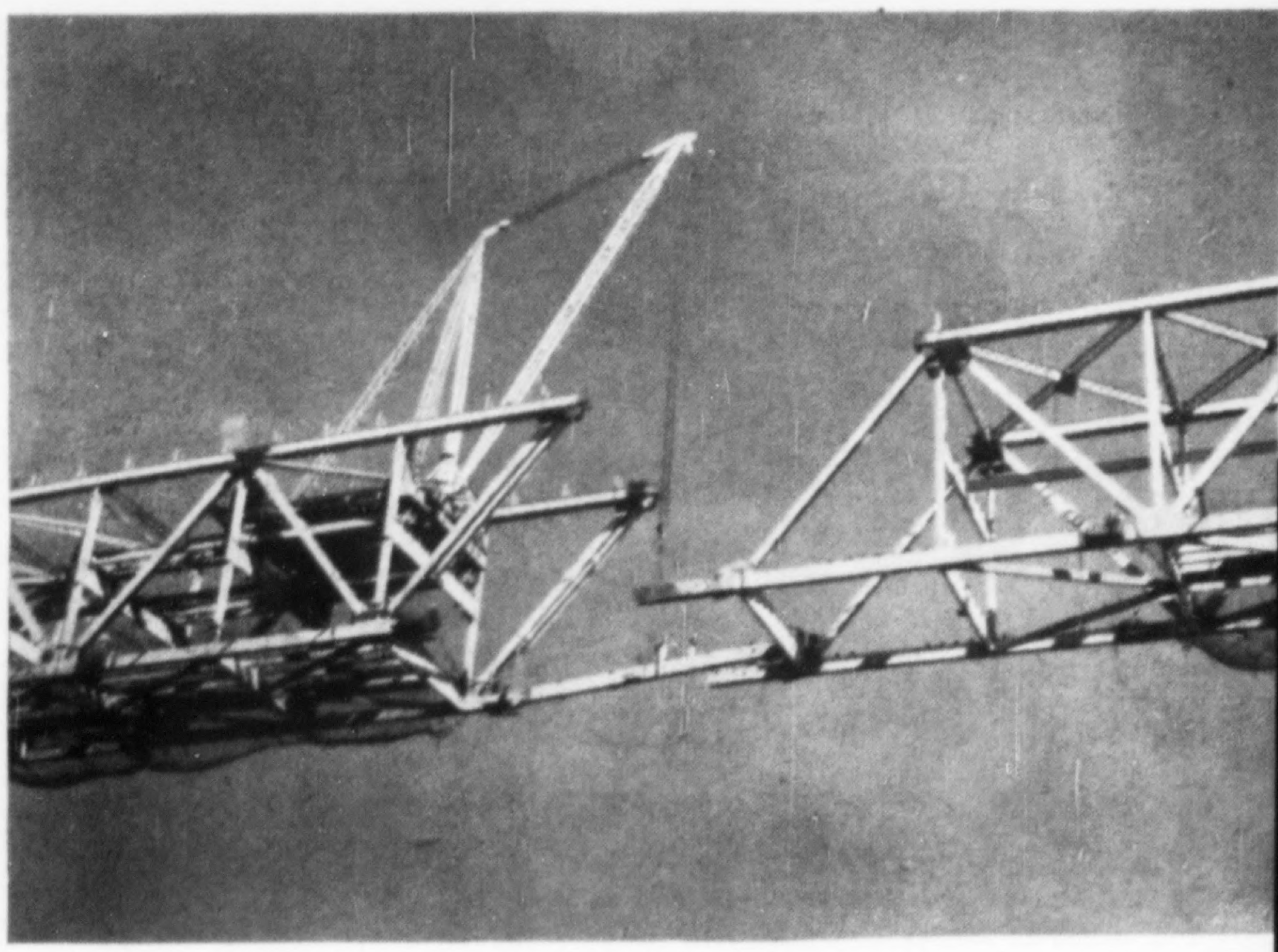
Now the stage is set for removing the erection span. First, safety nets are attached to the steel span for riveting work to follow. Then the connections at each end of the erection span are unbolted and the span is hoisted by the traveler and secured to the steel span. After the wooden bent supports are removed the erection span is slowly lowered by the traveler onto an awaiting barge. One traveler hoist lowers one end of the span and the other hoist working through a sheave arrangement lowers the other end. In this procedure the hoists control the movement by braking action.

Aside from the traveler, the most important item of equipment constructed for the steel work is a 75-ton capacity floating derrick—the "Judy Ann." Mounted on a 160x50-ft barge, the derrick has a 100-ton steam hoist. A tower 51 by 48 ft in plan is mounted on the barge. For initial work, the tower is 108 ft high. Later on it will be extended to 130-ft height. Mounted on the tower is a stiff-leg derrick with 125-ft boom. The entire assembly can lift 75 tons at a 50-ft radius. In addition to the 36 truss spans discussed in the foregoing, the $21 million superstructure contract includes thirty-six 100-ft long girder spans and two 1,070-ft cantilever spans each with 537-ft anchor arms. All girder spans are in place and the concrete deck on them is well advanced. No cantilever steel has been erected but some temporary falsework piers have been constructed.

• **Credits**—Design and construction of the Richmond-San Rafael Bridge is under the jurisdiction of the Division of Bay Toll Crossings of the California Department of Public Works for which Norman C. Raab is projects engineer. Ben Balala is resident engineer for the state on the bridge construction and Howard Whitty is resident engineer specifically responsible for steel erection.

For the Judson Pacific-Murphy Corp. and Peter Kiewit Sons Co., J. Philip Murphy is project sponsor. Francis J. Murphy is project manager, H. W. "Bill" Ziegler is erection superintendent, R. A. Chisholm is yard superintendent and W. E. Dreusike is office engineer. Earl and Wright, San Francisco consulting engineers, served as consulting engineers for the joint venture.





Closing link swings into position on the west cantilever span of the Richmond-San Rafael Bridge. And for the first time, the north arm of San Francisco Bay is bridged as . . .

Four Miles of Steel Near Completion

A 35-ton steel member slipped into place March 7 and the north arm of San Francisco Bay was bridged for the first time. With this closing of the west cantilever span—days ahead of the schedule set up by the contractor, Judson Pacific Murphy-Kiewit—the Richmond-San Rafael Bridge reached what is considered by most bridge erectors to be the climax in its construction.

The remaining steelwork, painting, deck paving and electrical work should be completed in ample time to permit the bridge to open in October.

Just a little over two months ago it seemed doubtful that the closure would be made on schedule—set for St. Patrick's Day by project sponsor J. Philip Murphy and project manager Francis J. Murphy.

Using the balanced method of construction, JPMK had completed one back span and one side of the cantilever span of the west channel. Then construction forces were shifted to the other back span and the other side of the cantilever. This left the cantilever span projecting 500 ft out from its supporting tower when heavy December storms hit—the same storms that flooded big areas in northern California. The steel already erected rode out the storms without damage, but the schedule was completely upset.

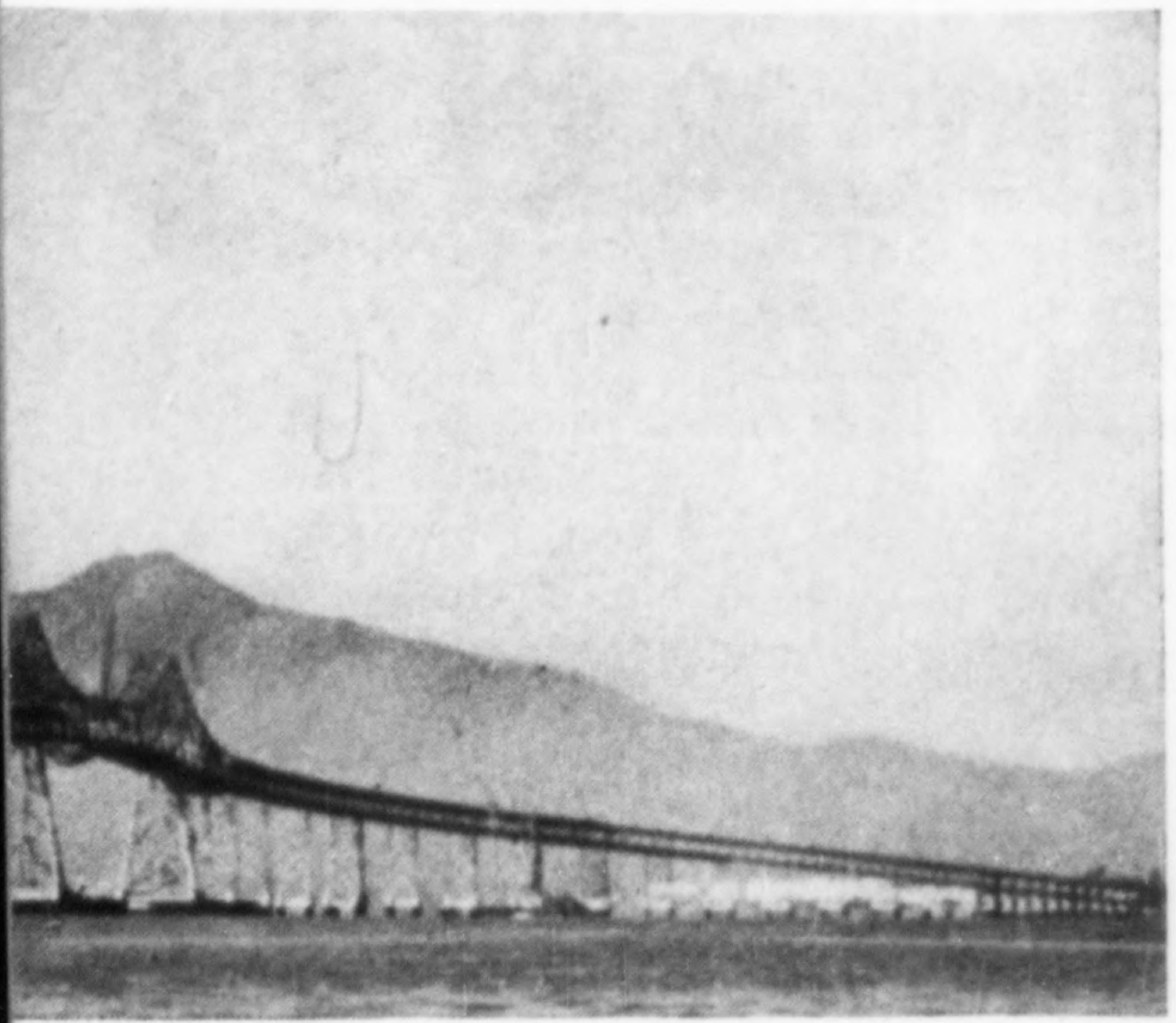
Then the weather cleared and things fell into place. Result was closure several days before St. Patrick's Day.

As has been reported in these pages before (ENR Nov. 4, 1954, p. 33), the 4-mile-long Richmond-San Rafael Bridge is composed of thirty-six 100-ft girder spans, thirty-six 289-ft truss spans and two cantilever spans. Each cantilever has a main span 1,070 ft long (providing a 1,000-ft clear ship channel) and two 535-ft anchor arms. Vertical clearance over the east navigation channel is 135 ft and over the west navigational channel, 185 ft from MHHW.

Construction of the bridge for the California Toll Bridge Authority is under direction of the Division of Bay Toll Crossings of the California Department of Public Works. The toll bridge eventually will have two decks, each carrying three lanes of unidirectional vehicular traffic. Only the upper deck will be open to traffic this year. The lower deck will be ready for traffic in 1957.

Erection feature of the cantilever spans is four reuses of temporary back span supports. Success of the work was made possible by careful planning on the part of the contractor—consulting engineer team (Earl & Wright, San Francisco consulting engineers, worked with Judson Pacific Murphy-Kiewit on this phase of the work).

• **Balanced erection method**—In formulating their course of action for cantilever span erection, JPMK officials first decided to use the balanced method of erection. In this process,



construction started from one of the cantilever towers. The cantilever span and the back span were built out from the tower at an equal rate. A pace was established so that there would never be a 50-ton overload on one side or the other. And JPMK equipped the job to do one back span and one-half a cantilever span at a time. The same travelers and temporary bents were used four times. And in the process, half a cantilever span was left extending from its tower for three or four months at a time.

To accomplish this type erection, temporary support was needed in the twelve-panel anchor arm. First, a support was needed at the second panel point to permit erection of the two 55-ton capacity travelers that would be used to place the steel. And secondly, additional support was needed to permit construction of the complete 535-ft length of the anchor arm.

Support at anchor-arm panel point 2 was provided by an inclined shoring strut that was given vertical support by the tower pier and horizontal support by the tower itself. This was found to be more economical than a separate pile-supported shoring bent.

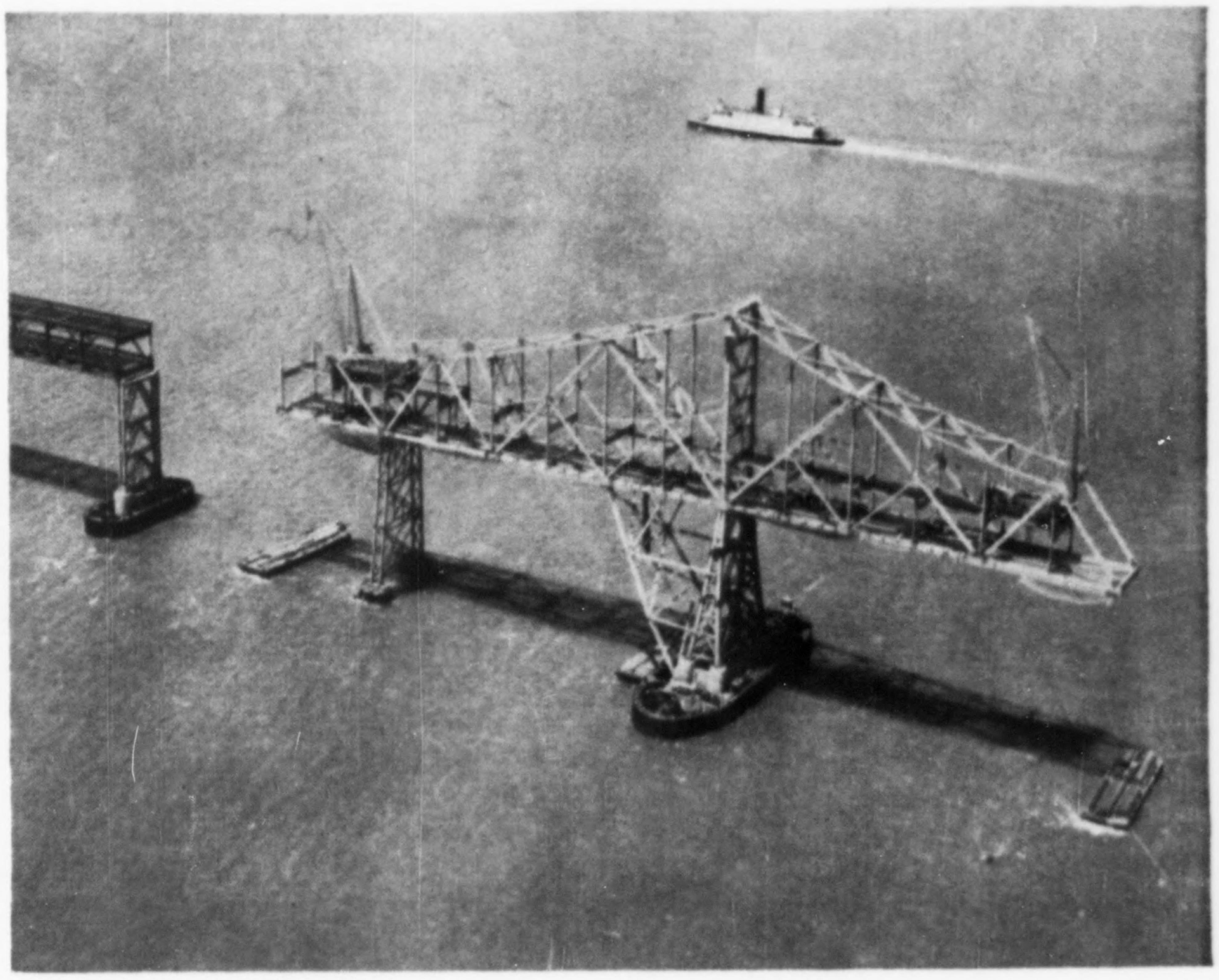
The inclined shoring strut was 138½ ft long for the east navigation channel where vertical clearance is 135 ft. After it was used for both sides of the east navigation cantilever span, an additional panel was added to the steel truss, making the inclined shoring strut 184 ft long. This length was used on the west navigation channel where vertical clearance is 185 ft.

The other anchor arm support was provided by a pile-supported shoring bent located at panel point 6. Cost studies proved this to be more economical than a shoring bent at panel point 4 or two shoring bents one at panel point 4 and one at panel point 8.

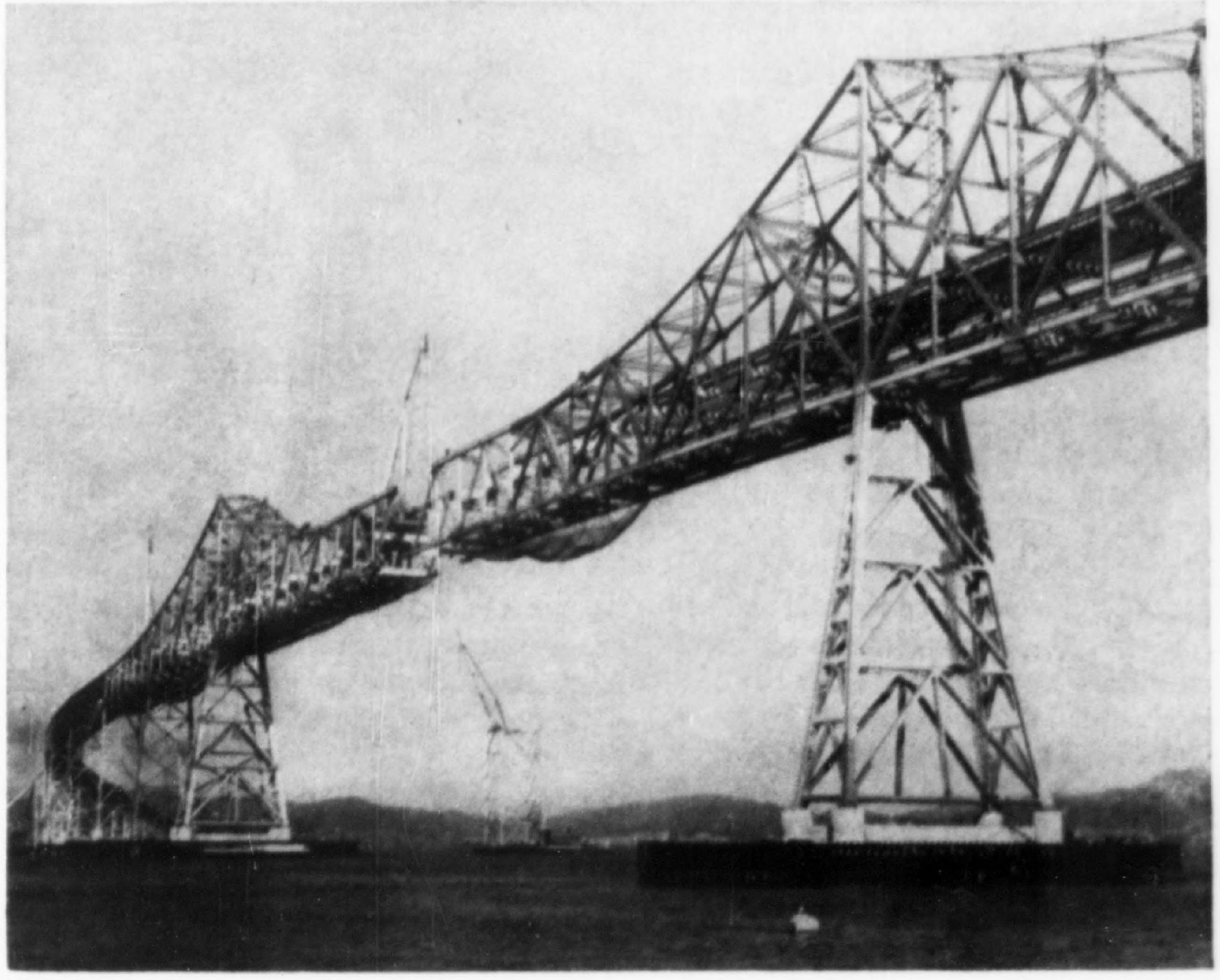
The shoring tower was supported on two clusters of eighteen 200-ft-long, 18-in.-dia pipe piles. The tower proper was 106 ft high for the first two uses and 156 ft high for the final two uses. As in the case of the inclined shoring strut, an additional panel of steel was added for the final two uses.

Piles supporting the temporary shoring bent were driven in a 50-ft water depth as much as 150 ft into the underlying mud and clay. The piling penetrated into firm formations at least 25 or 30 ft. But the piles did not penetrate to rock in at least two of the four cases. However, there was no indication of settlement during construction.

As the piles were driven it was noted that the mud plug on the inside came up to within 10 ft of the mud level on the outside. This means that no plug was formed at or near the bottom that would prevent the mud from rising in the pile as it was driven, and that the stability of the pile depended upon skin friction. The top part of each pile was filled with



BALANCED ERECTION of the two cantilever spans featured a temporary shoring bent in the back span as well as an inclined strut supported by the cantilever tower.



CANTILEVER SPAN was built half at a time. First half (right) was left extending 500 ft from its supporting tower while second half (left) was erected. During this time heavy storms hit, but did no damage to the half-built cantilever span.

. . . Four miles of steel

rock to stabilize the clusters and reduce vibrations. After JPMK was finished with one shoring bent location, the piles were cut off at the mud line. This salvaged some 50 ft of length that could be reused on subsequent temporary piers by welding to other 18-in.-dia pipe.

• Travelers erected—After the inclined shoring strut was erected by use of a floating derrick barge, lower chord members spanning the first two panels of the back span were positioned. And enough diagonal members were added to make the assembly rigid. Then the floating derrick barge hoisted one of the 55-ton travelers to the lower chord. More back span steel was placed until it was possible to erect the upper floor beams in the first panel (the bridge will have two traffic decks). The traveler already in position then hoisted the second traveler to this set of floor beams. Next the lower part of the first two panels of the cantilever span was erected including a set of temporary middle chords. Upper floor beams were placed and the cantilever traveler moved out to the first cantilever panel. It then hoisted the anchor-arm traveler to the upper floor beams, turning it around in the process. With both travelers on the upper set of floor beams it was then possible for steel erection to proceed out from the tower. The travelers, of course, were not hoisted in one piece. Each time a traveler was lifted or turned around, it was necessary to do the job piecemeal.

The 55-ton travelers were designed specially for the cantilever erection work by American Hoist and Derrick Co. They are equipped with a 125-ft boom and 80-ft mast. The 55-ton rating is with a 50-ft reach. Power comes from a diesel engine working through a three-drum hoist. The rigs will operate at nearly full 360-deg radius, being prevented from lifting directly backward by the fixed struts supporting the mast.

Reason for so many traveler moves in getting the work under way is that the towers supporting the cantilever span are A-frame type. On some other bridges, towers supporting these towers have been frames at least one panel long with straight vertical truss legs that, in effect, provide a working platform on top from which work can start.

Steel erection proceeded on both cantilever and back spans at nearly uniform rates. When back span steel reached one panel beyond the temporary shoring bent, it was possible to remove the inclined shoring strut. And after full completion of the back span, it was possible to remove the temporary shoring bent. Most critical phase of the back span erection was just before anchor-arm completion. But no major difficulties were encountered.

When back span and cantilever span steel was completed, the travelers were dismantled. This was accomplished either by truck crane riding on the already completed bridge deck or by temporary gin pole.

Two sets of jacks were used to make the closing cantilever span members fit. One set was mounted on each of the final bottom chord closing members. The two 200-ton jacks on each member together with a 6-in. slotted hole made the closure seemingly simple. The jacking action had the effect of moving back the relatively flexible cantilever towers.

For upper chord closing, jacks were mounted on the upper chord member spanning between the cantilever arm and the suspended span—a member that under balanced load conditions has no stress. Here a 500-ton jack was mounted that had a leverage of three resulting in a 1,500-ton pull. Critical phase of the cantilever work, both in early steel erection and in jacking operations, was keeping in tension the eye-bar upper chord members spanning the first four cantilever span panels.

The Richmond-San Rafael Bridge is a project of the Division of Bay Toll Crossings of the California Department of Public Works, for which Norman C. Raab is project engineer. Ben Balala is resident engineer for the state on bridge construction with Howard Whitty serving as resident engineer specifically responsible for steel erection.

The $21-million steel erection contract is held by a joint venture of Judson Pacific-Murphy Corp. and Peter Kiewit Sons Co. In addition to project sponsor J. Philip Murphy and project manager Francis J. Murphy, key personnel for JPMK are H. W. "Bill" Ziegler—erection superintendent, R. H. Chisholm—yard superintendent and W. E. Dreusike—office engineer.

Consulting engineers for the joint venture are Earl & Wright of San Francisco, for whom George C. Haun supervised investigatoin of erection stresses and Alpo Tokoa represented the firm in the field.

New Experimental Fishway

A new experimental fishway for passing salmon upstream around river obstructions has been installed on the Coweman River by the Washington State Department of Fisheries.

Although new here, the "Denil" is common in Europe. It is shorter and cheaper than the conventional pool-type fish ladder and makes fish passage possible over a wider range of flow variation. Its main advantage, like that of the Hell's Gate vertical baffle fishway used on larger streams, is in the elimination of manual operations. Pool-type fish ladders have a fixed operating range and will not pass fish at certain water levels unless the pool weirs are adjusted.

The Denil fishway is 30 ft long, 6 ft deep and has an interior wall-to-wall width of 3 ft. Bolted to the interior walls are six rows of sheet metal plates welded in a herringbone pattern and sectionalized for purposes of removal and repair. The interior width between baffles is 20 in.

Water current is broken up by the baffles into an easily-negotiated flow pattern, a function of their spacing and angle. No pools are necessary.

The Coweman falls normally would have been bridged by a pool fish ladder 48 ft long and 8 ft wide at a cost of $20,000. The Denil cost only $8,000, reports Robert J. Schoettler, director of the state department.