DESIGN & DETAILS OF A SINGLE TRACK SINGLE LEAF TRUNNION BASCULE BRIDGE

H. C. ANDERSON
H. W. SCHLINZ
T. E. RICHARDS

ARMOUR INSTITUTE OF TECHNOLOGY

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Anderson, H. C.
Design and general details
for a single track, single

THESIS

DESIGN AND GENERAL DETAILS

FOR

A SINGLE TRACK, SINGLE LEAF, TRUNNION BASCULE BRIDGE.

By H. C. Anderson
H. W. Schling
T. E. Richards Jr.

GENERAL DIMENSIONS

Length of trusses - 150'-0", (center line to center line)
Span - 120'-0", (center line to center line)
5 panels at 24' or total of 120'-0".
1 panel at 30'
Required clear channel of stream - 100'-0".
Required river clearance - 14'-6".

Alfred E. Phillips
Prof Civil Engineering

H. M. Raymond
Dean of Eng & Tech

L. C. Monin
Dean of Cul & Sciences

INTRODUCTION.

The main object to be attained by this somewhat peculiar design is to avoid the heavy steel bolsters which are commonly employed for supporting the trunnions of this type of bridge. As will be readily seen from the drawings, this object is realized by using a slotted abutment to accomodate the tail end of the trusses when the bridge is lifted, the tail end of the floor remaining stationary.

It is easy to see that in designing a bridge of this type, parts of which are more or less original and somewhat complicated, considerable experience in bridge work would be necessary in ord r to arrive at an economical and practical design. Along this line we have been very fortunate in having the kind assistance of Professor M.B.Wells, to whom we are indebted for many ideas and practical hints with regard to design and details of the structure.

LOADING AND SPECIFICATIONS.

A dead load of 22500 pounds was assumed at each panel point and the live load at each panelwas figured as 67500 pounds, using Coopers E 50 loading. The stresses were then calculated with these loads as explained in a later paragraph on "Stresses" and the members and the weight of each was then calculated from this data. Taking into consideration the floor system, members, wind bracing, etc., and roughly estimating connection plates, the dead panel load at each panel point was figured, with result shown on drawing-sheet #1. With these values for dead load at each panel point, the dead load stresses were refigured, and after proper combining of wind, dead and live stresses, the members were figured.

The dead panel loads were figured in the same manner as before but by using the new weights of members, These loads came so close to the former calculation, that the difference would not warrant an entire recalculation of stresses, so these dead panel loads were used in the final calculation of stresses.

The wind stresses were figured for the bridge with a moving load of 450 pounds per foot of bridge and a dead load of 150 pounds per foot of bridge, considering bridge as a simple span and closed. Then with a load of 200 pounds per foot of length the top and bottom bracing and chord wind stresses were figured, the bridge acting as a cantilever. The angle which the bridge will make with the horizontal when up is 70 degrees, but according to Green, when figuring wind stresses on a surface leaving an angle greater than 60 degrees, the wind is considered as acting at right angles to that surface so a wind load of 25 pounds per square foot was considered acting along the track and the effect on the trusses calculated. Considering that an open floor system is used and that there is traffic in the river the year round, no snow load was taken into consideration in the loading. In detailing and designing members, portals, sway and lateral tracing, floor beams and stringers, etc., Coopers General Specifications for Steel Railroad Bridges and Viaducts

(1906 Edition) were followed excepting in combining stresses in certain cases as shown later.

STRESSES.

In computing the stresses in the truss members, the live load was taken at 67500 pounds per panel per truss, this being the same as the maximum shear in stringer, although the maximum live load concentration which can occur at a panel is 92500 pounds, this stress having been combined with the dead load stress in the design of the hip vertical. This however would have been too great to be used as the panel load throughout the truss. Impact due to live load was not considered in the design, the live load allowable stress being taken at one half of the value which would be used if impact were considered. In the design of members, Cooper's Specifications for Railway Bridges were used throughout except as noted herewith: All calculations of members were made with the live load unit stresses as a basis, the dead and wind load stresses being reduced to live load equivalent. Thus 2/3 of dead load stresses and 1/2 of wind lateral stresses were combined with the live load stresses, algebraically. If wind load stresses were less than 30 per cent of the other <u>combined</u> stresses they were neglected entirely.

Rivets in members where reversal of stress occurred due to wind load only were figured merely for the maximum combined stress, the reversal being neglected. (See specifications).

In calculating the dead load stresses, the bridge was considered as a cantilever, that is, the counterweight was taken as just balancing the dead weight of the movable leaf, this weight having at that time been found only tentatively. The concurrent stresses were then combined and an approximate design of members obtained, allowances being made for connection plates, laterals, lacing, etc., when the approximate weights of members were found. In this way the corrected panel weights were found and the stresses and sizes of members again calculated, the weights of members being figured accurately.

The floor system and floor beams were designed according to Coopers E 50 loading. The weights of each member of the floor system were found as well as the center of gravity of the whole. The center of gravity of the truss members were also obtained and this combined with the corresponding values for the floor system gave the point at which the mass of the bridge might be considered as concentrated. Knowing this, the amount and distribution of counterweight was found, the center of gravity of the latter being on the line joining the center of gravity of bridge and trunnion, produced. By locating the center of gravity of the counterweight on this line and making the moment of the counterweight about the trunnion equal to total amount of the dead load on the moving leaf, the bridge would be balanced in any position and the power necessary to raise the same would be reduced to the amount necessary to overcome wind load gear losses and journal friction.

The counterweight end of the lower chord was designed to take the compression which would come on it with the bridge in a horizontal position, and also to take the <u>entire</u> tension due to the counterweight when the bridge was raised.

STRESSES.

EMBERS	DEAD LOAD, BRIDGE AS CANTILEVER	MAX. LIVE LOAD. BRIDGE CLOSED	WIND LOAD IN DIRECTION OF TRACK BRIDGE UP	LATERAL WIND LOAD BRIDGE CLOSED	LATERAL WIND LOAD BRIDGE UP	DESIGN FOR (USE LIVE LOAD UNIT STRESSES)
AI	+14100		+2200	+22200		
		-172900	-2200	-22200		-177500#
AB	32000		+5600	+0		
		-162000	-5600	-7200		-147100#
BC	+32000	-	+5600	+7200		
		-162000	-5600	-7200		-147100#
cD	+70400		12600	0	+43200	+136200#
		-162000	-12600	-7200	-43200	-162100
DE	+200800	0	35000			133900
			-35000			
E2	+283100	0	+49500			+188800
			-49500			
e2	+300000	0	+35000			+307000
	-200800	0	35000			240900#
de		+108000	+22400	+0	43200	
	-125600		-22400	-64800	-67500	-129400#
cd		+108000	+22400	+53200		+105200
	-125600		-22400	-64800		-175000#
bc		+162000	+12600	+64800		+163300
	-70400		-12600	-64800		129200#
ab		+108000	+1400	+53200		+129800
	-8800		-1400	-64800		-68900
Ia		+108000	+1400	+0		+125100
	-8800		-1400	-53200		-58320
Ab		+103700	+6700			+100000
	-37200		-6700			-75600#
Cb	+61500	+51900	+11200			+92900
		-51900	-11200			
Cc		+40500	+8800			
	-48000	-40500	-8800			-72500
Dc	+88400	103700	+15700			+147900
		-17300	-15700			
Dd	+22000	+59100	+3500			70100
			-3500			
De			+20100	+22000		
	-124200	-175000	-20100	-22000	-69100	-273900
YZ	+6000	+16900	+1000			+20900
			-1000			
dZ	0					
	0	-10800				-10800
Ec		0	+3500			
	-200800	0	-3500			-133900
Aa	+18000	92500	3500			+104500
			-3500			

Members indicated by asterisk should be figured for reversal of stress in rivets. (See specifications)

The part of the lower chord marked Ye on the stress sheet wa designed as a beam fixed at the outer end, to take lower lateral stresses. The top lateral stresses were calculated for two positions of bridge:- 1st, closed (in which case the bridge was considered as supported at both ends in resisting lateral forces). 2nd, as just off the abutments (in which case the bridge acted as a cantilever, and all lateral forces were transferred to the trunnion through the member De). The first case produced maximum stresses in all laterals except those in panel DC. For this panel the stresses of case 2 were put on the stress sheet for these members, which for the other panels the stresses of case 1 were taken.

OPERATING MACHINERY.

The operating machinery will be located between the two approved girders and beneath the track. It will be protected from the weathsr by the webs of the girders and by a solid floor built on that part of the girder. The power will be furnished by a compound D.C. Motor of 130 Horse Power, running at 600 R.P.M. under ordinary conditions when there is little or no wind to oppose the lifting of the bridge. The power necessary to lift bridge has been figured on the assumption of a wind pressure of 15# per sq. foot of exposed area, the wind coming in a direction parallel to the track, and the bridge to be raised in 40 seconds. This wind velocity produces a stress in the rack, at pitch line, of 21000# on each truss which must be counteracted by the motor. The efficiency of the entire mechanism was assumed at 60 per cent, this including losses in gears, gear shaft journals and trunnion bearings.

To raise the bridge in 40 seconds through 70 degrees would require a speed along the pitch line of 55 feet per minute. Then allowing 60 per cent efficiency, the foot pounds per minute at the motor would be 55 x 21000 x 100/60=1,925,000 foot pounds which is equivalent to 58.3 Horse Power for each truss or a total of 116.6 Horse Power.

For the design of the teeth on rack, and on the engaging pinion the maximum wind stress of 35000# was used, the tensile strength of cast steel being taken at 5000# per sq. inch in the design. With a rack 18" wide, this gives teeth having a pitch of 6.5" and a height of 4.5". The pinion operating the rack has 10 teeth, the diameter being 20.7" on the pitch circle. On the same shaft with this pinion is a gear of 10" face and 4" pitch and 2.75" height of tooth. It has 75 teeth and is engaged by a pinion of 10 teeth mounted on a 5" shaft. On this same shaft is placed a gear of 95 teeth having an 8" face and 3" pitch. Driving this is a gear on the motor shaft. This has a 3" pitch and is 11-1/2" in diameter.

The rack and pinion are to be cast steel, the teeth not being machined. The same applies to the intermediate gears. The pinion on the motor shaft and the corresponding gear are to be machined or cut.

No mention has here been made of brakes, methods of control,

signals and other devices which form part of the equipment in operating houses for bridges of this character, this being too large a subject to be included in a civil engineering thesis of this kind.

Due to the position of the machinery a slot will probably have to be cut in the rear wall of masonry, but as the machinery is not fully designed, this change in the masonry was not shown on the tracing.

Although a 120 Horse Power motor is to be installed, the power necessary to lift the bridge may at times of high wind velocity be much more, but as a compound motor will operate satisfactorily under an overload of 50 per cent this greater horse power is taken care of, and affecting the operation only in so far as it will take perhaps a minute to raise bridge. On the other hand under ordinary conditions the wind load will be considerably less than was assumed and the power required, and also the time of raising bridge, will be materially lessened.

LOCKING DEVICE.

In a bridge of this type, when the trusses are counterbalanced by a weight in such a way that the bridge will remain at any angle to the horizontal if no outside force is exerted upon it, it is necessary that the bridge be locked in some manner before trains or other traffic be allowed to enter upon it. If a locking system of some sort were not used, aside from the apparent danger of a serious accident, there would be a tendency for the bridge to rebound slightly just after a set of trucks had left it, assuming in this case that the train is coming off at the locked end, and by the time the next set came up there would be a tendency for the wheels to jump the small gap thus left with the result that there would be a pounding on the rails such as takes place at rail joints on straight track. This rebounding would be greatly increased if a wind of high velocity were blowing. With the train coming on the bridge there would be a pounding on the rails and an unnecessary jarring of the trusses. With a train going in the opposite direction the result would be practically the same excepting that the pounding would be on the other side of the rail joint.

Without a locking device on the trusses themselves it would be necessary to have a locking device on the operating gears and this would necessitate designing the machinery to take a great part of the live load, in fact we would have a continuous span, with three joints of support and the tooth that would be in contact with the operating rack would have to take all the live load reaction at that point. This would make necessary the designing of much heavier gears and this, along with the cost of replacing pounded rails very often, would increase the cost of construction and maintainance very noticeably.

The locking system used in this case consists in the main of two 3 inch pins 2'-3" long (one at each truss) which are operated by means of electric magnets. One of the magnets is placed on the masonry at each truss and the other on the truss, the

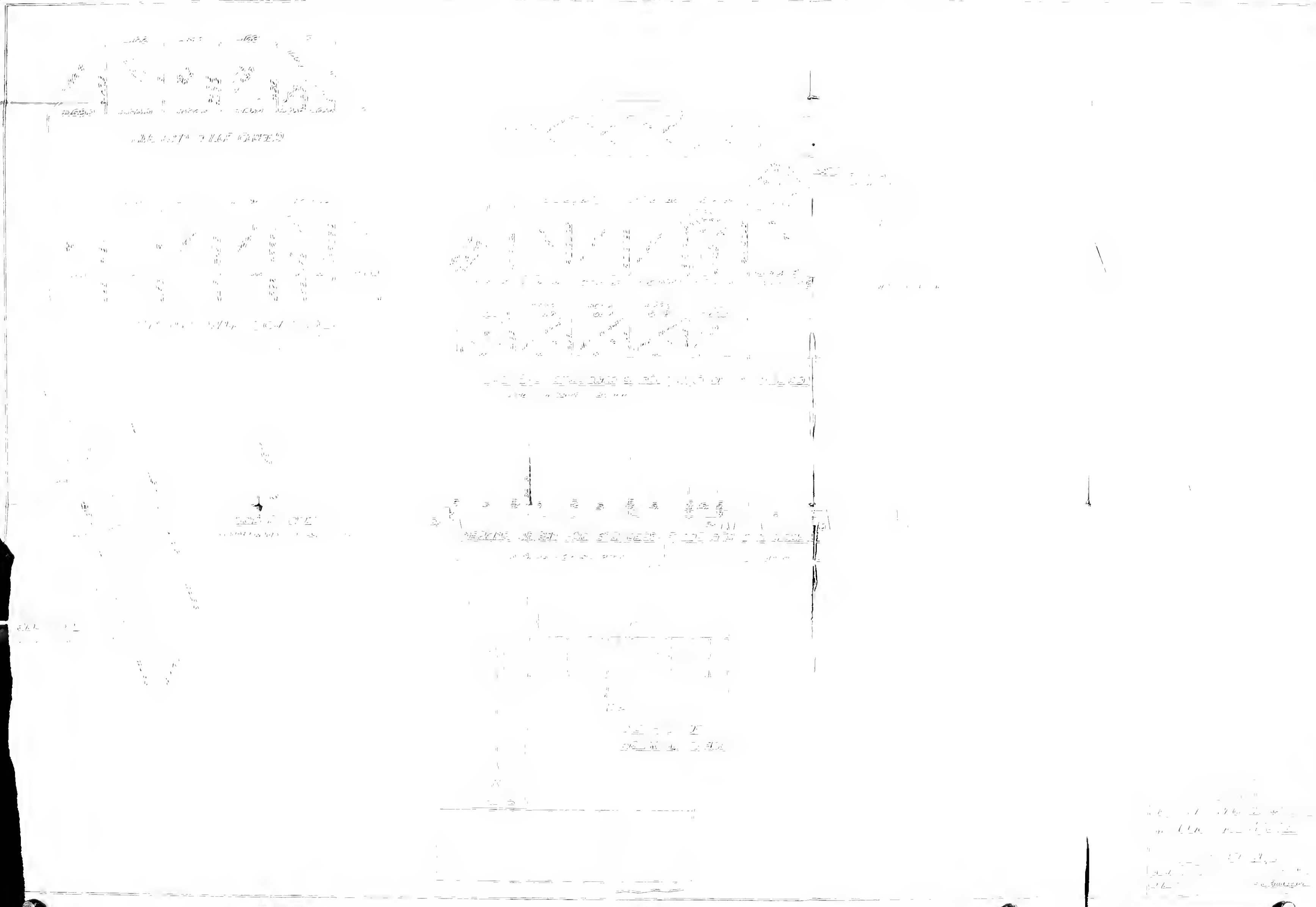
operator of the bridge being able to throw whichever magnet he desires into action by turning a switch, the wiring to be done in such a manner that only one magnet can be charged at a time and the other is always charged.

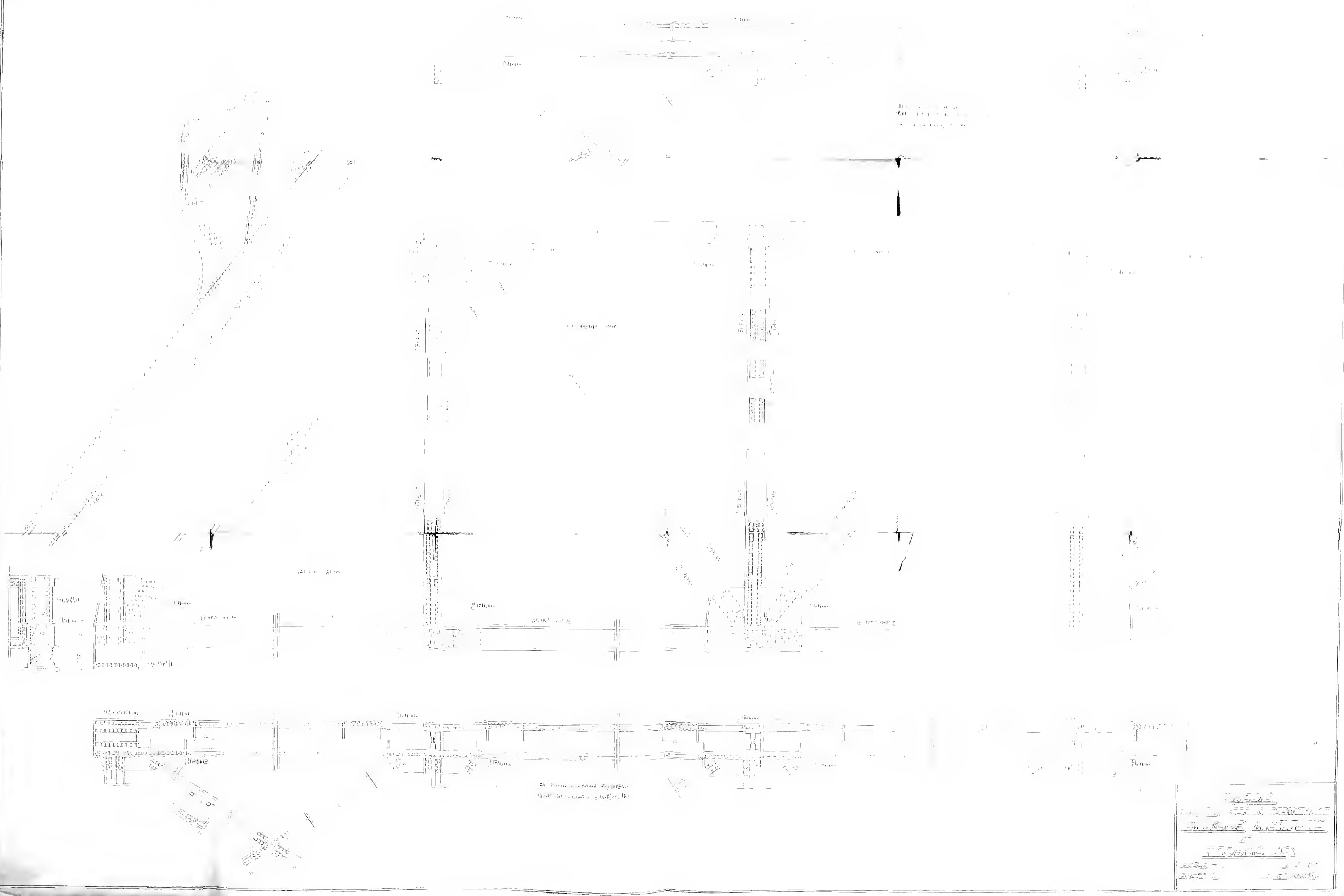
MASONRY.

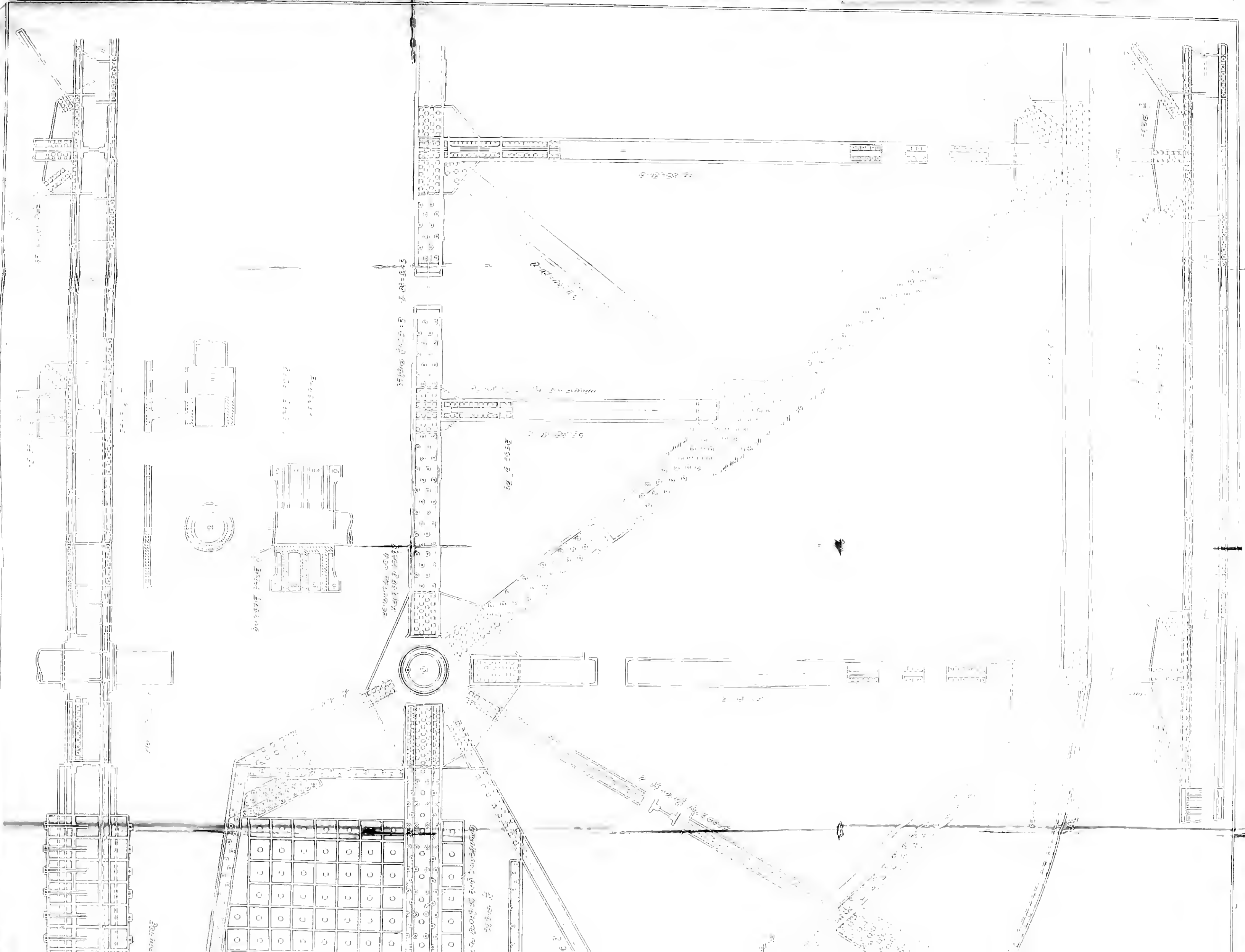
The substructure for supporting the bridge will be built of Portland cement, concrete reinforced as shown on the drawings. The abutments are to be also reinforced for temperature and shrinkage stresses. This reinforcing is not shown on the drawings but there is to be placed a 3/4 inch corrugated bar to every square foot of cross section. The abutments are assumed to rest on good clay subsoil with a bearing power of 4 or 5 tons per square foot. No piles are required, under the masonry as the pressure only comes up to about 2 tons per square foot. A row of protecting piles is to be driven around the piers on the channel side. The clear channel will be finally about 101 feet.

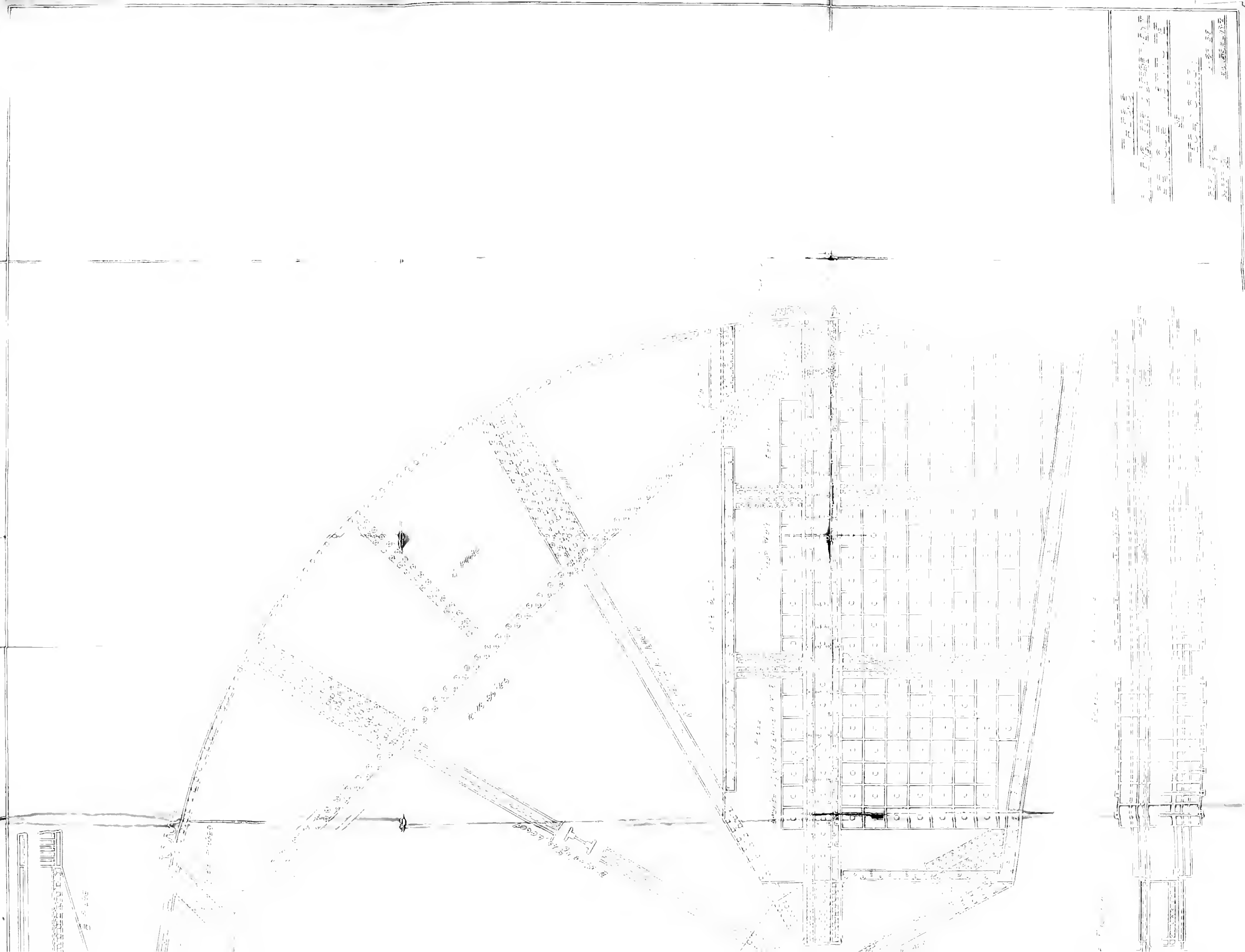
METHOD OF BREAKING TRACK.

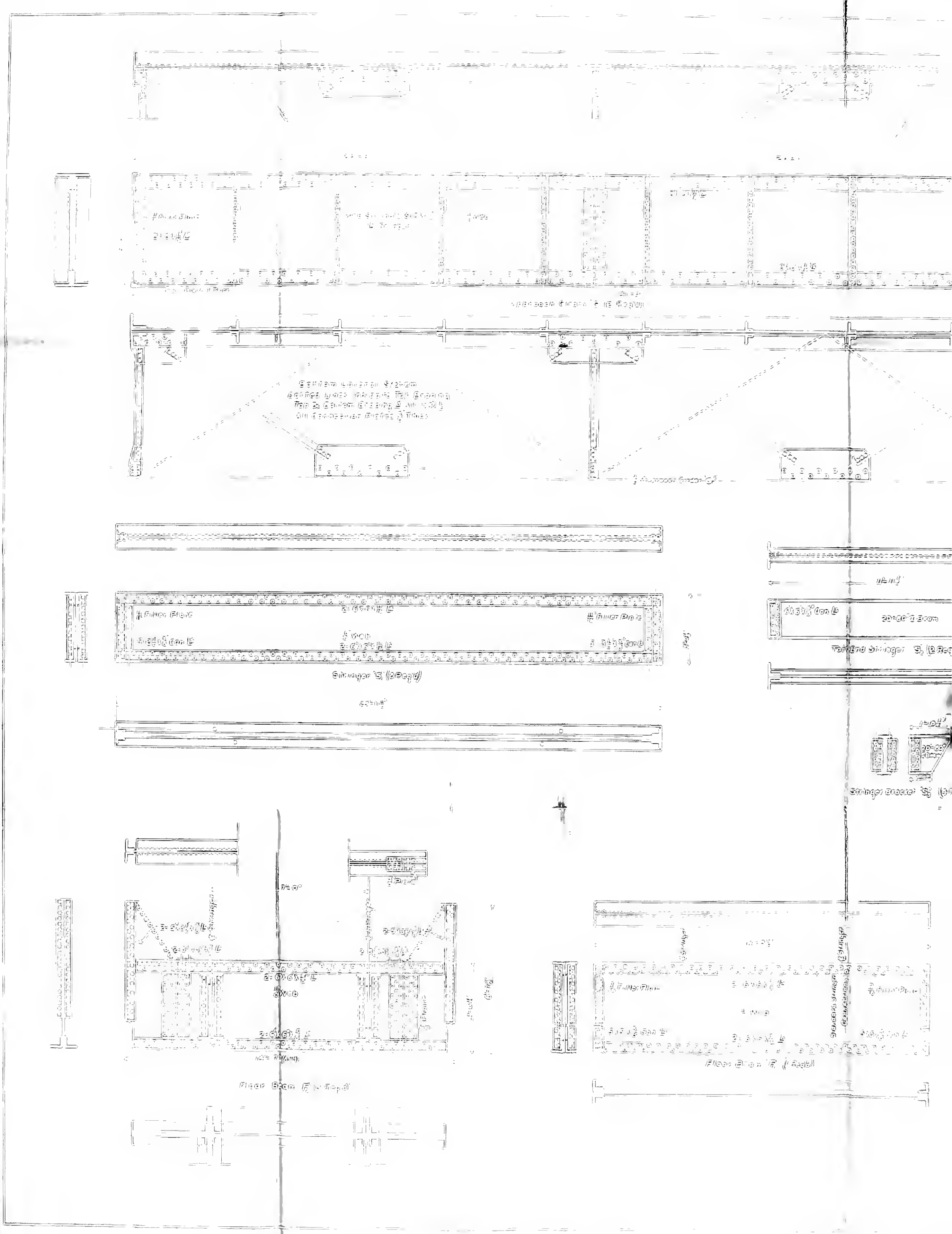
The way in which the track is to be broken is best shown by the sketches on the stress sheet. In working out the scheme used, attempt was made to make it as simple as possible and to support the rails as rigidly and as near the ends as possible.



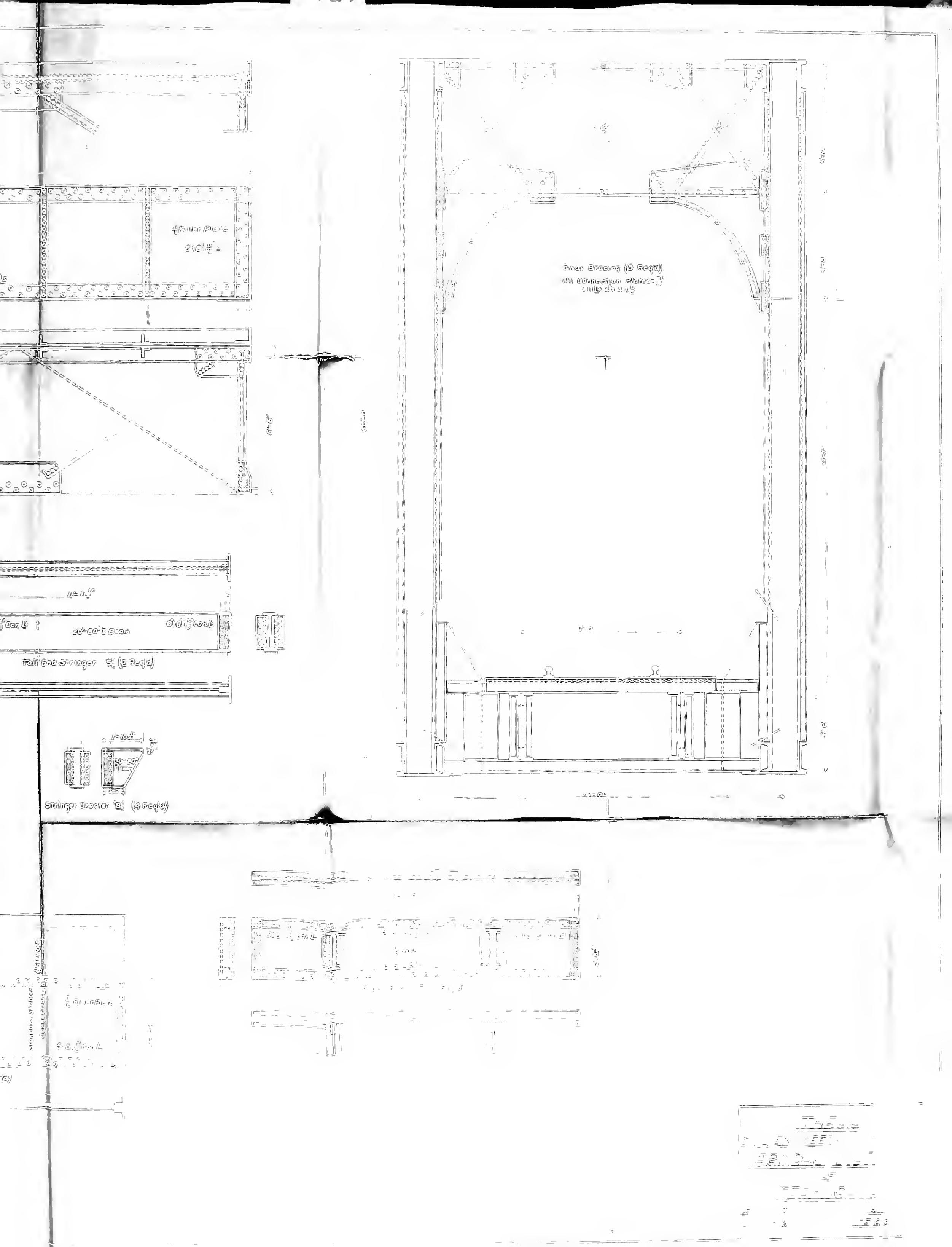




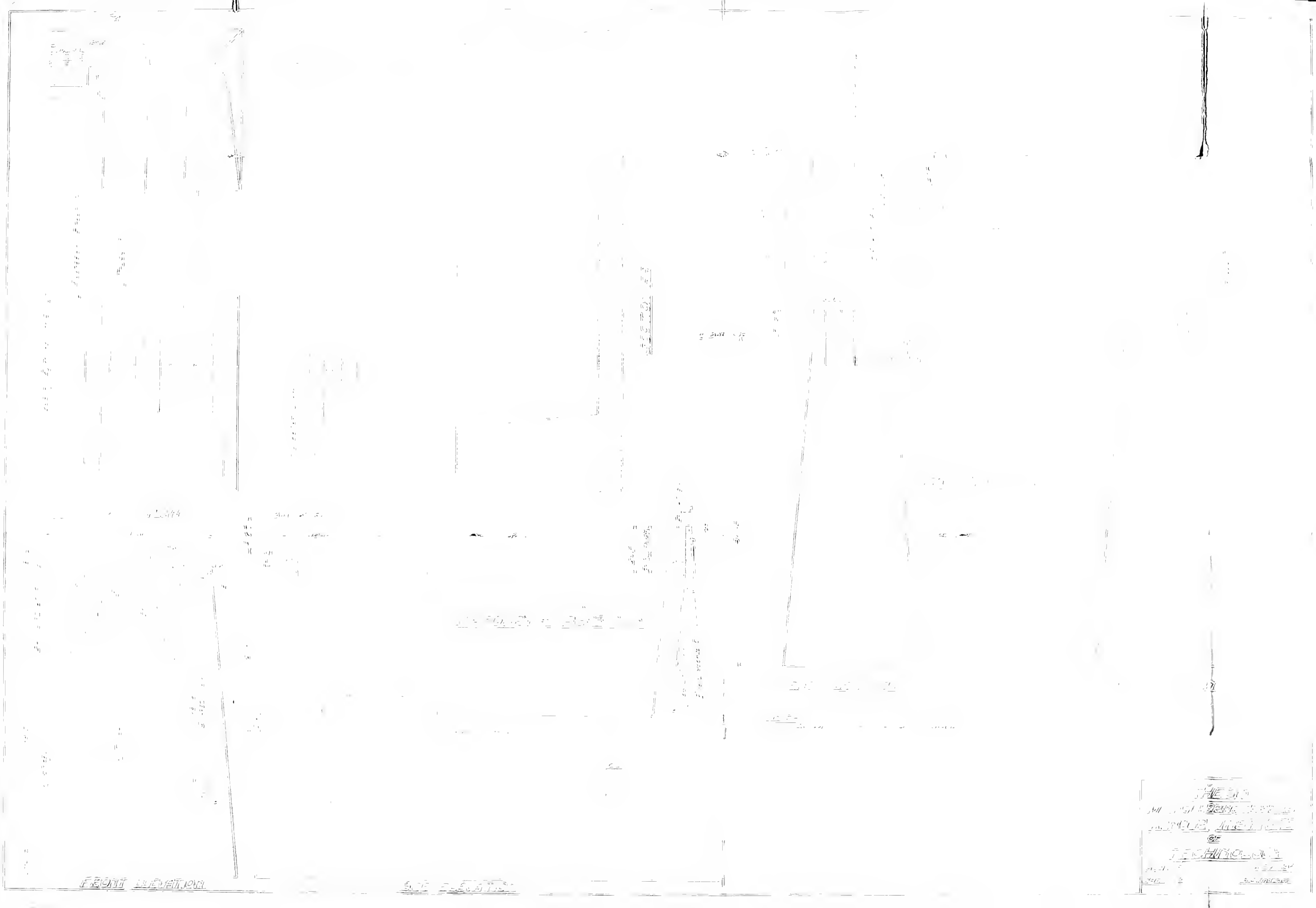




Bottom Lateral System
Floor Beam
Stringer
Filler Plate
Web
Track End Stringer
Stringer Bracket
Standard Stringer Connection



Sway Bracing (5 Req'd)
All Connection Plates
Filler Plate
Tail End Stringer
20-00 I Beam
Stringer Bracket
(4 Req'd)


FRONT ELEVATION
OF