1901

The sinking of piers on Red River Bridge on Kansas City Southern Ry.

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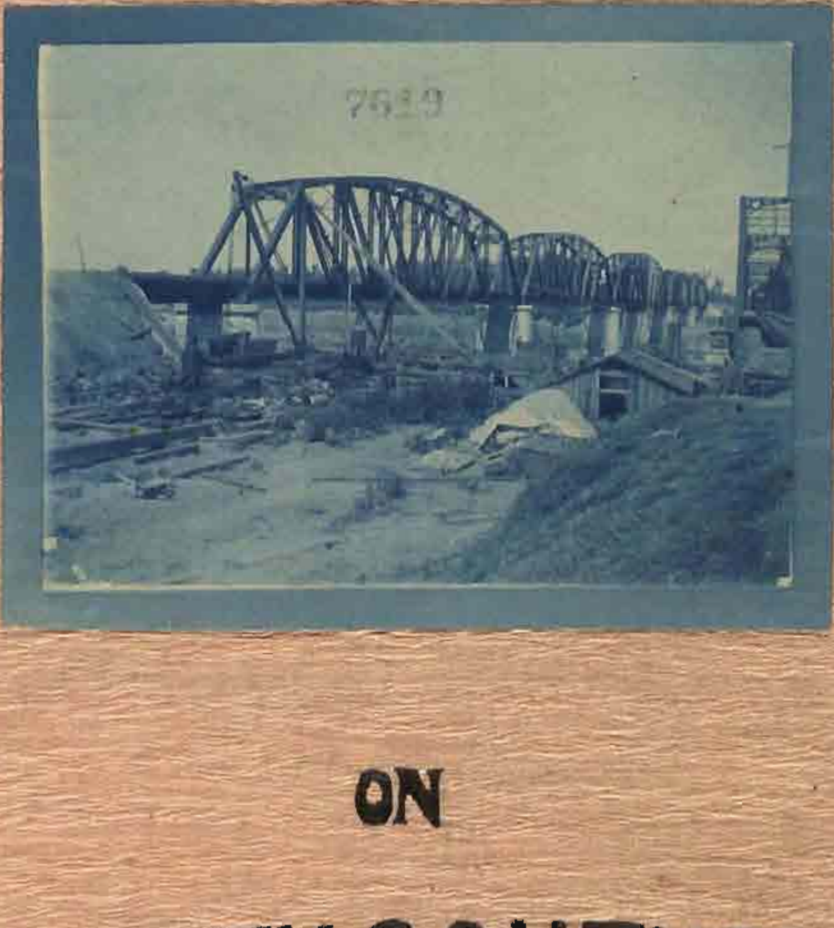
THE

SINKING OF PIERS

ON

RED RIVER BRIDGE



ON

KANSAS CITY SOUTHERN RY.

BY

A. SPENGLER

RES. ENG'R.

THE SINKING OF PIERS OF RED RIVER BRIDGE

on

Kansas City Southern Ry.

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In September,1899,began the work on the construction of the substructure for the Red River Bridge for the Kansas City Southern Railway at Index,Texas,ten miles north of Texarkana,Texas.

The new substructure was located about one hundred feet up stream from the old one,consequently it was not necessary to maintain traffic during construction. The object of the new bridge was to replace a much lighter one, which was too light for the increased weight of rolling stock of the railroad company.

The substructure consists of seven piers,including a pivot pier,and two abutments. The seven piers are concrete piers,which are supported by cribs and caissons of timber and Portland cement concrete,sunk by the pneumatic process to and into the soft bed-rock,namely blue shale of impenetrable thickness. At each end forty feet from the end piers there is an abutment of concrete. The following blue print shows a correct profile of the stream and depths to which foundations were stopped are also shown. These piers are carried down as far as were directed,being the intention to obtain a foundation safe beyond the peradventure of a doubt.

General view looking north of bridge site with tram-way to th the left and old bridge to the right.

In order to cut and pass through logs that were encountered, the caissons were fitted with an effective apparatus, viz: a steel cutting edge as per drawings. Suitable air locks and clay hoists were used for the purpose of entrance into caissons and the hoisting of the shale from below, respectively as the sinking in shale was in progress. Removable cofferdams were used above the cribs in order that the lower portions of the piers could be built in the dry, which were removed when the piers were completed.

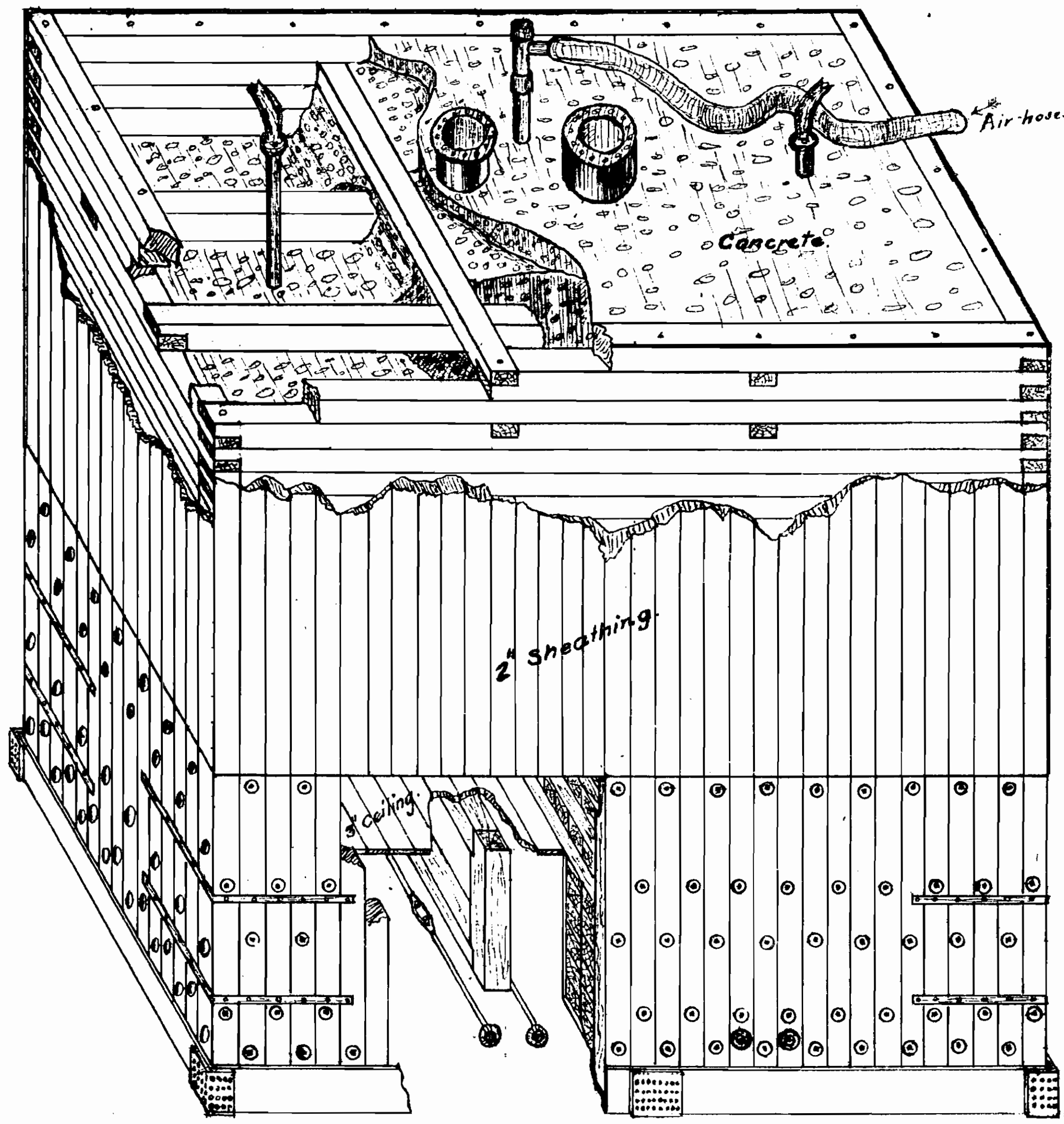
Cribs and Caissons:

The caissons were constructed of the best quality of American long-leaf southern yellow pine cut from untapped trees and sized to exact dimensions, free from defects which would have impaired its strength or durability for such purposes. Under no circumstances was any timber cut from dead logs allowed to be placed in any portion of the structures, but all timber was live timber.

Deck and side timbers were of 12" x 12" section and all full length and width of the caisson wherever it was practicable so to do. The cutting edges as before stated were shod with steel.

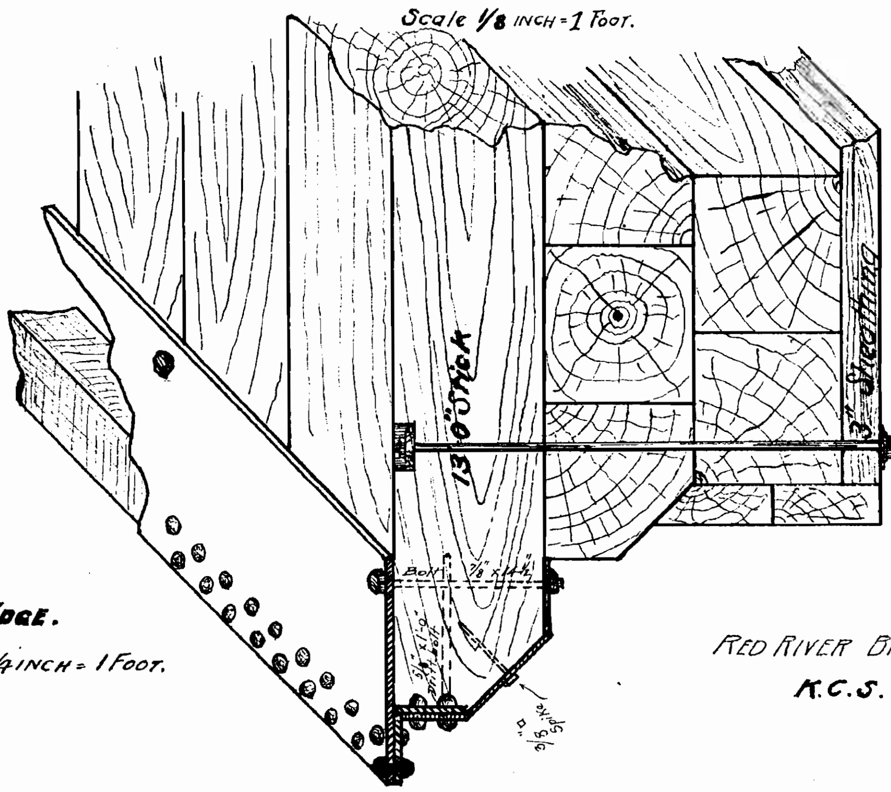
The drift bolts were of soft 7/8" steel and were spaced on the average of about four feet along each stick.

The deck of the caisson consisted of six courses, that is, ie. between the bottom of concrete in crib and the excavating or working chamber. All framing of the timber was made in so substantial a manner that the cribs and



CAISSON AND CRIB

Scale 1/8 INCH = 1 FOOT.



DETAIL OF CUTTING-EDGE.

Scale 3/4 INCH = 1 FOOT.

RED RIVER BRIDGE ON K.C.S. RY.

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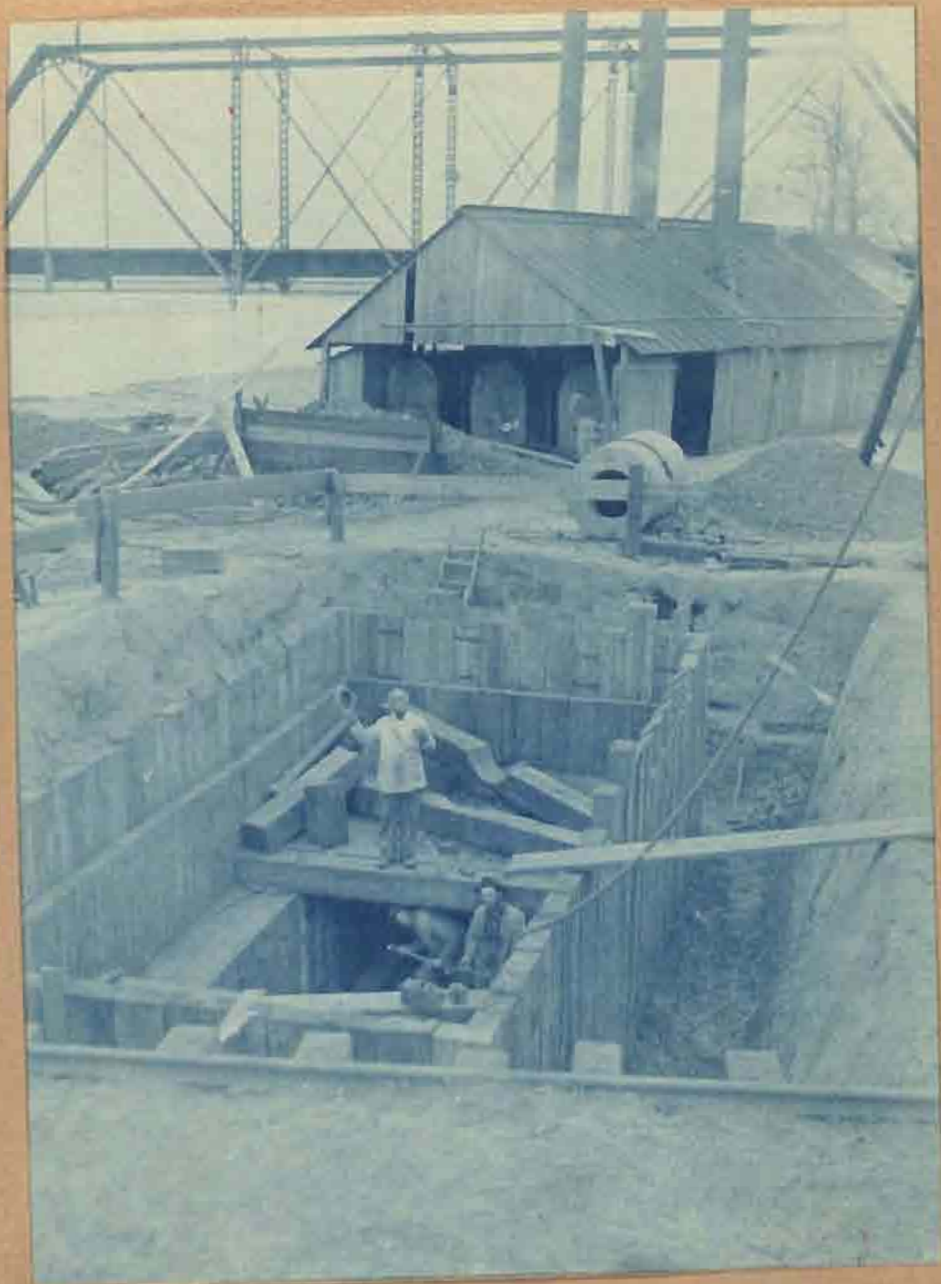
caissons held their shape when logs were encountered.

The piers of this bridge were seven in number, including one pivot pier, numbered 1,2,3,4,5,6 and 7, Number 4 being the pivot pier, numbers 3 and 5 the rest-piers and numbers 1,2,6 and 7 the balance.

Sizes of Caissons:

Caissons for piers 3 and 5 were built ~~xhx~~ 18'-0" x ~~x~~ 34'-0 and cribs for same being 16'-4" by 34'-0". Caissons for piers 2 and 6 were built 15'-0" x 34'-0" and cribs of same were the same size. Caissons and cribs of piers 1 and 7 were built 14'-0" ~~bx~~ x 31'-0". The total height of all caissons was 14'-0", allowing 8'-0" for height of working chamber. Width of Caisson walls were 3'-0" with six deck courses of 12" x 12" timber laid alternately length and cross wise. The outer course of the caisson walls consisted of 12" x 12" x 14'-0" vertical pieces. The two inner courses were laid horizontally as shown by the following plates. These courses were all well drift-bolted with bolts of various lengths as shown on accompanying plates. The ceilings and walls of working chambers were planked with 3" x 12" sheathing well spiked and calked with oakum. Each spike was driven almost home, then wrapped with oakum, then completely driven home, the oakum preventing the air from escaping around spike head. When the verticals were put in place and fitted into shoe, two 4" x 5/8" x 5'-6" long, wrought steel straps were strapped around the corners of the caissons and held by 3/4" x 1'-6" countersunk drift bolts.



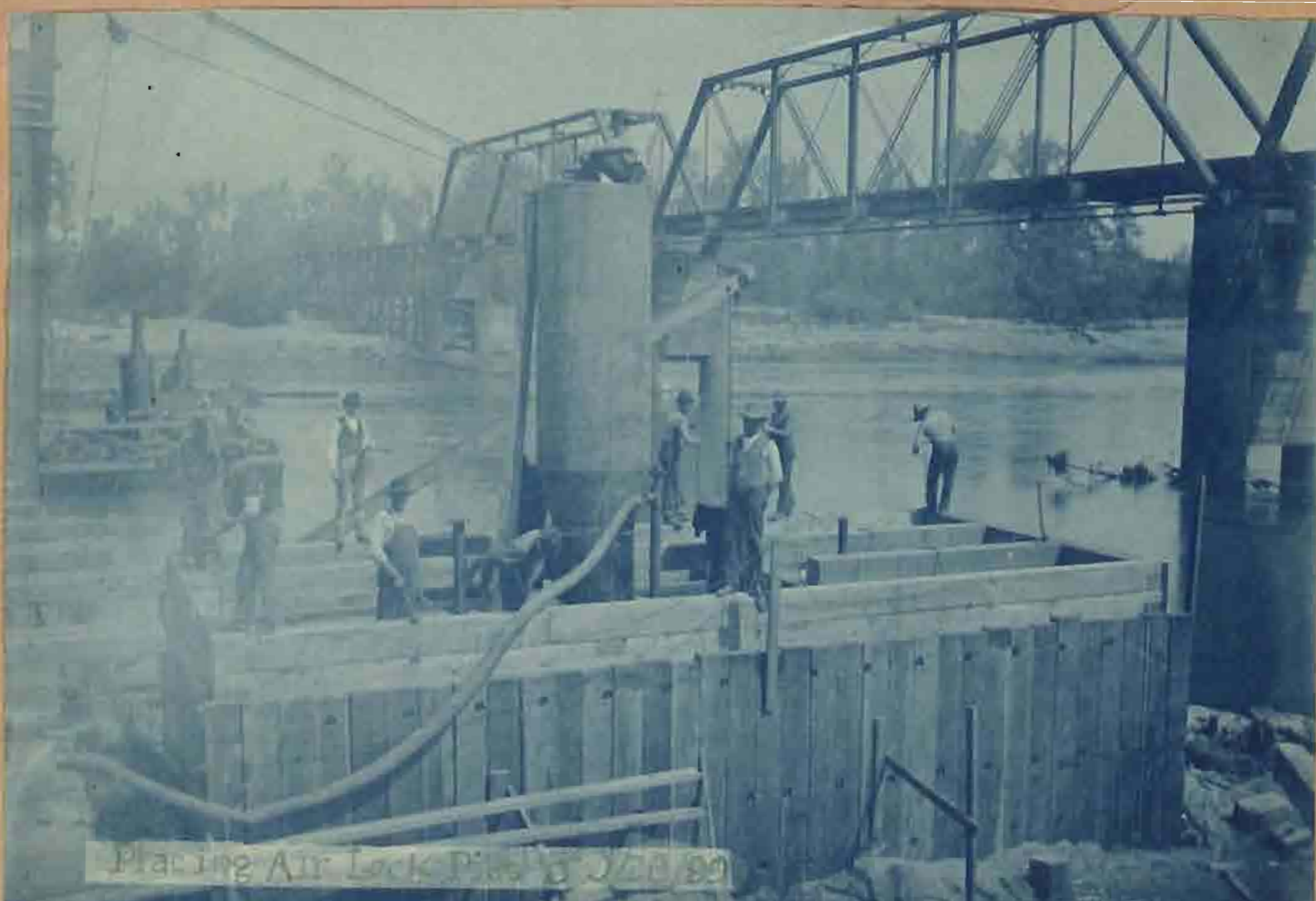
This view shows a caisson being caulked.

The building and background is the compressor plant, namely:- two compound Clayton Air Compressors and three boilers, also a dyamo, which furnished the light for the caissons.

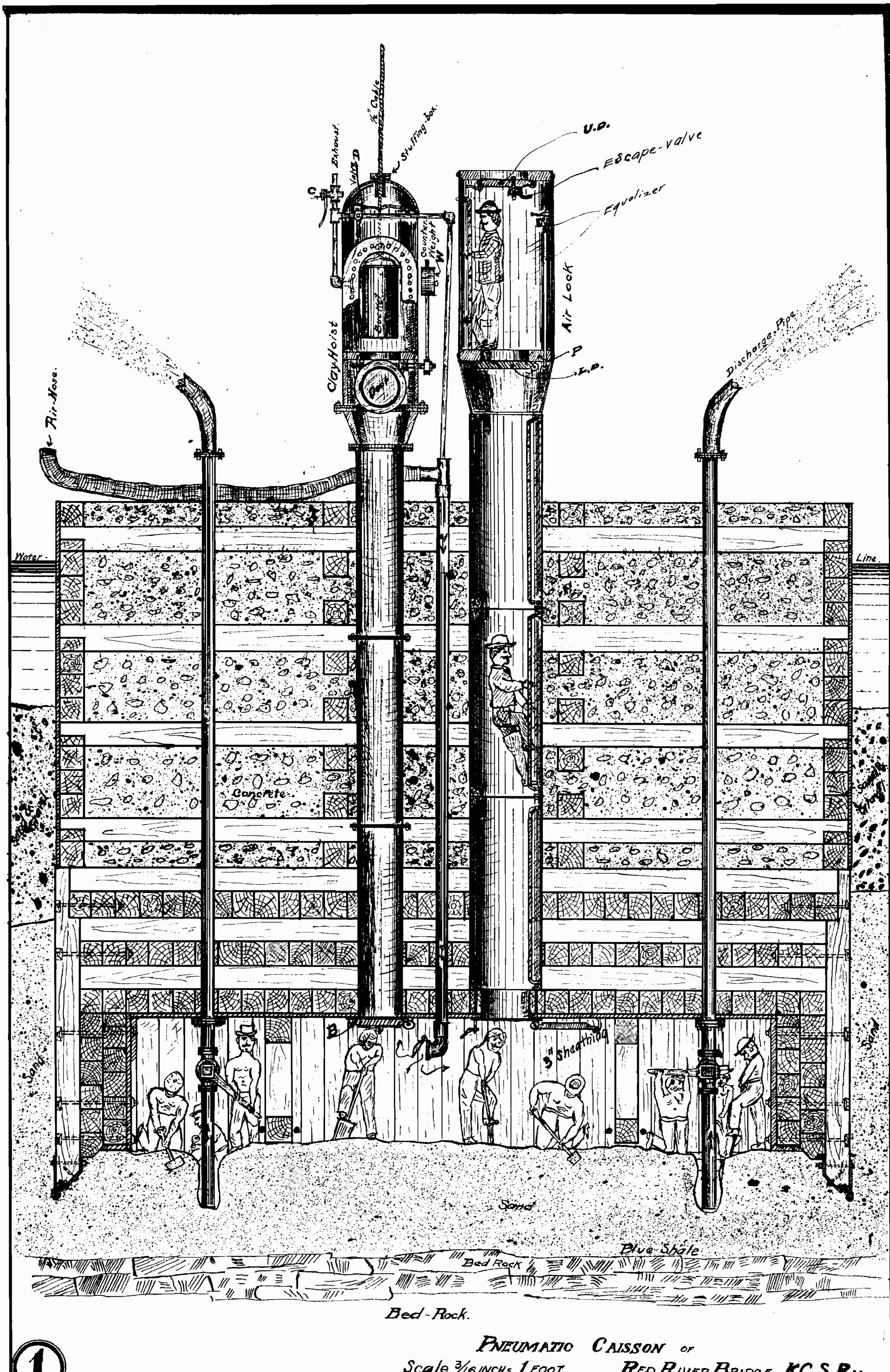
To prevent the colapsing of the walls of the caissons two cross frames used as buck braces were made of 12" x 12" timber. Two rows of 7/8" x 3'-5" bolts were run through walls alternately and fastened with bolts and washers to insure rigidity. Two 2" adjusting rods were placed directly under each cross-frame serving as tie-rods to prevent the bulging out of caissons. In the top course of the deck a 12" x 12" was left out on each side of the center, the space resulting therefrom was filled with concrete in order to form a better footing for mass of concrete in crib and also to form an arch for same.

Corners of cribs were connected by halved joints, details of which are shown in plate 2. The crib was tied by a 12" x 12"s,being dapped in every alternate course and their intersections drift-bolted.

In order to reduce the friction of caissons and cribs during sinking the sides and ends of cribs were sheath-ed with 2" x 12" yellow pine planks lapping over top of verticals of caissons and extending upwards breaking joints alternately. The top of crib was built to an elevation corresponding to extreme low water elevation,being 246!8 above sea level. When the caisson was finally landed to required depth in shale and the main body of pier was ready to be concreted it was necessary to provide the top of crib with a movable cofferdam which was kept pumped dry with a pulsometer, When the form of the pier was concreted sufficiently above water the cofferdam was removed.



Framing caisson 5 and placing shafting. Laying crib courses and placing airlock in position on caisson 5 9/22/'99.



1

PNEUMATIC CAISSON OF RED RIVER BRIDGE, K.C.S.Ry.

Scale 3/16 INCH = 1 FOOT.

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Doors and Shafts.

The caisson was provided with two castiron shafts, a main and a supply shaft, respectively 36" and 20" in diameter, extending from roof of working chamber to the top of crib. The different sections of the shaft were bolted together, a rubber gasket separating the same. The bottoms of the two shafts were provided with doors. provided also with rubber gaskets on top of same, hinged by 1 1/8" x 1'-4" pins and locked with a key moving in and fastened by two yokes in addition to a key-nut, securing the door and making the same air-tight. The main shaft was provided with an iron ladder in each section of shafting. The sections of shaft were eight to ten feet in length. The space around the shaft where the same passes through the timers was filled with Portland cement grout with proportions of 1 to 2, also the space around the frames of the bottom doors which were countersunk in the roof of caisson, was calked. The greatest care possible was exercised to obtain "a practically perfect air-tight" caisson.

Entrance to Working Chamber.

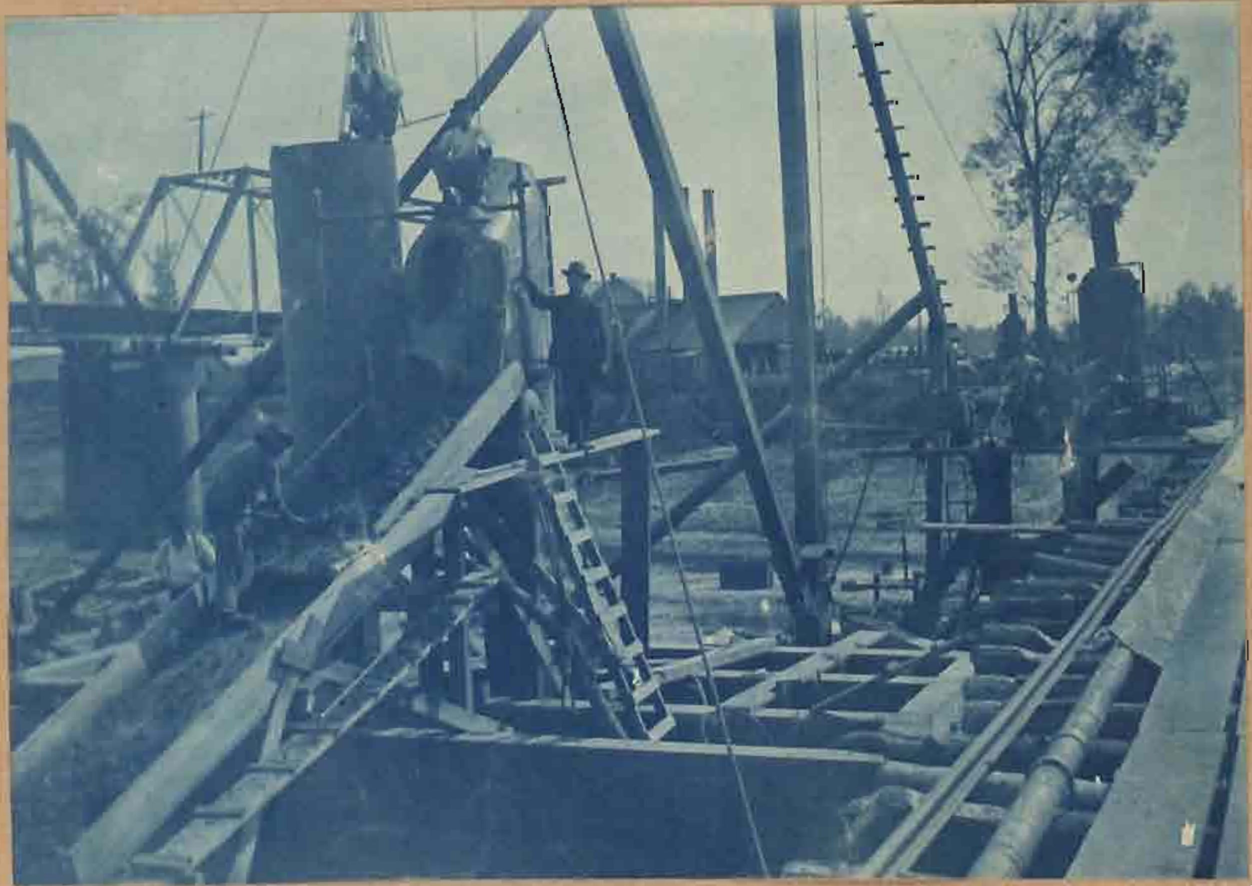
The entrance to the working chamber was gained by means of an air lock as per plate 1, provided with two doors, upper and lower. This lock was fitted with an equalizer, consisting of a pipe and valve attached to end of same. The pipe was so arranged as to extend beneath the partition P, which is of solid metal 4" thick, upon which is hinged the lower cast-iron door L.D., provided with a key-nut to bring it up hard against partition P before escape valve in upper door U.D. is opened to allow the compressed air in air-lock to escape. The upper door is also a hinged castiron door. The weight of each upper and lower door is about three hundred pounds.

Air-Lock. (See Plate 1.)

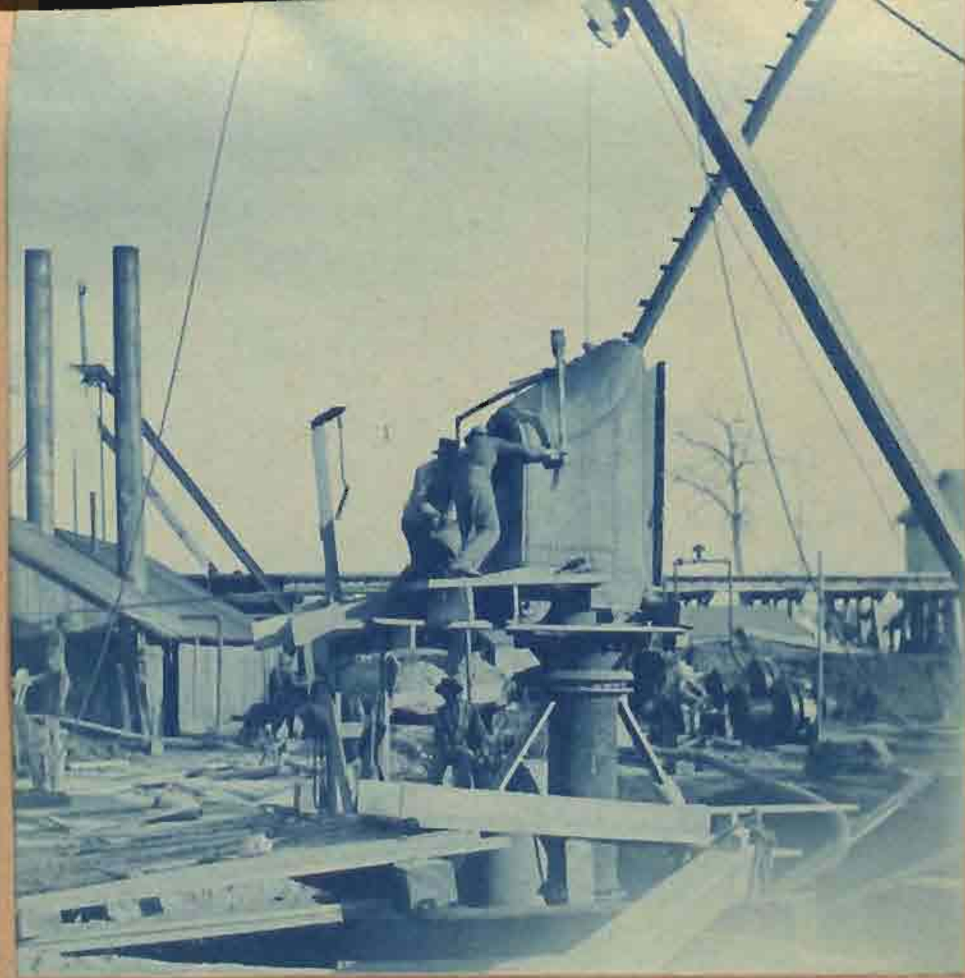
The air-lock consists of a wrought steel cylinder of 1/2" metal, four feet in diameter and ten feet in length with the last two feet tapering down to fit the 3'-0" shaft. The lock is provided with an iron ladder, two cast-iron doors (upper and lower), one escape valve in upper door, and one equalizer consisting of a 3/4" pipe run through lower partition P from upper part of air-lock, connected up inside of the lock. The top of lock consists of a solid metal collar-like partition P, lower side countersunk so as to allow rubber gasket of upper door to fit tight against same.

Method of Operating Air-lock.

After lock is placed in position on main shaft air is supplied to caisson by means of a four inch air pipe run to caisson as shown in plate 1. This necessitates the closing of the lower door of the air-lock, also the bottom door B of the supply shaft. The caisson is now ready for operation. In order to operate the air-lock during sinking it is necessary to have two lock men or tenders, viz: inner and outer lock tender. It is the duty of the inner lock tender to be ever at his post to answer all calls and signals from outside, open and close the inner door, and operate



These views show clayhoist and airlock opperated on the cribs The clay-hoist, in lower picture, is shown in action, the bucket having just been emptied. In the above picture, the one on the left is the clay-hoist, and next to it the airlock. The conditions are just the reverse in lower picture.



This picture shows the clay-hoist in operation.
The door has just been opened and bucket emptied.

This picture shows "Sandhogs" reentering air-lock.

In the background is shown the north trestle approach of the old bridge.

the equalizers from within. The duties of the outer lock tender are such as the closing of the outer door by means of a pulley, it being a very heavy door, answering all calls and signals from within, attending to the discharge pipes, viz: cleaning them out in case they get clogged up and changing the position of the "goose-neck" outlets of same.

The signals used are a sort of mechanical telegraph, certain numbers of raps signifying certain things, such as five raps meaning the admission to or demission from air-lock as desired, two raps to take up the bucket in clay hoist, three raps to equalize it back again, six raps meaning less air and seven raps meaning more air, eight raps meaning danger, to leave or abandon chamber at once. When sand pumps are used one and four raps signify starting and shutting off of pumps. These signals are nearly the same as used by all "sand-hogs" this country over.

The caisson supplied with air and bottom door of supply shaft B (see Plate 1) being shut and kept shut (until caisson has been sunk to the required depth in bed-rock, it is necessary now to use clay hoist or "go-devil" as it is more familiarly called by the sand-hog fraternity, to hoist the broked bed rock out of caisson) the upper door of air-lock being pulled up tight and held in place by compressed air, everything is ready for work.

To gain admission to working chamber as heretofore mentioned, five raps are given, the inner lock tender responding by a like number. The latter then pulls up the lower door of air-lock L D (see plate 1) by means of a pulley, and holds it securely in place, by means of a key-nut attached to the door. After lower door is up he opens equalized in upper door allowing compressed air to escape. When the pressure in the lock has finally become normal the upper door drops open. After decending in the air lock the upper door is again pulled up and secured by key-nut. The escape valve in upper door is closed and valve of lower equalizer is opened allowing compressed air to enter into lock through the pipe running through lower partition P. When the air from caisson has finally equalized that of the lock the lower door L D falls open allowing entrance to the caisson by decending the ladder provided in main shaft.

Method of Operation of Clay Hoist.

When bed-rock is reached, or when a stratum of material is reached the material of which will not pass through the discharge pipes readily, the clay hoist is bolted on the top section of the supply shaft. The means of operating the clay hoist are the same as those of the air lock, viz: equalizers and doors as per plate 1.

The bucket is filled with material of bed rock and is ready to be hoisted. The buckets used are cylinders of medium steel of 3/8" metal 18" in diameter and 36" high. There are usually two required, namely, one being filled while the other is being hoisted and emptied.

When bucket is filled the men strike two heavy raps with a maul on the suspended lower door B of the supply shaft. This is the signal to "hoist tender" to raise bucket by means of a single-drum hoisting engine. When the bucket has reached the top of the clay hoist the upper door is closed by means of a lever with a counter-balance weight W to open and close it with ease. The compressed air is cut off by a valve D after the upper door is closed and the air is allowed to pass out of the exhaust cock C, the air when escaped allowing the outer door of the hoist to swing open when the pressure in the hoist is equalized back to the normal pressure. The contents of the bucket are then wasted out upon a chute.

The intervals of time between the dumping of two consecutive buckets averaged about 3 1/2 minutes for the average depth of 54 feet from clay hoist to bed rock. The yardage in each bucket was 0.196 cubic yards or about 3.36 cubic yards per hour.

The bucket is then replaced in clay-hoist, the outer door closed, also the exhaust cock C, the compressed air is allowed to pass into the clay-hoist through the lower cock D. When the pressure of the air in the clay-hoist has equalized that of the caisson the door can then be opened by means of a lever with a counter-weight W attached. Upon the opening of the door the bucket is lowered down the shaft to the caisson to be again refilled.

Platforms to Lower Caissons into the River.

At the time of the commencement of the building of the caissons the river was low enough to allow the caissons of piers 2,5 and 6 to be built on the sand bars then formed. Caissons of piers 1 and 7 were built on the shore. Piers 3 and 4, being river piers, it was necessary to build the caissons of same on platforms, then to be lowered into the river afterwards by means of screws.

Platforms: Eight 12" diameter piles were driven on each side of and 18" from caisson line and capped with 12" x 12" timbers 38 feet long, fastened to piles by 3/4" drift bolts. Upon these caps 12" x 12" timbers 26 feet long were placed loose, crosswise, and spaced about 13" centers. The cutting edge was then bolted together in proper position upon the platform and the building of caissons was then commenced on this platform as per plans and as previously explained.

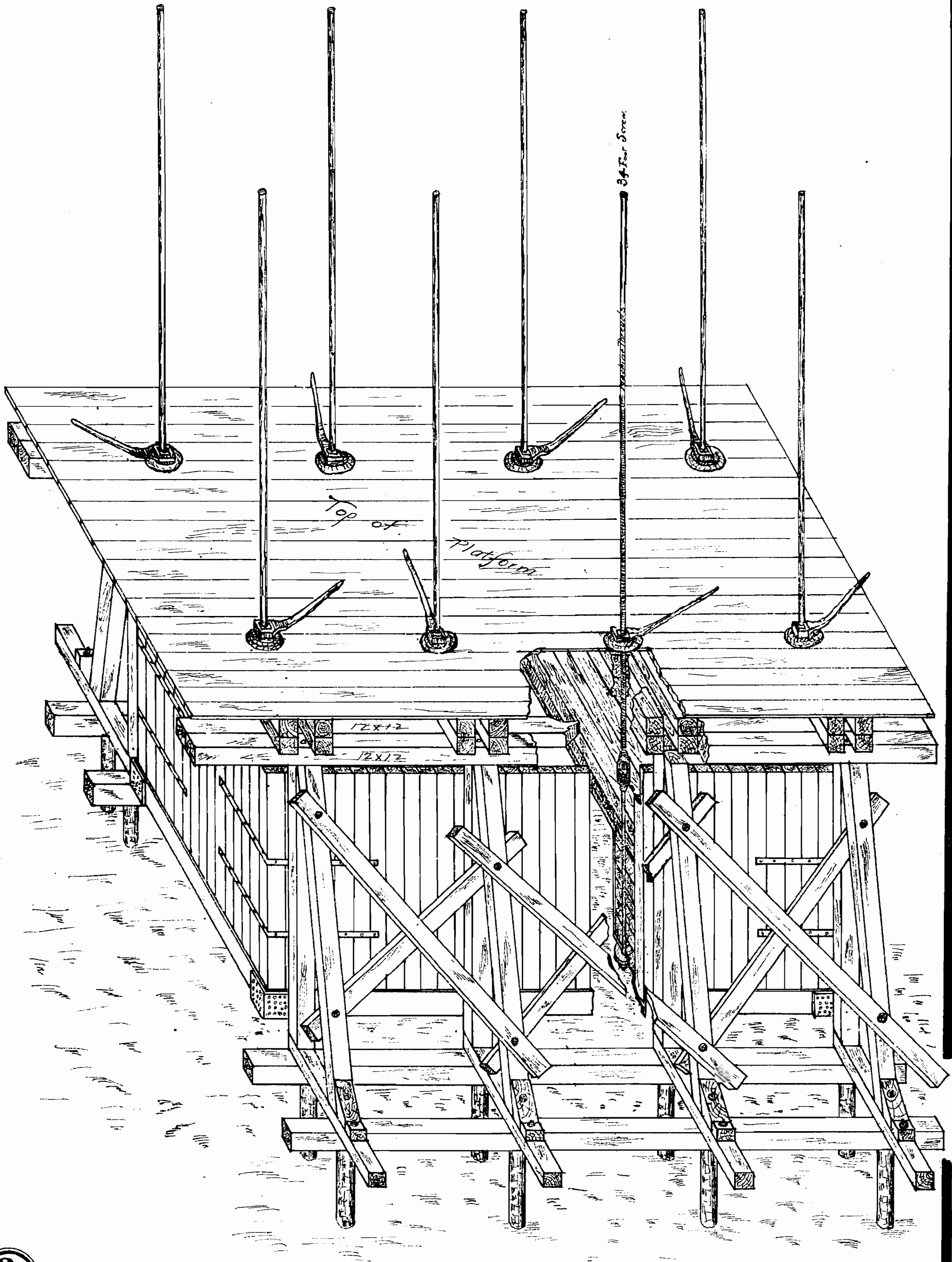
The screws used to lower the caisson at the completion, from the platform to the river bed, were of machine made threads, 3/32" in thickness, the diameter of the threads being four inches.

A three inch rod was then run up between the second and third course of wall with a 14" diameter cast washer and nut three inches thick, bearing up against bottom of these courses as shown in plate 3. This rod was run up through these courses and coupled to the 4" screws by means of a clevis or sleeve nut. The following plate 3 shows the manner in which the foregoing was executed.

CAISSON 3 RAISED OFF PLATFORM,

READY TO BE LOWERED.

Scale 1/8 INCH - 1 FOOT.



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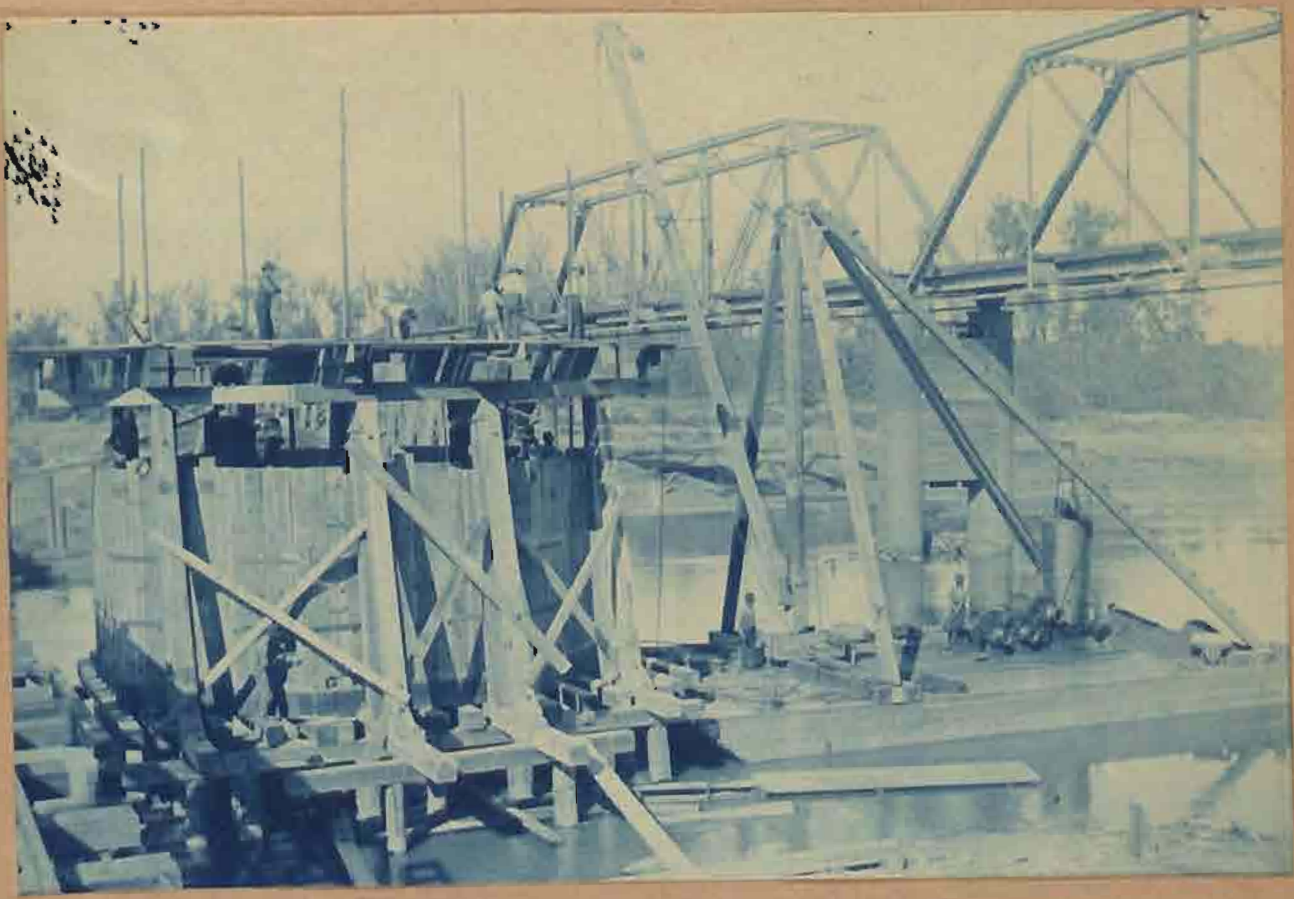
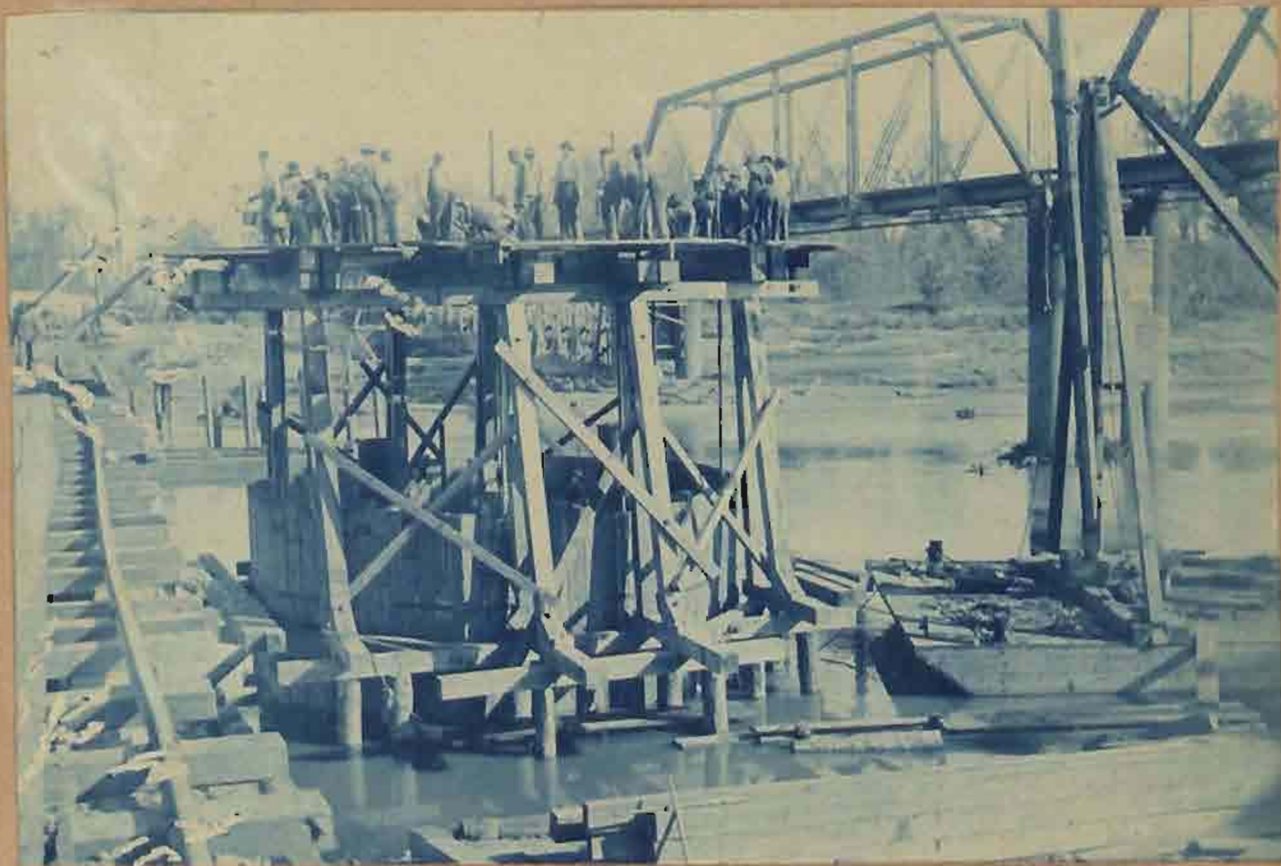
View shows men driving piles for the lowering platform for caisson 3 and 4.

Those for caisson 4 are driven in the distance.



View Represents caisson 4 built on lowering platform
(Before raising to take out timbers under cutting edge.)

Men lowering caisson.



Caisson 4 lowered on river bed.

Concreting the Piers.

The cement used was Hemmoor Portland cement,which was indeed a most satisfactory brand. It easily satisfied the following specifications,viz:"it shall be ground so fine that at least 97% in weight will pass a standard sieve of 5000 meshes per square inch,and at least 90 % will pass a 10000 mesh per square inch. When moulded neat into Bricketts and exposed three hours or until set in air and the remainder of 24 hours in water,it shall develope a tensile strength of from 100 to 250 pounds per square inch. When moulded neat into bricketts after exposure of one day in air and six days in water it shall develope a tensile strength of from 250 to 500 pounds per square inch,and after exposure of one day in air and 27 days in water it shall develope a telsile strength of 400 to 600 pounds per square inch. It shall be an eminently slow-setting cement. When moulded neat into pats with thin edges and either left on glass or not,to set in water said edges must show no signs of checking.

Bricketts mixed in the proportion by weight,one part cement to three parts sand,kept one day in air and remaining time in water shall show a tensile strength of 100 to 150 pounds per square inch after seven days,and from 150 to 250 pounds per square inch after 28 days. The contractor shall provide a suitable building for storing cement in which the same must be placed before being tested."

Preparation of concrete: The interior concrete for all piers was mixed in the following proportions;

"1 part Portland cement,

3 parts clean coarse sharp sand,

5 parts broken stone to pass a 2 1/2 " iron ring."

The exterior six inches of all faces of piers which are exposed to the atmosphere or water are to be built of small broken stone concrete, carried up simultaneously with the backing, the proportion by volume being,

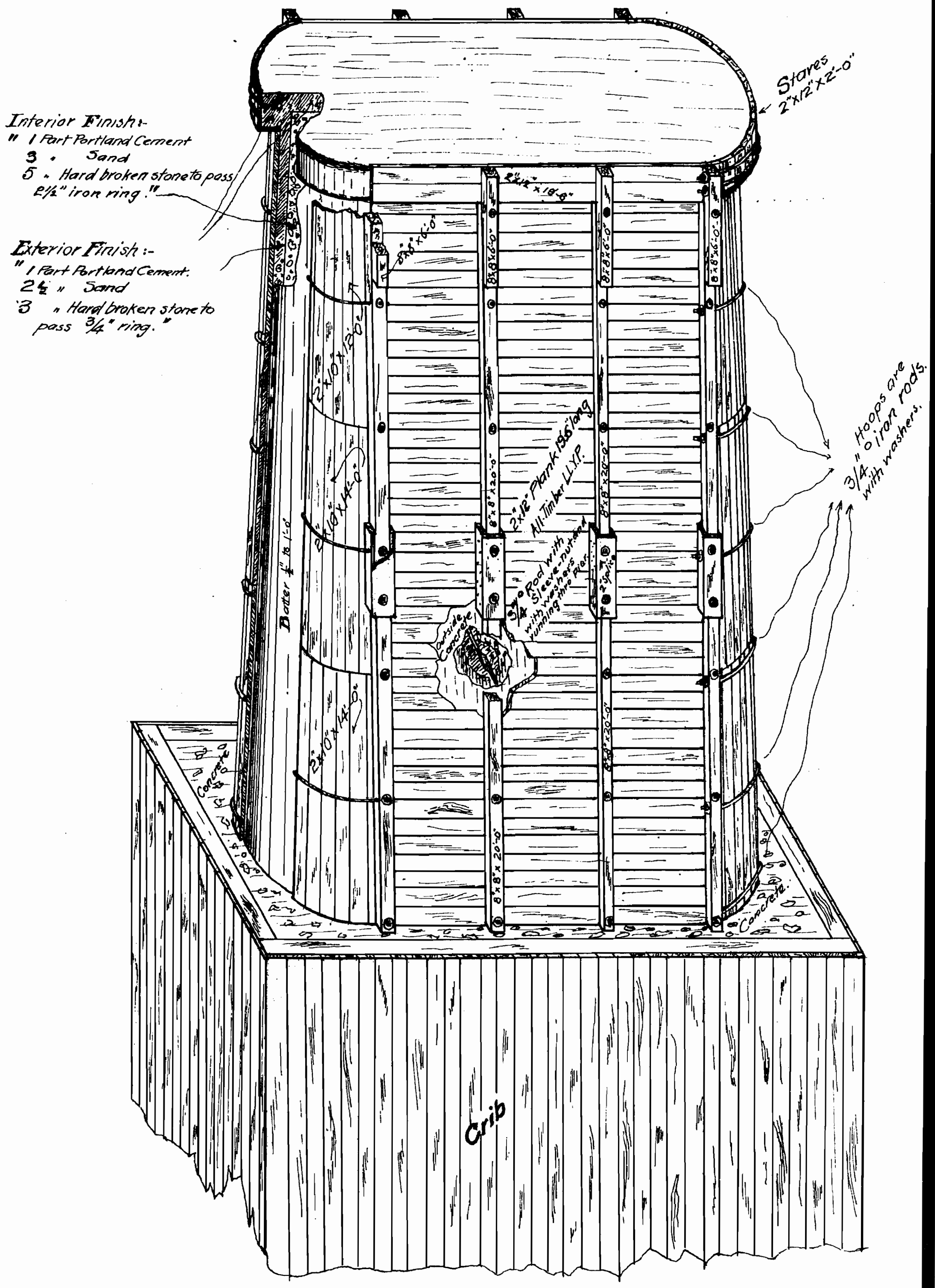
"1 part of Portland cement,

2 1/2 parts of clean coarse sharp sand and

3 parts of hard broken stone small enough to pass through a 3/4" iron ring."

This concrete is to be tamped solidly against the timber forms so that there will be no voids on the exterior surface, which is to be left permanently as it comes from the moulds.

The stone was clean and free from all dirt and dust, and sound hard rock ~~xxx~~ approved by the engineer. The sand and cement was mixed dry, then sufficient clean water was added, then the mortar thoroughly mixed, after which the broken stone was added. The stone was thoroughly drenched with clean water before it was mixed with the mortar. All ingredients were determined by volume. The concrete was then mixed with shovels instead of with machinery. The amount of water added was just enough that when the concrete was tamped the water oozed through the surface. All concrete was thoroughly rammed in layers not exceeding nine inches in thickness.



TIMBER FORM FOR CONCRETE PIERS.

Scale ⅛ INCH = 1 FOOT.

RED RIVER BRIDGE
On K.C.S.RY.

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Timber Forms for Piers. (see plate 4.)

Suitable forms of timbers were provided to give the constructions the dimensions and finish shown on the drawings. Care was taken to make all forms strong enough to resist the ramming of the concrete without bulging out or in any way changing their positions. No forms were removed until after concrete deposited therein had stood 36 hours, or as much as the engineer deemed necessary. In case of any of the surfaces of concrete drying or hardening during construction, they were all swept thoroughly clean with brooms, then wetted thoroughly with clean water so a perfect compact between the old and new work was made, and thus insuring that the concrete was truely monolithic. The forming of such dry surfaces was, however, always prevented when practicable.

Sealing or Concreting the Working Chamber of Caisson. (plate 1).

When ready for the sealing to begin clay hoist was left on the supply shaft as it was used for hauling out the shale while penetrating the same. A platform was built on the level of the bottom of the outer door of clay-hoist, to dump the concrete for the working chamber. The concrete was deposited there by means of a box attached to a derrick line or by means of wheel barrows. As soon as all was ready for the shoveling concrete down the supply shaft the signal was given to close the bottom door B of supply shaft in working chamber. Then the lower door in clay hoist with counter weight W was taken out entirely and replaced by a wooden funnel about 14 inches square and four feet long. The middle door now being out altogether and outer door of clay hoist being open the key in bottom door B was taken out (for the pressure of air in caisson kept the door in place even when concrete was dropped upon it) and all was ready to receive concrete on the bottom door B thrown in from above. When the whole batch of concrete was thrown in funnel down the shaft on bottom door B, outer door of clay hoist was closed and air valve D was turned on to allow compressed air entrance into clay hoist. When compressed air had equalized the pressure in supply shaft the bottom door B with mass of concrete on top of it (usually a batch contained a cubic yard of concrete) suddenly swung open and concrete was thus deposited on the floor of the working chamber. The door was thoroughly cleaned with a cloth, care being taken that the rubber gasket on door was free from any material to prevent it from being perfectly air-tight when closed, two raps were given and bottom door B swung shut, and secured by key until signal was answered from above, which was to open the exhaust cock C, thus allowing the pressure in shaft to again become normal, allowing the outer door to swing open and securing bottom door B and allowing same performance to be repeated. The concrete in working chamber was shoveled in place by the sand-hogs and tamped and all was made ready to receive the next batch. The average length of time for sealing the working chambers was 26 hours. As more concrete was thrown in the chamber the

Concreting Form Pier #2, 1/10/1900.

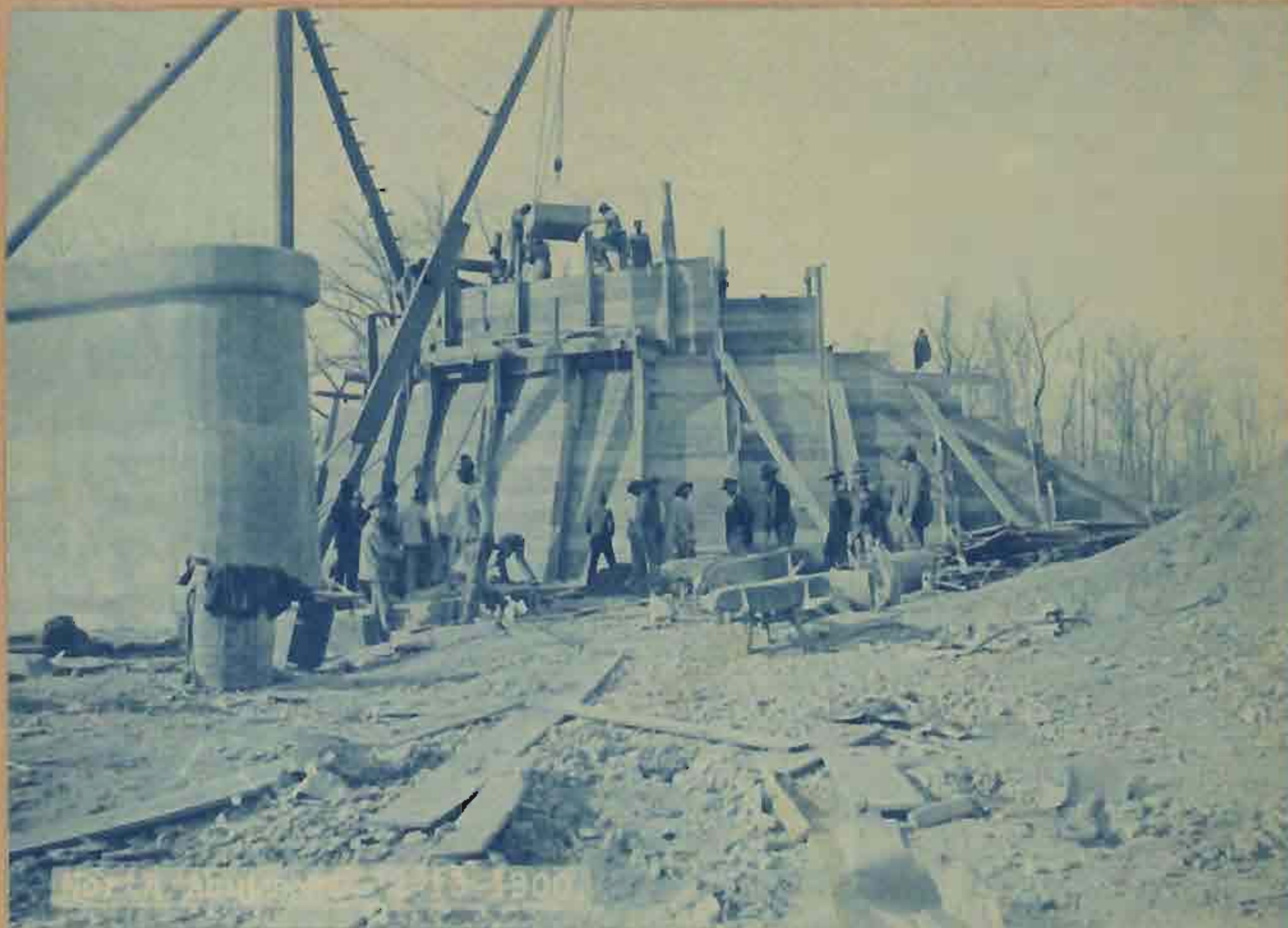
Concrating the form of pier 2.

Concrete is raised by means of a hoisting engine, operating a wooden box containing about one cubic yard of concrete.

This view shows the first high water we had to contend with IO/30/'99. The total raise was twelve feet. The gaps shown in tram-way was caused by drift tearing out the same.

Caisson 3 can be seen in the distance. This caisson was lowered in the river by screws just a few days previous.

The crushed form of pier 5 can be seen in the fore-ground, also the clay-hoist just out of the water at pier 4.



Men concreting north abutment's form.

Foundation for same was carried down to a hard stratum of clay eight feet below the surface of the ground.

This view shows river just before the second rise 11/16/'99.

The forms for piers 6 and 5 respectively are shown in the distance

This shows river ten feet high, also a mass of drift held in front of form of pier 5.

Rivers final raise, showing it at its highest, being a twenty-one foot raise.

Forms were all swept away.

The old bridge in the distance.

Diver and outfit on derrick-boat.

Diver going under water to unbolt clay-hoist off of shaft, which is in danger of being swept away by high water.

smaller the space would become and the longer it would take to dispense with a batch.

Rate of Sinking.

The following plate 5 shows the rate of sinking the different piers. All elevations referred to are those of the cutting edge. The general average depth of all piers sunk to shale or bed rock in one day was three feet, The average depth for single piers was as follows;

For	piers	1 = 2.68	ft.	excluding		penetration	in	shale
"	"	2 = 1.94	"	"		"	"	"
"	"	3 = 4.08	"	"	"	"	"	"
"	"	4 = 2.85	"	"		"	"	"
"	"	5 = 2.49	"	"		"	"	"
"	"	6 = 3.88	"	"		"	"	"
"	"	7 = 3.08	"	"		"	"	"

The greatest depth for any one pier for any one day was six feet. The penetration of shale is not figured for it varied in different caissons, owing to the varying hardness of the shale. Whenever suitable hardness was found sinking was stopped and the floor prepared for sealing up of the caisson, by cleaning off of mud and foreign substance so as to prepare it for the concrete to seal up the working chamber.

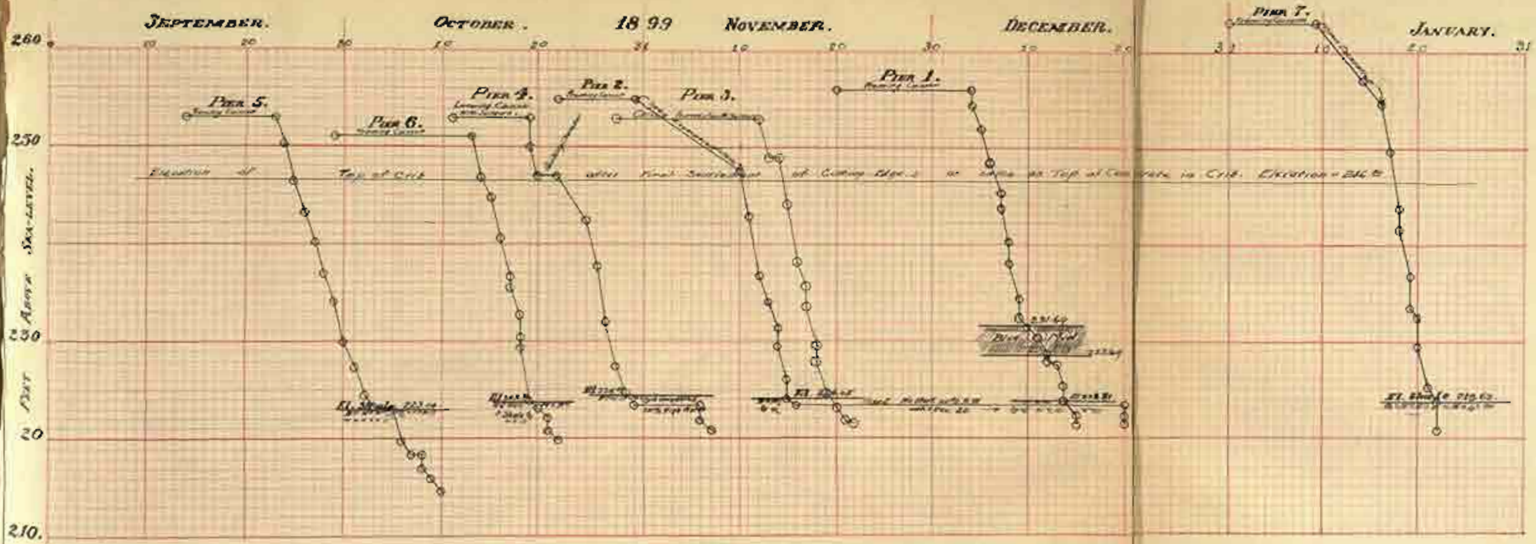


Diagram Showing Rate of Sinking of Piers 1,2,4,5,6 & 7

Vertical Scale = 10 Feet to 1 Inch.
Horizontal " = 10 Days " " .

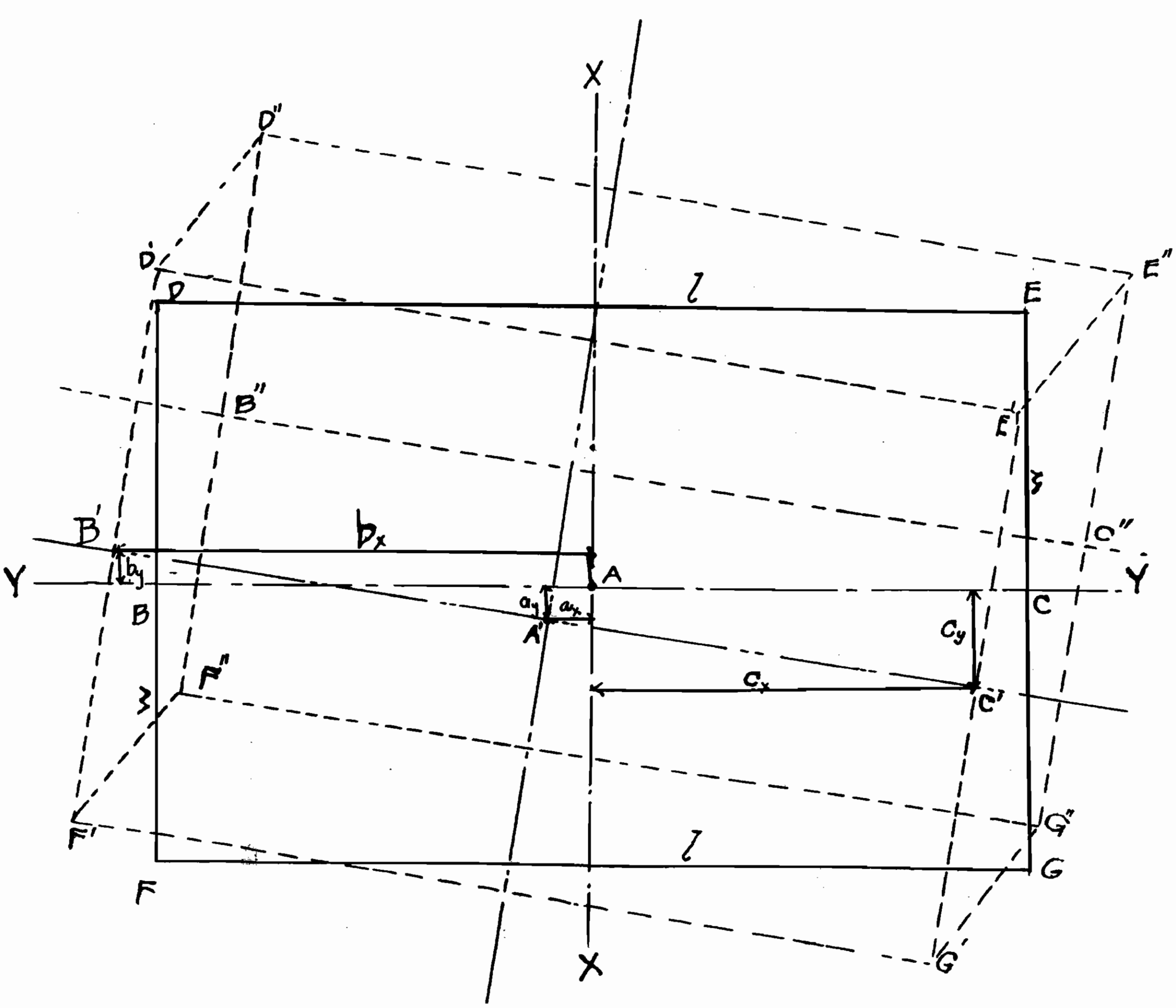
RED RIVER BRIDGE.

On M.C.S. Ry.

5

Method of Locating the Position of a Caisson During Sinking.

It has been my experience that so many graduates of civil engineering that enter the field of bridge engineering have not the slightest idea how to get at the method of locating the position of a pneumatic caisson or cofferdam during sinking. This most important feature of substructure work in bridge engineering should have the attention of those graduates about to embark upon this work, as many a graduate that enters the service of a resident bridge engineer is sometimes called upon to perform this work during the latter's temporary absence. For this reason I have worked out the following scheme of the method above described.



N.B. The subscripts indicate a direction perpendicular to the plane corresponding to the letter of the subscript.

In the accompanying diagram let X X and Y Y be two co-ordinate vertical planes, the former on the bridge tangent and the latter at right angles thereto, and containing the up and down stream axis B A C of the caisson; ie. the vertical axis of symmetry of the latter passes through the point A.

D, E, F and G are the correct positions of the four corners of the crib or caisson. Let the position of the top rectangle of the crib at any time during sinking be indicated by the primed letters, and that of the bottom at the same time by the letters marked seconds.

The field work consists of the running in of the lines X X and Y Y, finding their intersections with the edges of the crib, thus locating B' and C' and determining their distances from the co-ordinate axes, and taking levels of the top of the crib at the four corners.

It is understood that the vertical distances from bottom to top at the four conners have been measured, marked on the timber, and recorded in the note book, so that if the top surface of the crib is not truly parallel to the bottom surface of the caisson, the elevations of the four corners can be corrected accordingly.

Let b_x equal perpendicular distance of B' from X X

"	c_x	"	"	"	"	C'	" X X
"	a_x	"	"	"	"	A'	" X X
"	b_y	"	"	"	"	B'	" Y Y

Let c_y equal perpendicular distance of C' from Y Y

" a_y " " " " A' " Y Y

Let h " height from bottom of caisson to top of crib.

Let l equal length of crib (F G or D E)

Let w " width of crib (D F or E G .)

Let e_d equal corrected elevation of corner D'

Let e_e equal corrected elevation of corner E'

Let e_f equal corrected elevation of corner F'

Let e_g equal corrected elevation of corner G'

Let e_m equal the mean of e_d, e_e e_f and e_g.

Then $b_x - a_x = c_x + a_x \therefore a_x = 1/2\ (b_x - c_x)$ (eq. 1)

$b_y + a_y = c_y - a_y \therefore a_y = 1/2\ (c_y - b_y)$ (Eq.2)

Equasions 1 and 2 locate the position of the point A' in respect to the co-ordinate planes.

The amount that any properly vertical line in either of the faces D' F' or E' G' or in any parallel plane of the crib and caisson is out of position in said plane between top and bottom measured horizontally is

$(e_f - e_d) \frac{h}{W}$ or $(e_g - e_e)$ h/w but as the lines D' F' and E' G' are very slightly divergent from the plane X X ,no error of consequence will be involved by assuming that this variation is parallel to X X, therefore the distance parallel to X X between the projections of A' and A" on any horizontal plane is ;

$x = (e_f - e_d)$ h/w equal $(e_g - e_e)$ h/w (Eq.3).

Similarly the distance paralel to Y Y between the projections of A' and A" on any horizontal plane is,

$$y = (e_d - e_e)\, h/\ell = (e_f - e_g)\, h/\ell \quad \text{(Eq.4)}.$$

The coordinates of A" in relation to X X and Y Y will therefore be,

$$x'' = a_y \pm x \qquad \text{(Eq.5)}$$

and

$$y'' = a_x \pm y \qquad \text{(Eq.6)}$$

The corrected heights of the four corners above and below a horizontal mean plane are respectively,

$$v_d = e_d - e_m \qquad \text{(Eq.7)}$$

$$v_e = e_e - e_m \qquad \text{(Eq.8)}$$

$$v_f = e_f - e_m \qquad \text{(Eq.9)}$$

$$v_g = e_g - e_m \qquad \text{(Eq.10)}$$

The amount that the crib has been rotated about a vertical axis is measured by the sine of the angle of inclination of the line D' E' to the line D E or

$$\sin\theta = (c_y - a_y) \div \ell/2 \qquad \text{(Eq.11)}$$

The data to be given daily to the contractor are as follows,

1st How much too far north or south the point A' is.

2nd How much too far east or west the point A' is.

3d How much too far north or south the point A" is.

4th How much too far east or west the point A" is.

5th How much each of the four corners is high or low above the mean plane.

6th How much the crib is rotated about its vertical axis, and in which direction is the rotation.

This information is given respectively by equasions 1,2,5,6 (7,8,9,and 10) and 11.

In case that the points B' and C' both lie on the same side of the Y Y the sign of b_y in equasion 2 would of

Pier 6 equals 496.967 Cubic yards.

" 7 " 431.991 " "

Total, 3768.626.

The total cost of the seven piers was $110.000.00

Respectfully submitted,

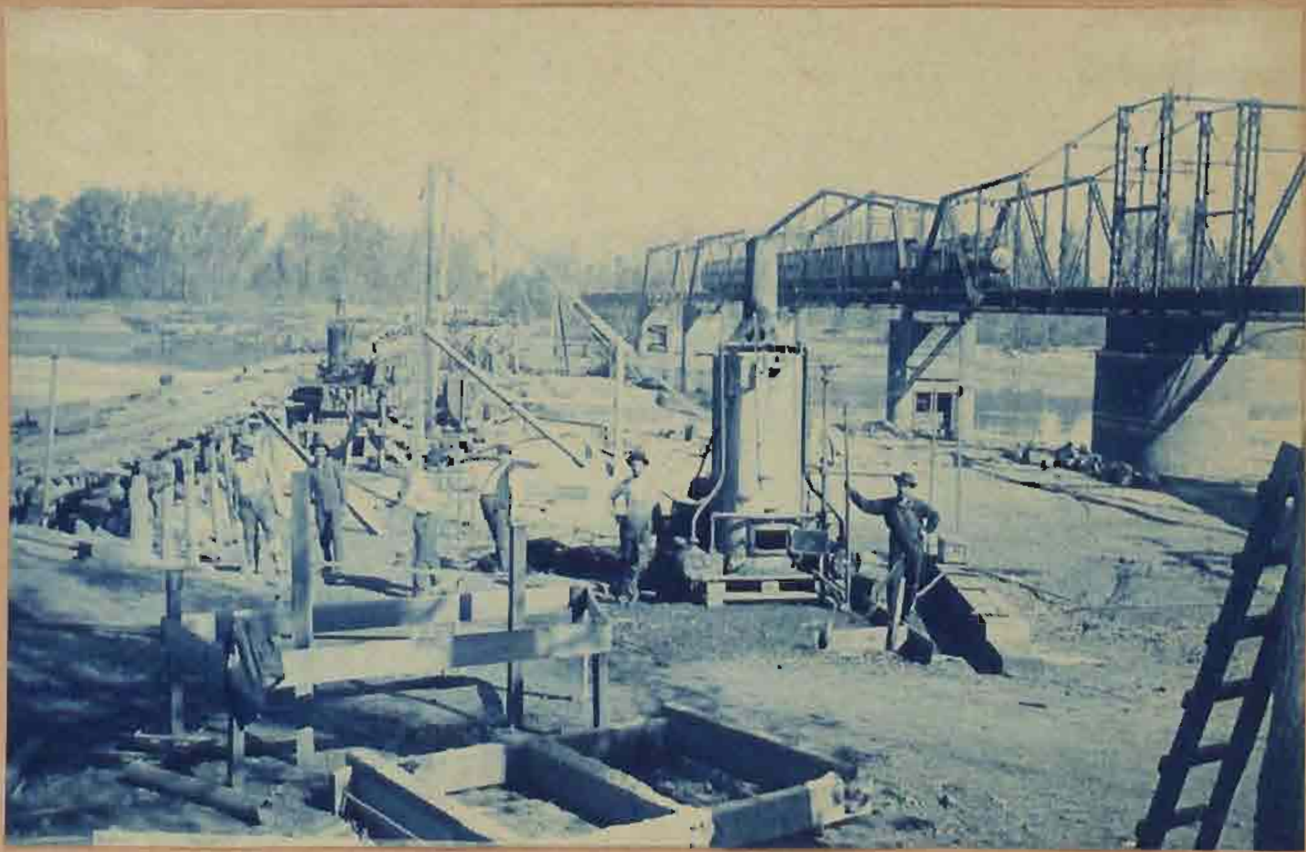
[illegible]

Resident Engineer of Red River Bridge on Kansas City Southern Railway.

Approved [illegible]

View of new piers and tram-way used for hauling material to the several piers.

In the foreground there can be seen a pile of drift, left by the last high water. 11/16/'99.



General view looking north. 10/19/'99.

General view looking south three days before high water.

11/21/'99.

New bridge site is to the right and old bridge to the left.

General view looking north. 2/13/1900.

The form of south abutment is shown in the fore-ground.