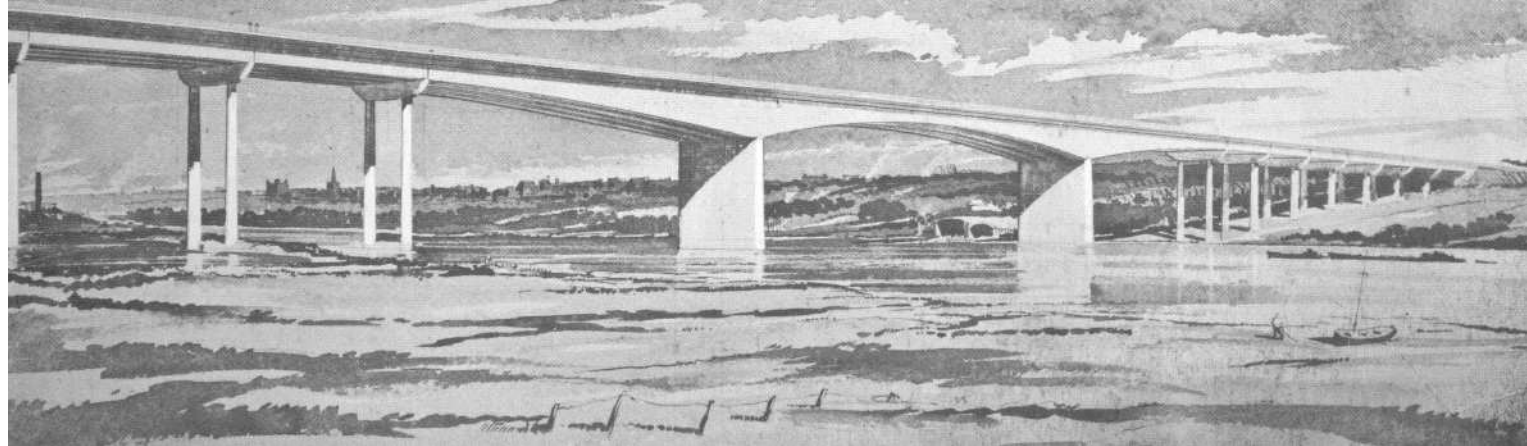


THE MEDWAY BRIDGE

on the M.2 motorway



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THE MEDWAY BRIDGE ON THE M. 2 MOTORWAY

Consulting engineers and agents for the Ministry of Transport
FREEMAN, FOX AND PARTNERS

Contractors
J. L. KIER AND COMPANY, LIMITED
CHRISTIANI AND NIELSEN LIMITED

THE MEDWAY BRIDGE

INTRODUCTION

The Medway Bridge forms part of the new 25-mile long M.2 motorway, which will leave the existing A.2 main road one mile outside Strood and rejoin it 1½ miles beyond Faversham.

The motorway will eliminate traffic congestion in the Medway towns, which at present is choking the main route between London and Dover - especially during the summer months when holiday traffic streams towards the Channel ports and the north Kent coast.

The bridge crosses the River Medway between the City of Rochester and the Parish of Cuxton. The exact position of the crossing was dictated by the line of the motorway which was tentatively fixed in 1954 by engineers from the Ministry of Transport and Civil Aviation, as it then was. Freeman, Fox and Partners were subsequently asked to report on the crossing, and several schemes in steel and concrete were investigated, the final choice being dictated by aesthetics as well as economics.

The report recommended that two bridge designs be prepared: one with the approach viaducts and main spans in prestressed concrete; the other with viaducts in prestressed concrete and the main spans in steel. Eventually, tenders were invited for a prestressed concrete bridge as well as two steel designs of similar appearance - one all welded, and the other welded and bolted. The designs were all approved by the Royal Fine Art Commission.

In August 1960, a tender for a prestressed concrete bridge submitted jointly by J. L. Kier and Company Limited and Christiani and Nielsen Limited, was accepted at an estimated cost of about £2 ¹/₃ million, which was a few per cent cheaper than the welded and bolted steel alternative.

GENERAL DESCRIPTION OF THE BRIDGE

SPANS

The bridge, with its approach viaducts, has an overall length of 3, 272 ft 6 in. - nearly 2/3 mile. There are three spans over the river: a central span of 500 ft, to give the navigational clearance asked for by the Medway Conservancy Board, and two side spans of 312 ft 6 in., chosen for aesthetic and economic reasons.

The west viaduct has a total length of 1,350 ft and eleven spans; the east viaduct, a total length of 797 ft 6 in. and seven spans. The west abutment passes over the main railway line between London and the north Kent coast, and is known as Shake Hole Bridge. Another railway line, between Maidstone and Strood, passes below one of the spans of the west viaduct.

BRIDGE DECK

The bridge deck is, for the most part, 113 ft 6 in. wide. However, at the western end the width is increased to allow additional 12 ft lanes for acceleration and deceleration at the approach to the junction with the A.228 Cuxton Road.

The bridge carries two 24 ft wide carriageways with 1 ft margin strips, flanked by 8 ft hard shoulders. Bicycle tracks and footpaths are also included, to cater for local requirements.

The carriageways are straight on plan, except for the last four spans of the east viaduct which lie partly on a 5° transition curve and partly on a circular curve of 2,865 ft radius. The west viaduct has a vertical curve between the abutment and piers 9 and 10, apart from which the bridge is horizontal throughout its length.

The top of the horizontal deck is 116 ft above Ordnance Datum Level. Although this is higher than necessary for navigational clearance over the river, it avoids excessive earthworks on the adjacent sections of the motorway.

The bridge carries G.P.O. services and has provision for future lighting of the carriageway if required. Navigation lights on the main piers and at the centre of the 500 ft span will be provided to guide shipping using the river.

THE BRIDGE STRUCTURE

ABUTMENTS

The west abutment is formed by Shake Hole Bridge, which itself has two abutments: the east one is of reinforced concrete cellular construction, whilst the west one is of mass concrete.

The east abutment consists of a buried two-bay portal frame with tapered columns on spread footing foundations. The back of the abutment has vertical joints to minimize stresses arising from the bending of the bridge seat beam.

VIADUCTS

Foundations

The viaduct piers rest on 22 in. hexagonal driven piles of solid reinforced concrete, except where the hard chalk stratum was less than about 20 ft below ground level, when spread reinforced concrete footings were used in preference. The piles vary in length from 40 ft to 65 ft.

Piers

Each viaduct pier, with the exception of No. 1 at the extreme western end, consists of a reinforced concrete portal frame, cast in situ, varying in height from 30 ft to 100 ft above ground level. The columns are rectangular on plan with a taper, in their longitudinal direction, of 1 in 60. At their tops, they measure 7 ft 6 in. x 8 ft, or 7 ft 6 in. x 7 ft, according to their height. The cross beams are 10 ft 6 in. deep and either 6 ft 6 in. or 7 ft wide; they have cantilevered sections at each end to reduce the maximum moments. Pier No. 1 is solid, with a 2 ft thick wall between the columns to eliminate bending moments due to shrinkage in the portals.

Superstructure

The viaduct superstructure is of composite beam and slab construction, simply supported for dead load and continuous for live load. For the most part, eight beams span between each pier, varying in length from 100 ft to 135 ft, with a maximum weight of about 190 tons. The beams are of precast concrete, prestressed with Lee McCall bars. The six inner beams are of I section, whilst the two outer ones are box beams to provide stiffness for the cantilevered

section of the deck, and also to match the main spans over the river. The beams are generally placed at 12 ft 3 in. centres and support a 9 in. thick reinforced concrete deck slab, cast in situ. The slab is cantilevered out 10 ft 9 in. beyond the edge beams to carry part of the bicycle track and footway. The beams rest on roller bearings at each pier, the viaduct structures as a whole being anchored at the abutments which are designed to resist all longitudinal forces.

MAIN RIVER SPANS

Foundations

The foundations to the two main river piers are reinforced concrete spread footings, 31 ft wide and 106 ft long, founded at a depth of some 45 to 50 ft below mean water level.

Piers

The two main river piers consist of reinforced concrete shafts varying in thickness from 10 ft at the bottom to 6 ft at the top. The shafts are solid from the foundations to a height of 5 ft 6 in. above high water level; above this they are of cellular construction. The tops of the piers are heavily reinforced and incorporate continuous hinges cast in high quality concrete. The hinges resist all longitudinal forces, whilst providing free articulation for the two side spans.

Superstructure

Each longitudinal half of the river-span superstructure, apart from a 100 ft gap in the centre, is carried by independent box girders of in situ concrete, cantilevered from the two main piers. Each girder consists of four 9 in. thick webs, a 9 in. thick top flange slab, and a bottom flange slab varying in thickness from 12 in. to 24 in. The top slab acts as the bridge deck and is cantilevered out 11 ft beyond the outer webs. The bottom slab is parabolic on the cantilever (central) arms and for part of the anchor (side) arms. The depth of the girders is 35 ft 6 in. over the main piers, 9 ft at the ends of the anchor arms, and 7 ft 4 in. at the ends of the cantilever arms. The girders are prestressed longitudinally and vertically by Lee McCall bars.

The 100 ft gap in the centre is bridged by a suspended span of similar construction to the viaduct superstructure. The two ends of the span, however, are half joints - one pinned and the other on rollers.

SURFACING

The carriageways, marginal strips and hard shoulders are surfaced with 1 ½ in. thick mastic asphalt with coated chippings; the bicycle tracks and footways are similarly surfaced with a ¾ in. thick sand-rubbed asphalt. Precast concrete kerbs, set in mortar and secured by steel dowels, are provided at the edge of the bicycle tracks, and at the outer edges of the hard shoulders and carriageways.

The reservations between the carriageways and bicycle tracks are filled with concrete and paved with mastic asphalt.

Reflecting road studs will be provided on the carriageways along the lane markers.

BARRIERS AND PARAPETS

In the central reservation between the two carriageways, a crash barrier is provided consisting of steel channel posts supporting flexible steel guard rails on either side, and an anti-dazzle screen of expanded metal mesh on top.

The outer reservations, between the carriageways and bicycle tracks, are provided with barriers consisting of steel verticals supporting 4 ft high anti-climbing metal mesh on the bicycle track sides, and flexible steel guard rails on the carriageway sides. Solid reinforced concrete walls are provided in addition to these barriers where the west viaduct span passes over the Maidstone-Strood railway.

The footway parapets consist of rectangular steel tube verticals supporting a rectangular steel tube top rail - 4 ft above the footway level - and panels of solid steel palings.

DRAINAGE

Drainage outlets are provided at the hard shoulders and, where required, at the carriageway kerbs. The outlets are connected to a drainage system under the deck which discharges all surface water through down pipes in the piers. The bicycle tracks and footways are drained by means of cast iron channels through the reservations.

INVESTIGATION AND DESIGN

SOIL SURVEYS

The soil surveys carried out in 1954 and 1958 showed that the River Medway runs in an old flat bottomed valley in the Middle and Upper Chalk, which has been partly filled in by deposits of gravel, sand and peat. The chalk is heavily fissured and varies in consistency, depending on the degree of softening round the fissures. At the top, it consists of pieces of hard chalk in a soft weathered matrix, but lower down it is more compact and there is little of the weathered matrix. It was decided to found all the piers on this material, either on piles or spread footings - depending on the depth of suitable chalk below ground or water level - the footings to be constructed in cofferdams where necessary.

FOUNDATIONS

For the viaduct pier foundations, piling was found to be practicable and tests were carried out on both bored and driven piles. In view of the difficulty in deciding when a bored pile had reached a chalk stratum capable of carrying the loads, driven shells piles were specified with a safe working load of 155 tons. However, the contractor finally chose the solid hexagonal piles which have been used. Loading tests have shown that these piles give a permanent settlement of about 1/10 in. under 1½ times the working load.

With piers 1 to 5, at the end of the west viaduct, where spread footings have been used, excavations revealed a pronounced fissuring of the chalk formation, the main fissures running parallel with the river. It was therefore thought prudent to grout the formation by drilling for about 20 ft and by pressure -grouting below the footings, to provide lateral stability to the blocks of chalk.

In order to avoid any underwater obstacles to shipping, the foundations to the two main river piers had to be below the river bed level, and it was found that spread footings of the dimensions used would be the most economical.

MAIN RIVER SPANS

In view of the possible settlement of the main piers, continuous river spans would have been uneconomical. A statically determinate structure was therefore chosen, consisting of two balanced cantilevers and a suspended span. It was decided to use independent box girders to simplify analysis and construction.

The girders were designed on the assumption that the contractor would use the cantilever method of construction, thus avoiding the use of temporary stagings in the navigational channel of the river.

Model tests on the girders were carried out by the Design Department of the Cement and Concrete Association at their Research Station at Wexham Springs, Buckinghamshire. The tests were carried out to check strain distribution and to investigate the possibility of buckling. A concrete model of one 200 ft cantilever was made to a scale of 3/40, the total length being 15 ft, with 11/16 in. thick webs and deck. The model was prestressed by 0.1 in. diameter wires placed through ducts in the deck and webs. Loads were applied to simulate the Ministry of Transport's 'abnormal load', which has a total maximum value of 180 tons, and also to simulate the effects of the self-weight in the structure. For the final test to failure a very severe single-point load was applied to test the possibility of buckling. Failure occurred, without buckling, at a load equivalent to several times the total value of the 'abnormal load'.

METHODS OF CONSTRUCTION

VIADUCTS

Piles

The piles to the viaduct piers are cast on the site on concrete beds up to six layers high. Each layer of piles acts as bottom formwork to the layer immediately above, waxed paper being used between to prevent the piles from sticking together. After seven days, the piles are lifted by travelling gantry or crane and stacked for 28 days before driving. The piles are driven with 6-ton single-acting steam hammers running in false leaders. The pile caps to piers 6, 7, 8, 9, 10, 11 and 14 are below High Water Mark, so the piles are driven inside sheet pile cofferdams. Where the mud below these caps is very soft, it is replaced by lean concrete to provide lateral stability and support for the pile cap

during construction.

Piers

The pier shutters, supplied by Stelmo Limited, comprise two steel L-shaped sections, 17 ft in overall height with 2 ft deep top and bottom rings. Each cast of column is 15 ft high and the 2 ft rings which carry working platforms are interchanged on succeeding casts, the top ring on one cast being left behind when the shutter is stripped to become the bottom ring on the next lift. Adjustment for the 1 in 60 batter on two faces is made where the ends of the L-shaped pieces butt.

The top of the pier columns are chamfered and form a seating for steel collars which serve as supports for the cross beam formwork during construction. The collars carry a maximum load of approximately 280 tons each and are prestressed.

The side formwork, supplied by Acrow Limited, to the cross beams consists of plate steel girders designed to carry the vertical loads, and to resist lateral pressure from the wet concrete. They are raised into position on the collars by crane or derrick.

The formwork to the beam soffits is then erected, the reinforcing cage fixed in position, and the concrete of each beam placed in one operation.

Superstructure

The viaduct beams for the superstructure are made in casting yards at the shore end of each viaduct. The soffit formwork to the beams is carried on rolled steel joists in the longitudinal direction; these in turn are carried by concrete cross walls at about 6 ft centres. Packings between the walls and the rolled steel joists are made sufficiently flexible to permit movement caused by vibration during concreting, shrinkage and elastic shortening.

The end blocks of the beams, which are congested with reinforcement and ducts, are cast first, in a horizontal position, to facilitate compaction of the concrete. This also ensures that the concrete in the end blocks is older than that in the remainder of the beams, allowing earlier prestressing and handling.

After curing, the end blocks are positioned on the casting beds. Mild steel reinforcing cages, together with the

prestressing ducts and tendons are then fixed in place, the latter supported on preformed steel locating frames. The formwork is of steel with brackets welded on at intervals to hold the external vibrators. The concrete is placed by bottom-opening skips, lifted by a derrick which also handles all other materials and formwork in the yard.

The remainder of the I beams are cast in one operation, the box beams in two. The U sections of the box beams are cast first and subsequently the top slabs, the soffit formwork to these being left inside the beams. After striking the side forms, two bars are stressed to counteract shrinkage. After three days, sufficient bars are stressed for the beams to be jacked, rolled sideways on steel balls, and stored. Final stressing is carried out after 28 days, and all the ducts subsequently grouted. Gamma ray tests are made to check the efficiency of the duct grouting.

The completed beams are picked up from the storage yard and carried to within reach of the launching equipment by portal carriages which run on tracks, placed initially on the approach ramps to the abutments, and subsequently on two beams of a completed span.

The launching equipment consists of a steel trussed girder, triangular in section, with a front tower support and rear leg supports. The girder is travelled forward on a bogie under the leg supports, with the tail end of the girder counter-balanced by the first box beam for the next span to be launched, and the main part of the girder cantilevered forward from the legs. The launching bogie runs on the top of beams already placed in the previous span. When the forward tower has reached the pier ahead the nose is jacked down, the bogie removed and the rear legs packed. The concrete beams are transported across the span on two carriages running on the bottom chord of the girder, then jacked down and rolled sideways into position on steel balls.

When beams on adjacent spans have been placed in position, short stressing bars connecting brackets below the bottoms of the beams are stressed, and the beams are jacked down onto permanent bearings. The in situ deck slab is now cast, with the exception of short sections over the piers which are left un-cast to preserve the simply-supported state of the beams. The final stage is the casting of diaphragms between the beam ends together with the remaining portion of deck slab.

MAIN RIVER SPANS

Foundations

Excavations for the river pier foundations have been carried out inside steel sheet pile cofferdams, and for most of the work, grabs of various types have been used. In the final stages of excavation, the material immediately above formation level and that clinging to the sheet piles was loosened by water jets guided by divers. Final preparation of the formation was completed by divers operating an air lift, which brought up the slurry and loose chalk. Large lumps of chalk had to be manhandled into the grab.

The fissuring of the chalk made de-watering impossible. The cofferdams were therefore sealed by 21 ft thick plugs of concrete placed under water by special bottom-opening skips of 4 cu. yd capacity. For bottoming and plugging, the pier foundations were divided into five sections each by placing precast concrete panels vertically across the cofferdams and holding them in position by 'Universal' steel beams. After de-watering the cofferdams, the top of the underwater concrete was cleaned and levelled off; the reinforced concrete slab was then cast on top in the dry.

Piers

The main river piers are cast in 9 ft lifts using timber formwork with horizontal grooves at 4 ft centres to mask construction joints and shutter bolt holes.

Superstructure

The main river-span superstructure is constructed in two longitudinal halves, the system of construction being identical in both cases.

The girder sections over the piers are constructed first and are partly of precast concrete units supported on steel beams spanning between the main piers and temporary steel towers located in each shore span.

Each girder is then built out in 10 ft sections on either side of a pier, care being taken to keep a downward reaction on the steel tower to guard against overbalancing. Vertical timber boarding is used for the outside of the girders; plywood panels are mainly used for the inside. Formwork for each stage is supported from a cantilevered carriage on either side of a pier, anchored to the previously completed sections. Each section is cast, allowed to

harden and then stressed by Lee McCall bars. Stresses in the girders are checked at every stage of construction to ensure that they are within permissible limits during erection as well as under working conditions.

As the cantilevered construction proceeds and the two carriages get further away from the pier, the out of balance moments grow larger and the reactions on the steel tower become excessive. A second tower is therefore erected, approximately 160 ft from the end of the anchor span. As soon as this tower is passed by the cantilevered carriage in this span, the support to the concrete girder is transferred from the first to the second tower. The cantilever arm is completed first, being only 200 ft long as compared to the 312 ft long anchor arm. The cantilevered carriage for this section is then dismantled and used again for the construction of the anchor arm of the second half of the bridge.

The cantilevered construction of the anchor arm is continued as far as the negative moment over the tower, in relation to the cross section of the bridge, will allow. A third tower is then erected, and a controlled reaction introduced by means of hydraulic jacks.

The construction of the anchor arm is next completed, the reaction over the third tower being carefully controlled so that the bending moment on the second tower should not be in any way increased.

When the structure is complete, there are only positive bending moments in the last 75 ft of the anchor arms; prestressing tendons are therefore placed in the bottom slabs. It is necessary, for construction purposes, to introduce some extra top tendons in these sections of the anchor arms. These extra tendons are finally removed, the girders being then simply supported by hinges at the main piers, and rollers at the shore piers.

The 100 ft suspended span over the centre of the river is cast and launched in the same way as the viaduct superstructure, being of similar construction - except that the beam soffits are curved.

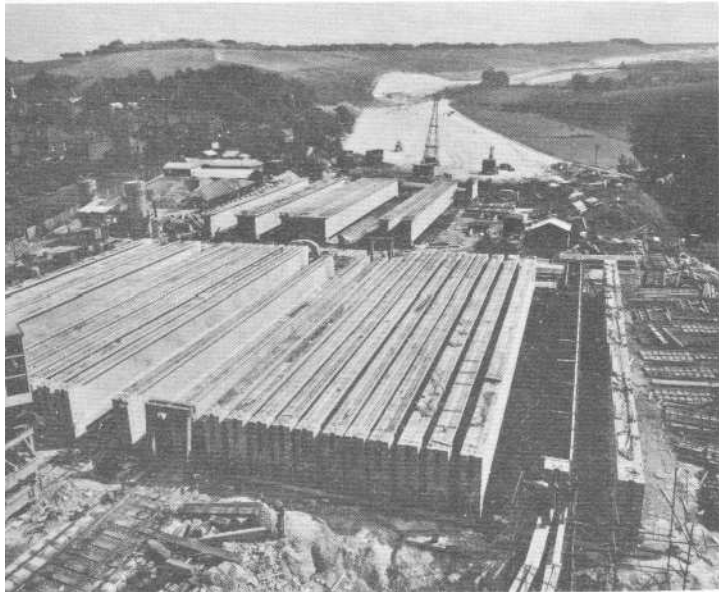
APPENDIX

Overall length, excluding embankments	3340 ft
Main span	500 ft

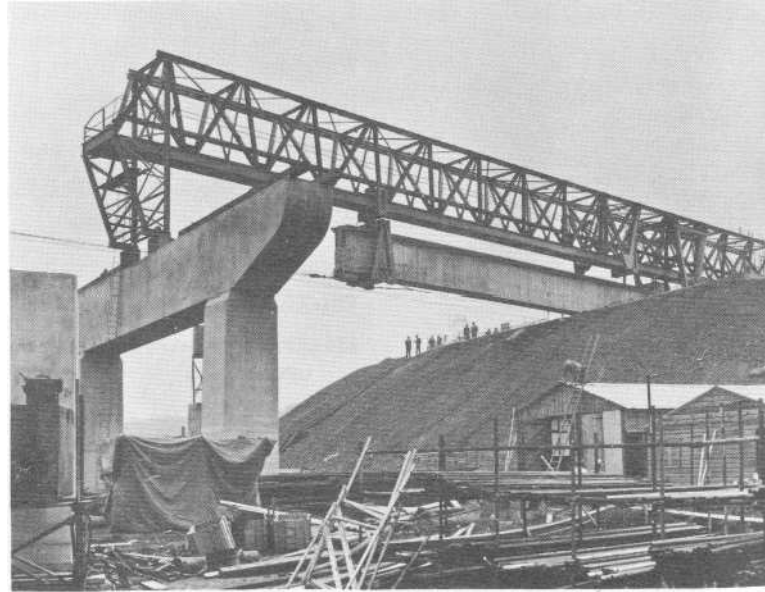
Anchor spans	312 ft 6 in.
Width of bridge	113 ft 6 in. - 137 ft 6 in.
Height of road surface above mean tide level	116 ft
Number of viaduct spans	18
Number of precast beams	162
Maximum weight per beam	195 tons
Maximum length per beam	135 ft
Total number of piles	498
Length of piles	45 ft - 65 ft
Weight of piles	9 - 13 tons
Design load per pile	155 tons
Maximum load on a pile cap	2, 600 tons
Total weight of mild steel	5, 420 tons
Total weight of concrete	118, 000 tons
Total length of prestressing bar	187 miles
Working load per bar	47 tons
Maximum prestressing force at the main piers	Approx. 26, 000 tons
Average concrete strengths (during first 15 months)	3 days, 7 days, 28 days, 90 days

Class C & D (O. P.C.) Mix 1 : 6.6	3835	5255	6800	7575
Class A (O. P. C.) 1:4.0	5975	7360	8560	10180
1 4. 5 + additive	6155	7220	8300	10200

Beam casting yard on east bank.

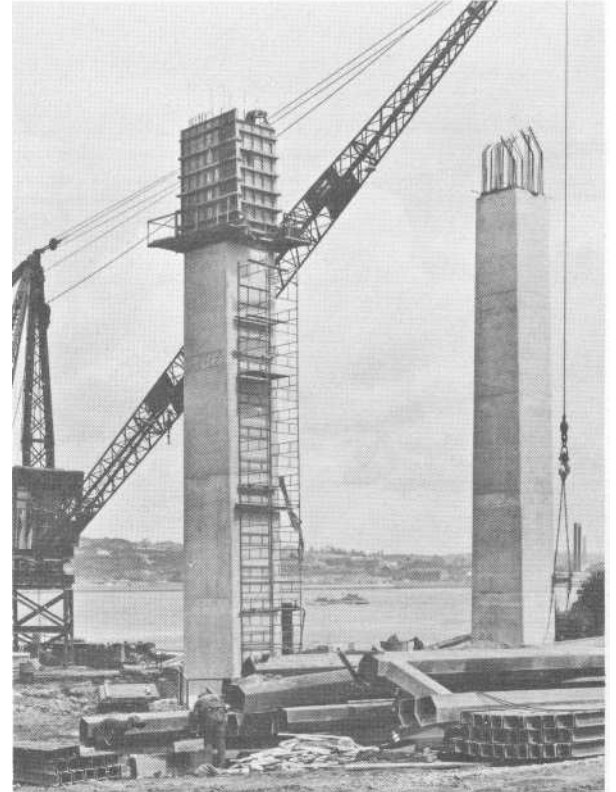
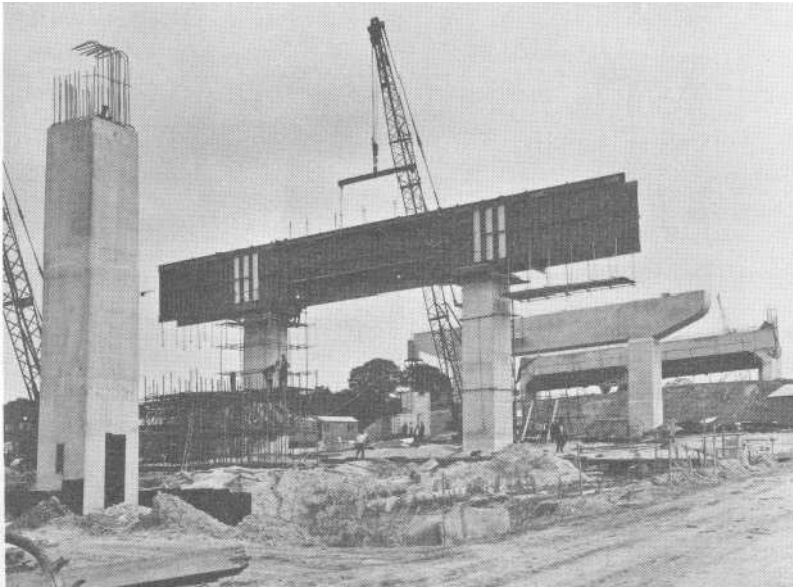


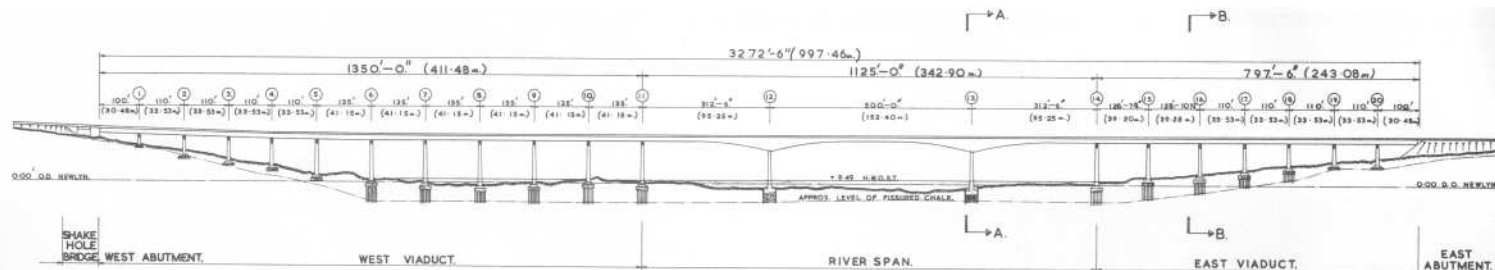
Beam launching on viaduct span.



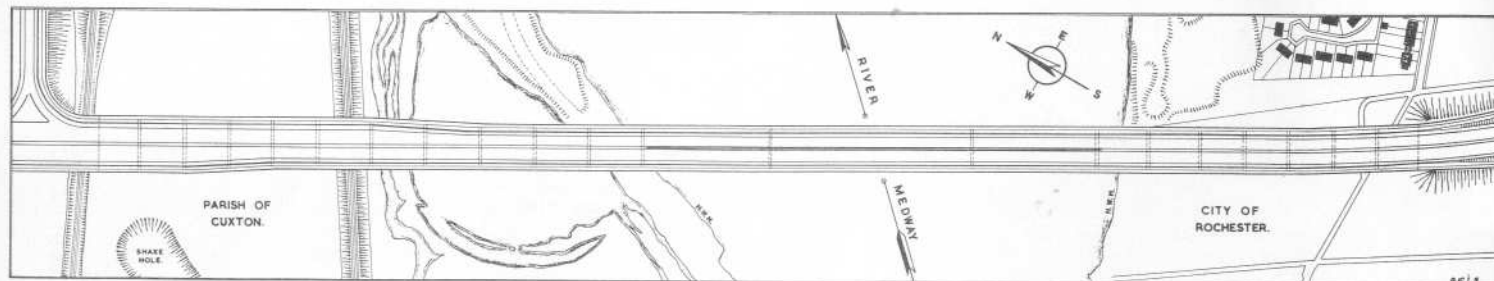
Column casting.

Cross beam formwork.

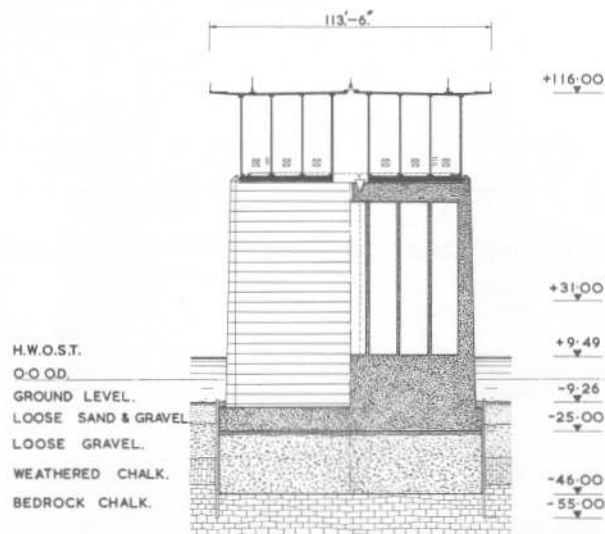




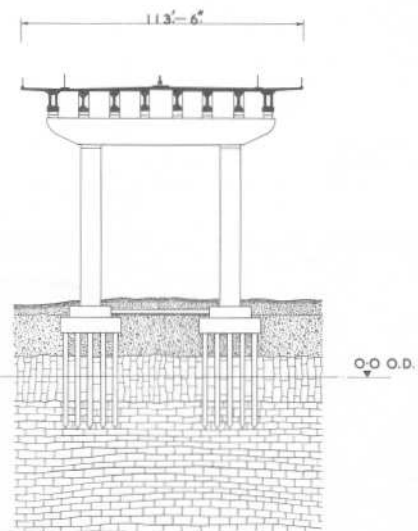
MEDWAY BRIDGE
ELEVATION.



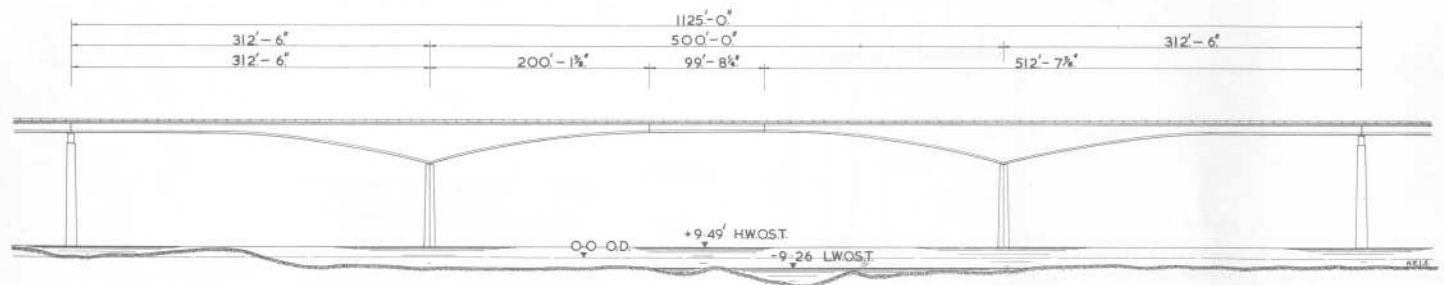
PLAN.



SECTION A.-A.
PIER № 13.



SECTION B.-B.
PIER № 16.



W. VIADUCT

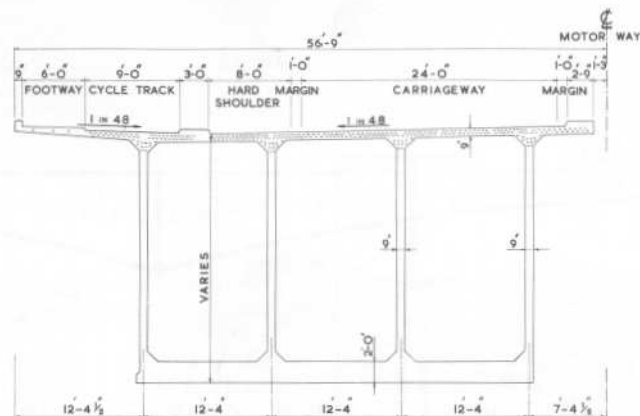
ANCHOR SPAN

CANTILEVER SPANS

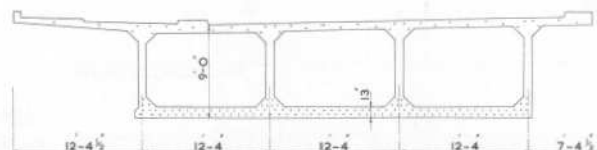
ANCHOR SPAN

E. VIADUCT

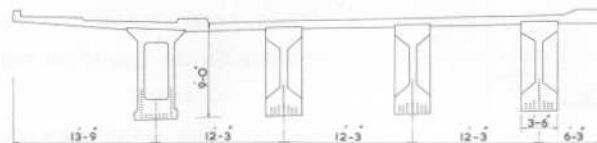
RIVER SPAN ELEVATION.



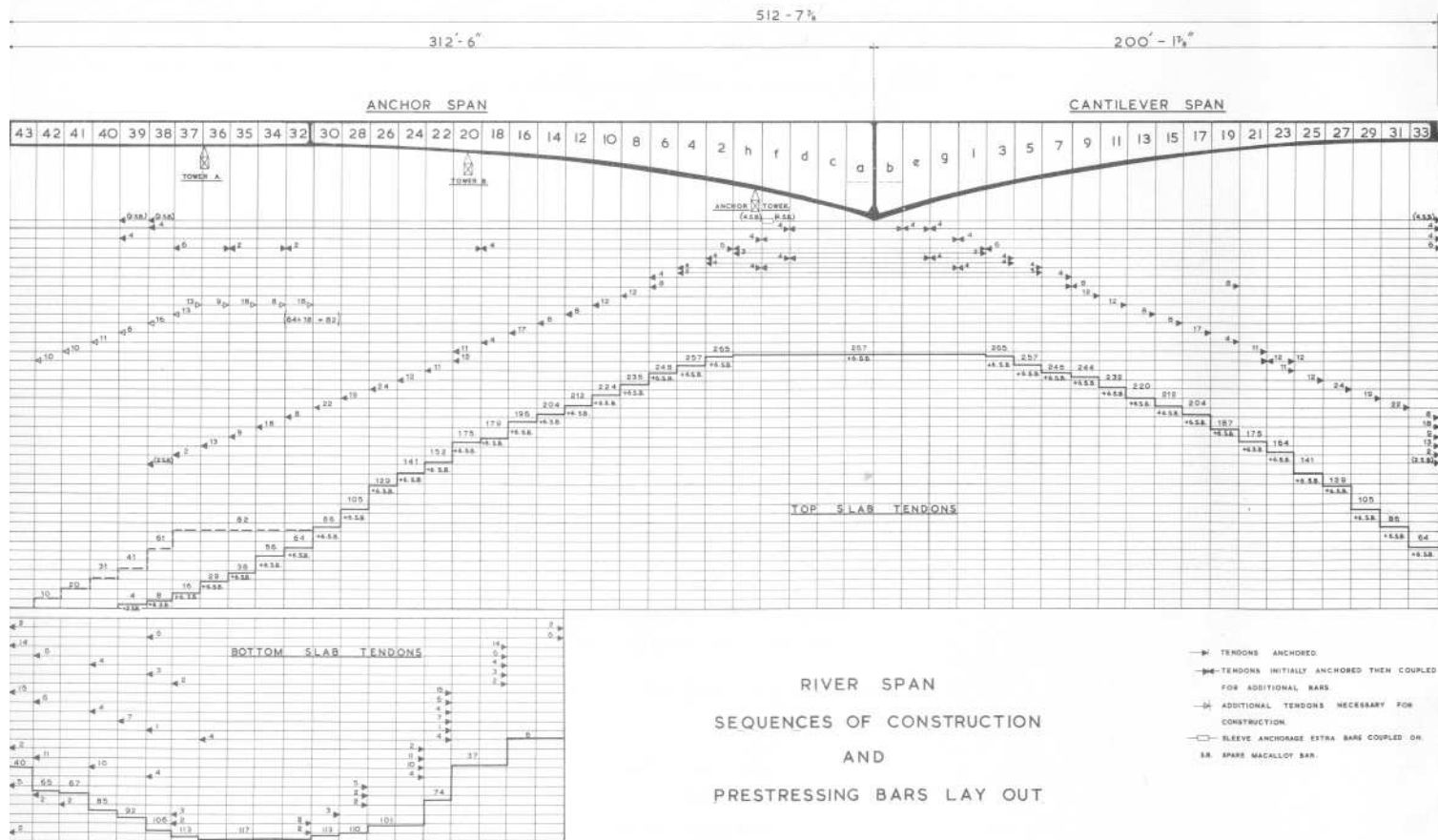
RIVER SPAN CANTILEVER ARM
SECTION THRO' ELEMENT 'd'

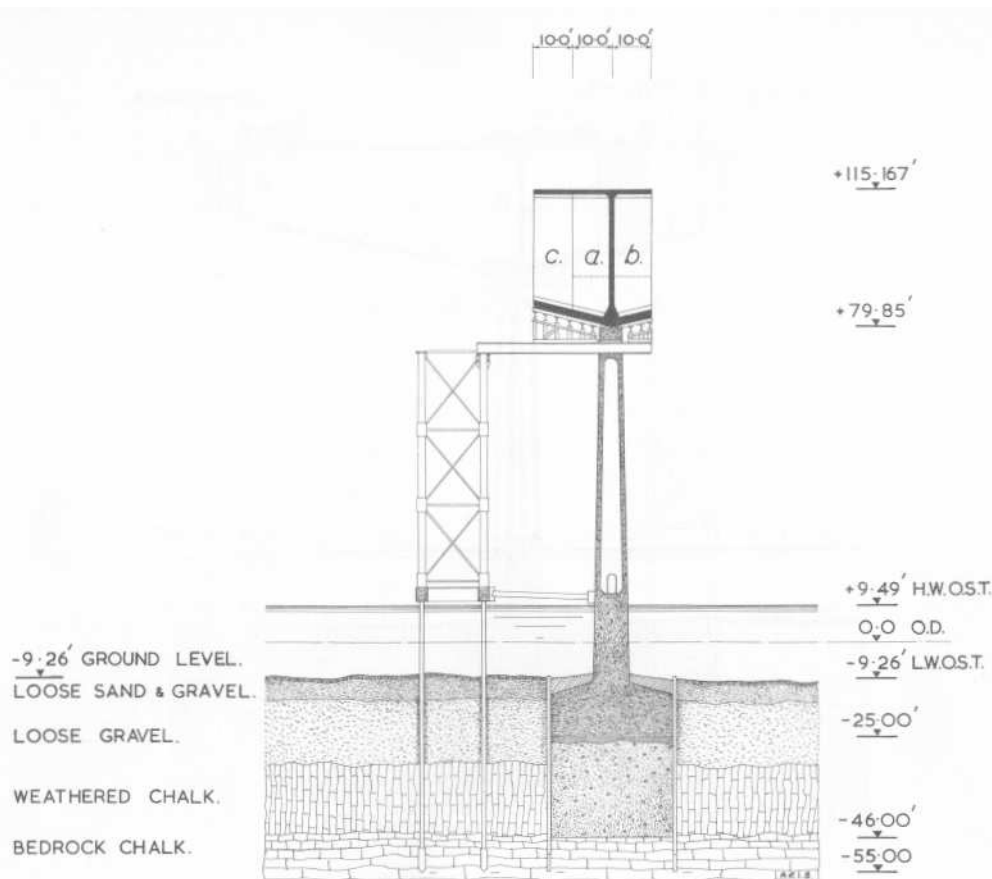


RIVER SPAN ANCHOR ARM
SECTION THRO' ELEMENT '35'



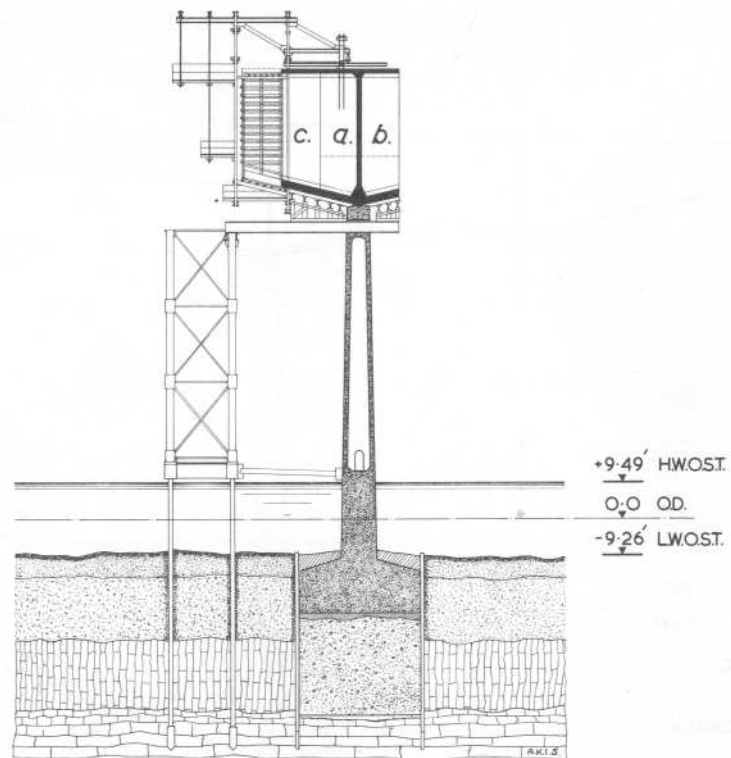
VIADUCT SPAN
SECTION THRO' MID SPAN





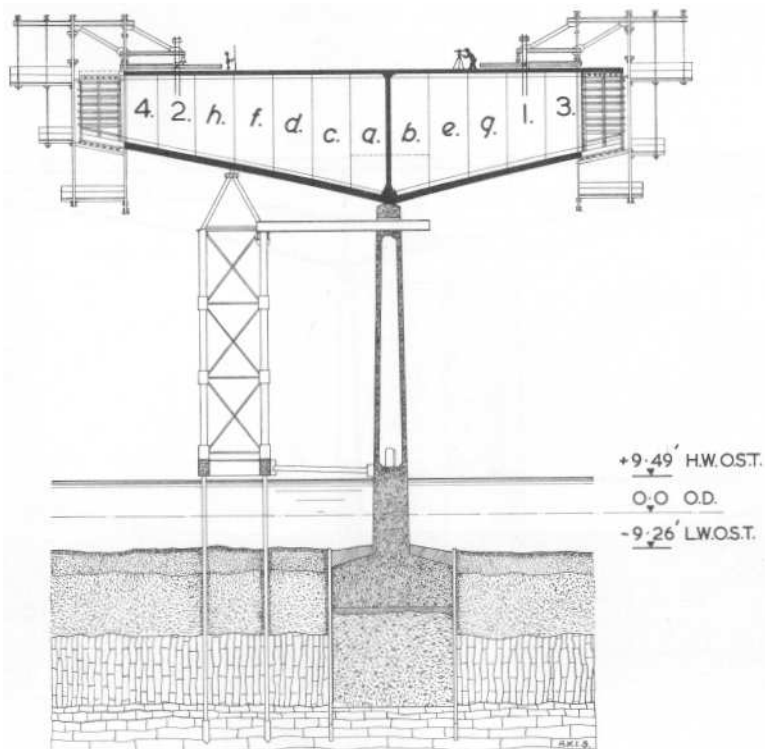
1st. STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.



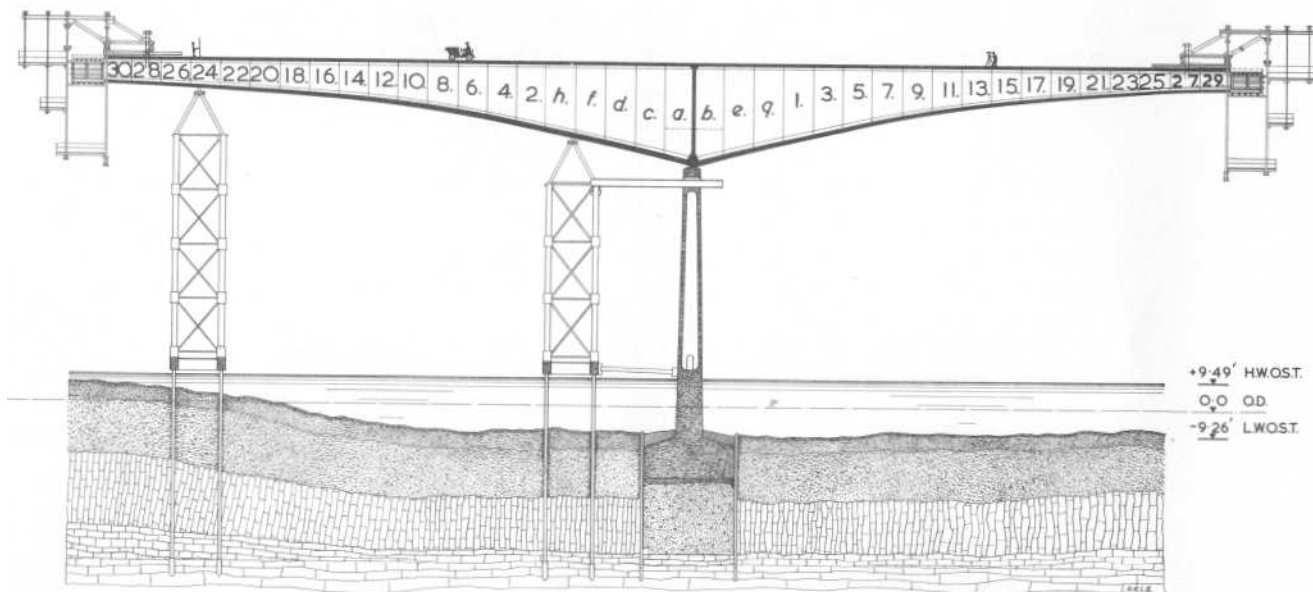
2nd STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.



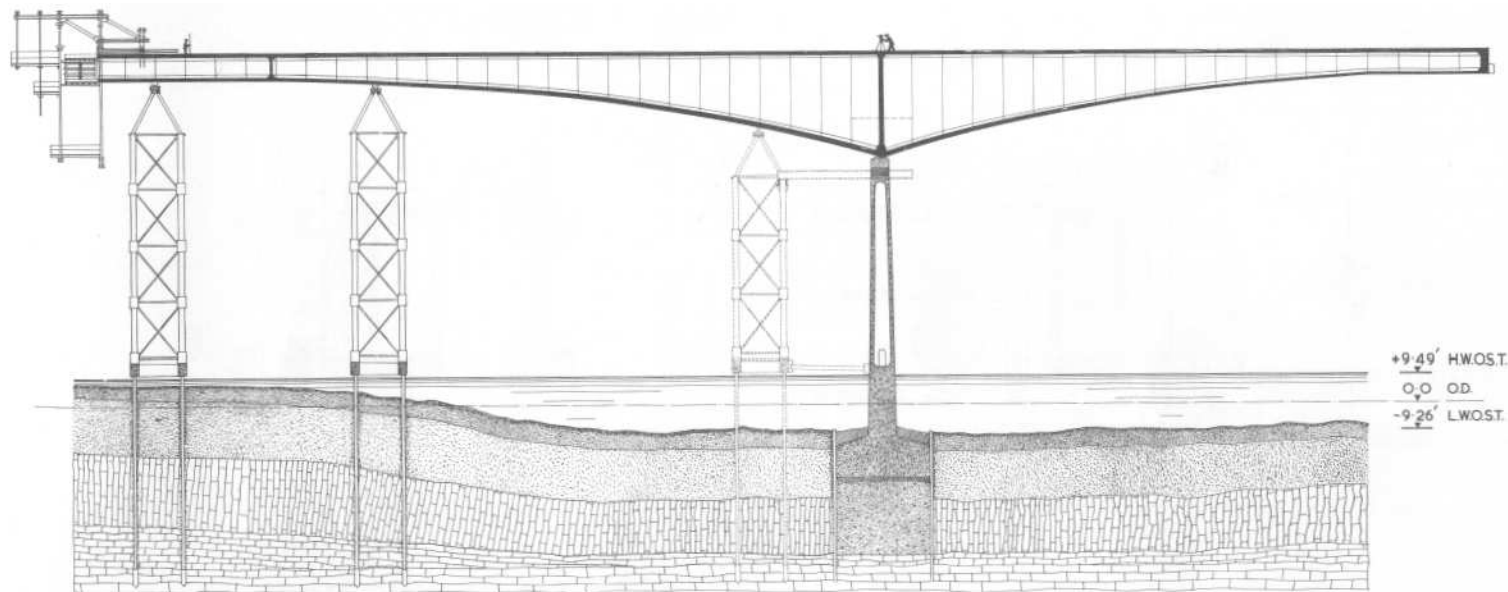
3rd. STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.



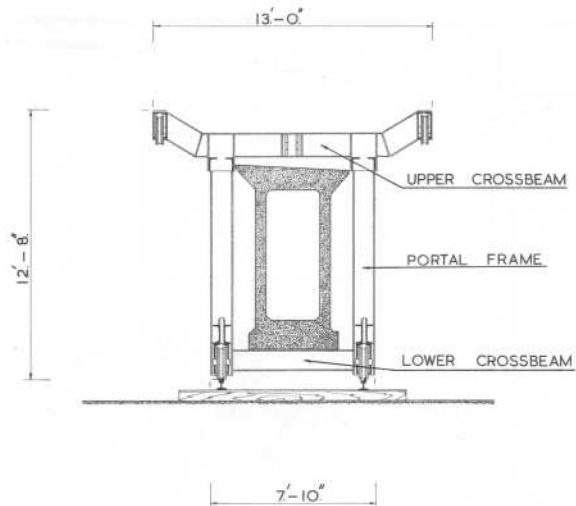
4th STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.



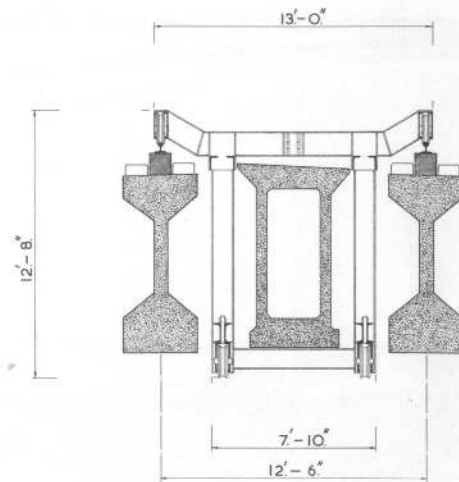
5th. STAGE.

CONSTRUCTION OF ANCHOR AND CANTILEVER SPANS.



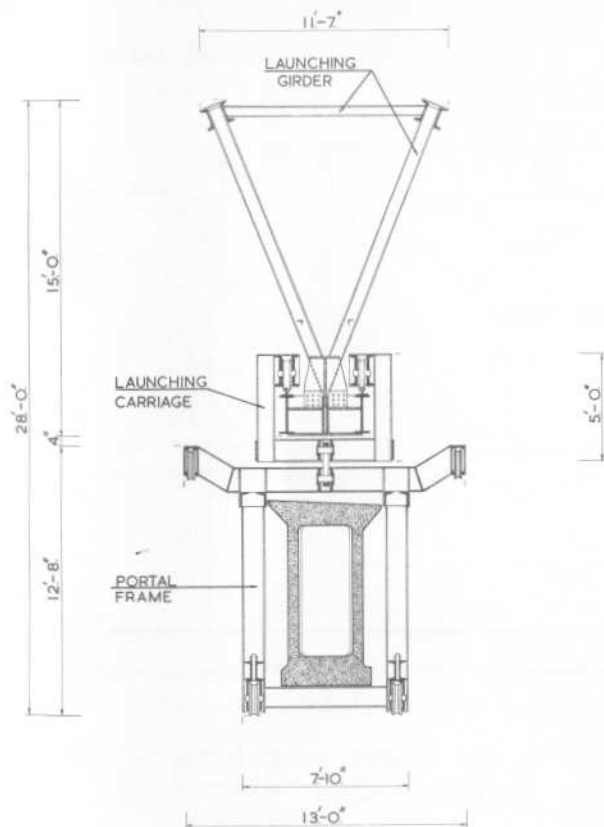
FROM CASTING YARD TO BRIDGE ABUTMENT.

TRANSPORT OF PRECAST BEAMS.



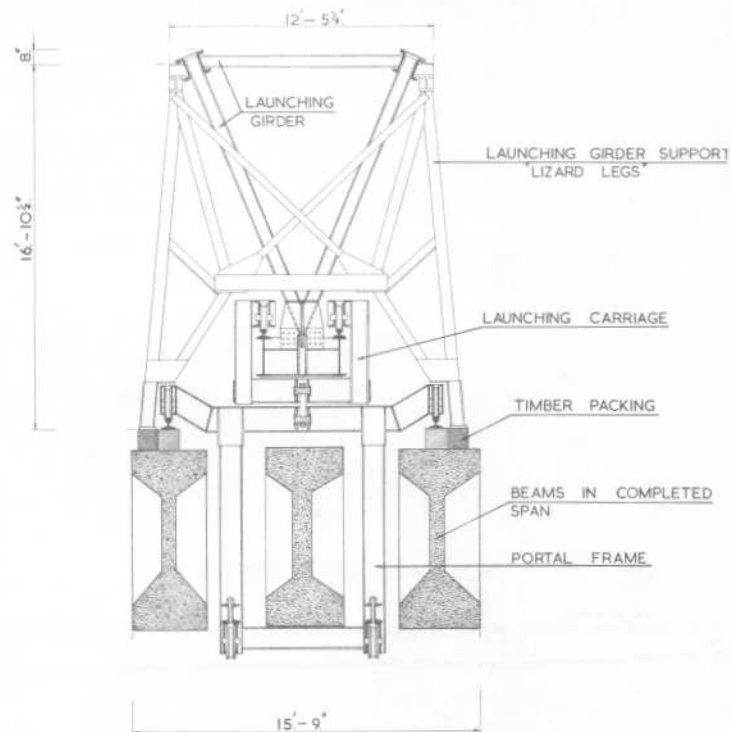
FROM BRIDGE ABUTMENT TO LAUNCHING GIRDER.

TRANSPORT OF PRECAST BEAMS.



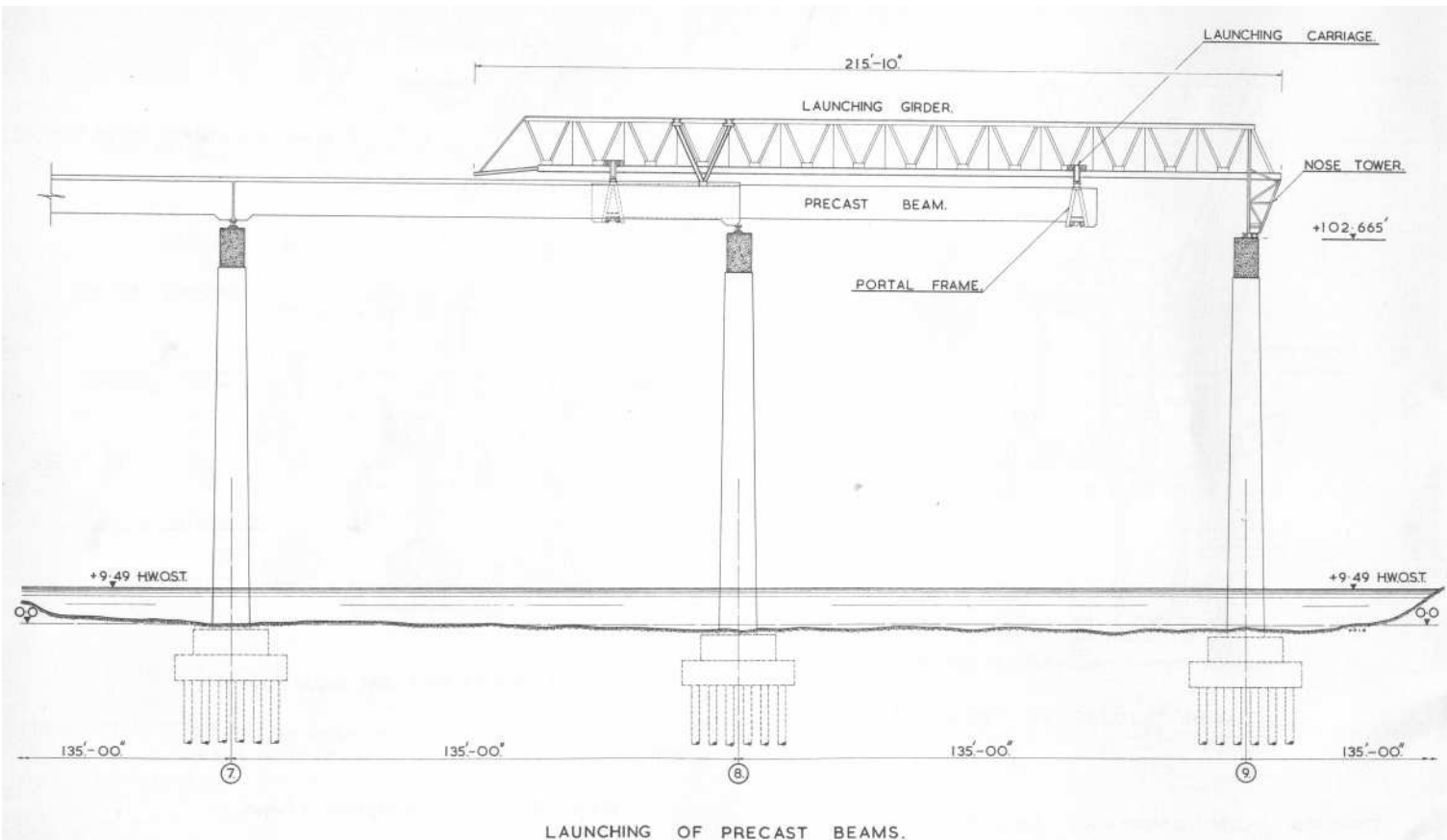
SUSPENDED FROM LAUNCHING GIRDER.

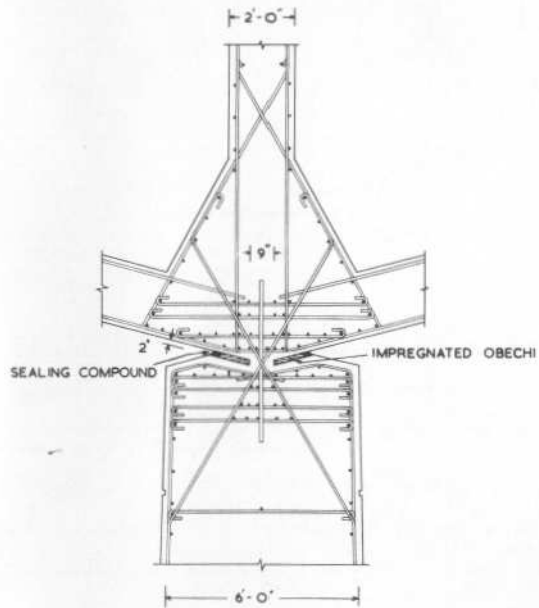
TRANSPORT OF PRECAST BEAMS.



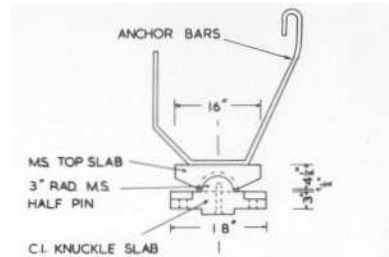
PASSING REAR SUPPORT OF LAUNCHING GIRDER.

TRANSPORT OF PRECAST BEAMS.

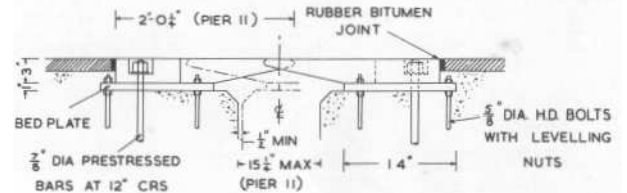




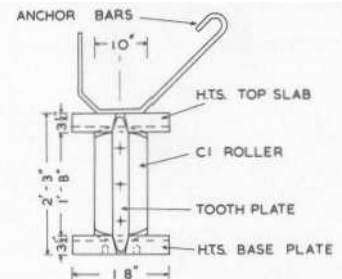
MAIN PIERS
SECTION THROUGH HINGE



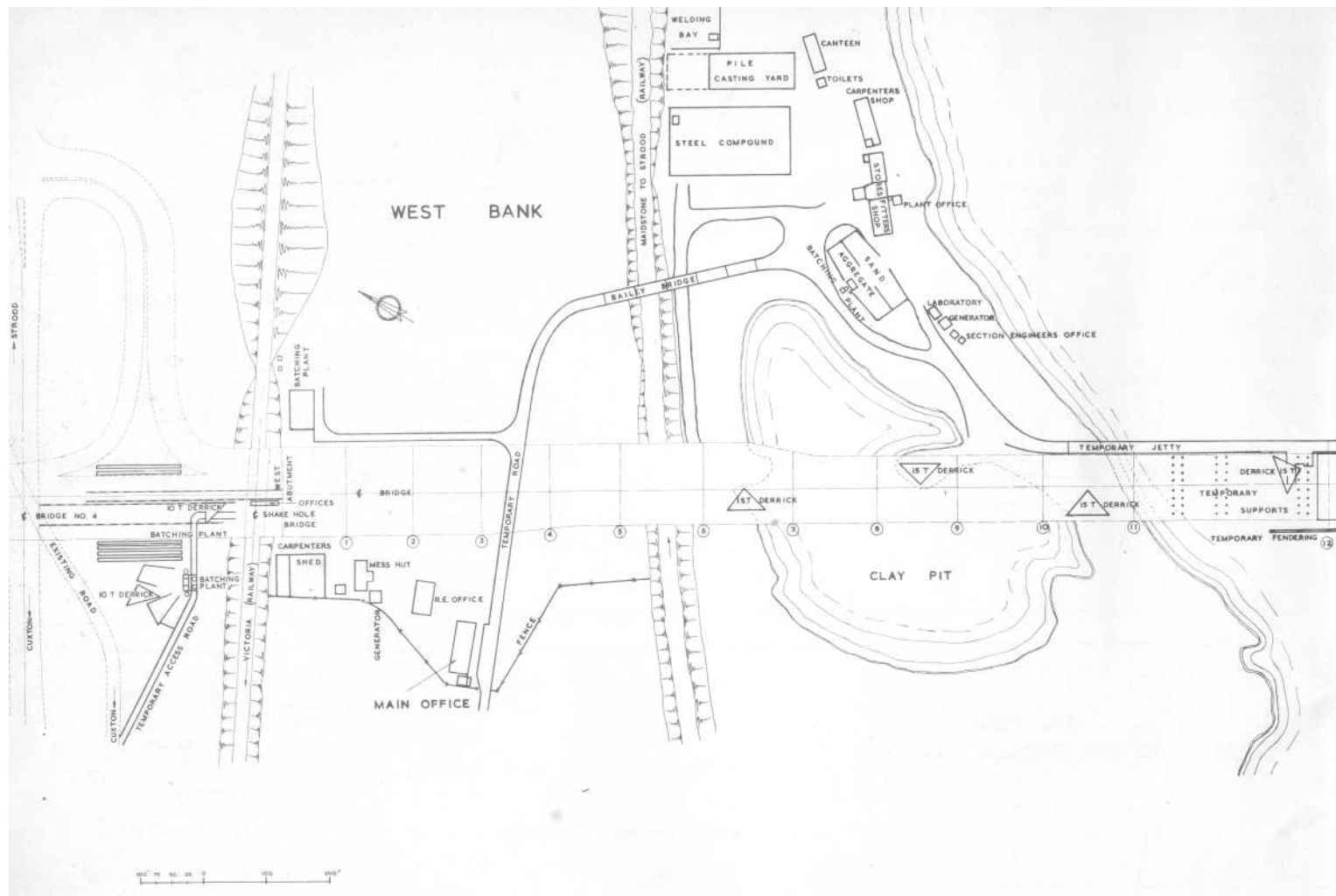
HINGE BEARING - ABUTMENTS



TOOTHED EXPANSION JOINT



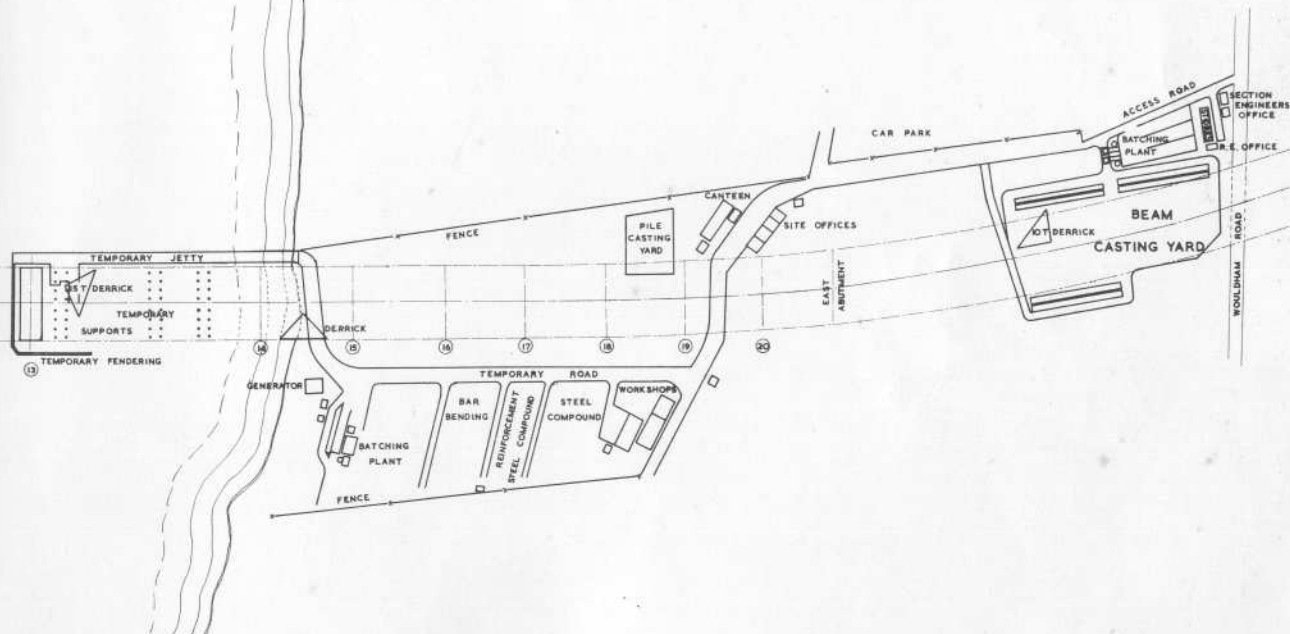
ROLLER BEARING - VIADUCTS



M E D W A Y

R I V E R

EAST BANK



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