Thesis by Frank R Firth.
August 1866.

Engineering Notes upon Mississippi and Missouri River Bridges.

The Mississippi River separates the East from the West. The resources of the West are agricultural and mineral; for its produce it desires in exchange Iron. Timber. Coal Machinery and manufactured goods from the East. We can only avail ourselves of the advantage of our country's position between the Oceans by building railways from shore to shore. Each fact enforces the necessity of overcoming the obstacle a flooded or frozen river affords. While the so-called West was east of the river and the Pacific uncrossed by Commerce this necessity was prospective; now it is present. To develope our resources patriotic capitalists, and to reap the sure return shrewd financiers have furnished sinews to the enterprise. The tributary arms of the two existing Pacific Railways have crossed and are crossing the Mississippi, several wait now upon the banks of the Missouri. Every bridge yet built or projected is for railway use, but not all exclusively so. The Mississippi is spanned at Clinton. Davenport and Burlington; the Quincy bridge in six weeks will be finished: at St Louis and Dubuque work is in progress and soon will be commenced at Keokuk. The Missouri is not yet bridged, but construction is being carried forward at Kansas City and St Charles. There are projects, one or two of them matured, to cross this river at Atchison. Leavenworth, St Joseph, at, above, and below Omaha and at Sioux City. The Mississippi and Missouri like the Nile flow through broad alluvial bottoms, and are fed by melting snow upon mountains, for which reason they are subject to floods entirely independent of the local conditions of the countries through which they flow

The period of high water on the Miſsiſsippi and Miſsouri is from April to July. Extreme difference in height of water observed at ~~Kansas City~~ St Louis is 41'.39 at ~~St Louis~~ Kansas City 36'.88 at Quincy 20'. The two rivers have general width of 2000' and depth of from 1 to 40 feet. (at the points where bridges may be built; that is, above St Louis). are characterized by shifting channels, rapid scouring currents and are closed by ice from two days to two months annually. The difficulties they present to the engineer are very unequal. The Miſsouri is turbulent. the Miſsiſsippi tranquil above its junction with the first, ~~after~~ below that, the river is Miſsouri, except in name. The fall of the Miſsouri is about 14" per mile, rapidity of current ranges from 2½ to 8 miles an hour according to low or high stage of water and it scours to the depth of 40' below low water.

at Kansas City piles driven 15' into the river bed have been washed out in 4 days, when rate of current was 4 1/4 miles an hour. and depth of channel increased 25' in the same time; every obstacle placed in the current occasions immediate cutting and deposition, of about equal amounts. An accompanying tracing shows the state of the river bottom at Kansas City at different times during the same season. The limestone bottom of the channel is swept bare and buried deep again each year. The average fall of the Mississippi (by Mississippi I shall only designate the river north of Alton) is 5" per mile and velocity of current from 1/2 to 4 miles an hour. the mean velocity being 2 1/2 miles. Its ordinary fluctuations of level range within limit of 15'. So far then as scouring efficiency is a simple function of the velocity the power of the Missouri is about (v^2) 4 times as great, while the other circumstances of which scouring power is a function of velocity of flow,

are all more powerful in the case of the Missouri. The natural slope assumed by the banks where impinged upon by the current is about 2 to 1 {angle of repose in still water 10°44–12°57' exposed to currents or waves 5°54' to 7°51'.}
(steamboats drawing 4 ft of water make landing at any point indifferently)

The methods of giving permanence to present channels. protecting banks and engineering works from scouring action and controlling the river currents are

1° Rip Rap Stone 3° Concrete Blocks 5° Fascines
2° Sand Bags 4° Cribs or Stone Piers 6° Sheet Piling.

The first method is that generally employed. Large blocks of stone are thrown in about a pier or down the face of a bank which is being undermined, no artificial arrangement is attempted and more material is added as often as the sinking of the first makes room: a permanent condition is at last obtained (the lower stones having reached the limits of scouring action). This is considered as ultimately the cheapest means of protection. 2° & 3° possess no advantages for permanent works. 4° is too expensive for any but special cases 5° Fascines require replacement.

and 6° Sheet piling is undermined and overthrown by the Missouri but can be employed upon parts of the Mississippi. Both rivers change direction of their axes 120° at many points. The alluvial bed of each river consists of. silt. sand. clay. rolled granite. gneiss and marble pebbles and contains drift timber of every dimension. Notably violent floods have left a record in layers of larger stones. Different seasons add lenses of different character to the series. The Missouri drift is much finer than that of the Mississippi which is due to the greater distance the pebbles and sand of the first have been rolled and rubbed, having frequently travelled 2000 miles or more. Amount of buried timber is much greater in the Missouri.

1 Cuft Missouri River Silt weighs 77 lbs
1 " " " " wet " 118 "
1 " " " " Shore Silt dry " 90 "

Dry Sand fine 1 Cuft weighs 99 lbs
" " medium " " 101 "
Satd " " " " 125
Dry " Coarse " " 106 "
Satd " " " " 132 "

The very small specific gravity of the silt explains the facility with which it is transported. The methods of excavating employed upon these rivers are 1° Steam Shovel 2° Noria 3° Syphon Pump 4° Sand Pump 5° Water Jet 6° River current directed and controlled 7° Agitators to put the silt in such a state of suspension that a current can remove it. The Steam Shovel is employed when there is plenty of seaway upon stiff resisting materials which place the Noria at a disadvantage 2° The Noria is in common use. especially the vertical arrangement. That employed at Quincy and Kansas City throws 20 buckets a minute which have each 2/3 cu ft capacity and half full would give a total of $\frac{20 \times 2/3 \times 60}{2 \times 27}$ cy ds pr hour = $\frac{400}{27}$ = 14.91 cy yds pr hour while grapp performance is about 4 cy yds in same time 3° Efficiency of Steam Syphon as of water jet depends upon the velocity of flow, which greatly exceeds the rate of fall of the particles of sand or silt due to gravity. The Steam Syphon as it removes matter in suspension has to transport at least nine parts of water to one of silt. Calculation of its effect is very simple. a Diver directs its sucking mouth and at Quincy the Steam is drawn from the boilers of a steamer alongside the pier when it is employed. 4° Sand Pump. Not less than 4 volumes of water are required to give sufficient fluidity to sand and in practice considerable more is found necessary. 5° The Water jet is of service in loosening

~~and~~ sand and throwing it down into the pit or hopper of the Noria. as well as to remove material from beneath a pier which is lowered as building progresses above the surface of the water. Jets are at times arranged in systems about the lower edges of an inverted Caisson but single jets are directed by a diver. The efficiency which depends upon the velocity of the jet is much increased by bringing the nozzle in the sand several inches.

Vel to scour fine sand	1/2	ft pr 1"
" " " Coarse	" 3/4	" " "
" " " Stone	3	" " "

At Kansas City a diver buried to his neck by a fall of sand extricated himself by the jet he was using. The head of water due to depth at which jets are used of course is balanced by the head of the jet itself. The common diameter of nozzle is 7/8" (See description of foundation of Pier 4 Kansas City Bridge in later page). 6° Where piers built upon a grillage or within water tight Caissons; or cribs are slowly lowered upon a sandy bottom scouring occurs: this effect is increased by employing directing aprons and is to be taken advantage of wherever possible. This method of directing natural force was employed at Quincy 7° Agitators.

have not been used in founding a bridge but may be employed wherever there is a brisk current. The new Delta Dredges employ this invention of Mr Ellets.. Iron or steel shod piles penetrate the riv bottom readily and when employed are driven to a depth of 25'–35'. The most serious obstacles encountered in sinking foundations are wrecks (at St Louis 3 were encountered in one spot) and buried drift wood, to remove such obstructions divers are employed and provision is made to employ the pneumatic process if necessary, in employing caissons as hereafter described. Buried Oaks and Cottonwoods 12" in diameter and larger are found in the Missouri River deposits. No boulders ten inches in diameter are ever encountered.

The especial sources of danger to river foundations are 1 Undermining, 2° Ice, 3° Steamboats and 4° Rafts (upon the Mississippi; they cannot hold together upon the Missouri).

1° Undermining or scouring. ~~By~~ The removal of sand to a considerable depth upon one side of a pier while no corresponding excavation occurs upon the other side exposes a pier to very severe lateral thrust. Upon the Missouri River this depth of scour may be considered 30' the amount of thrust will depend upon the excess of wt of saturated sand (125 lb) over that of water and its angle of repose, and may be calculated as in case of ~~embankment~~ retaining walls. The angle of repose of this sand in water may be taken at about 15° and Rankine's formulae employed to test the stability of a pier whose dimensions are given, when exposed to this condition.# A Pier capable of withstanding this danger is strong enough to resist the others. This is the most severe trial to which it will be subjected.

2. Ice. Piers are exposed to (a) Gorged Ice and (b) Running Ice.

Horizontal Sand arches may form between vertical columns several feet apart.

(a) In the Winter the rivers are at a low stage of water; narrow passages in the channel and Bridge Piers by causing detached masses of ice to pack together produce gorges which extend up stream for miles and by damming up the channel sometimes produce a rise of 8 feet. When the gorge upon one side of a Pier breaks away it is exposed to lateral thrust from the mass upon the other side, and when a floating wedge-like mass strikes the gorging band between two Piers, one of them being in the condition just mentioned, either ice is crushed all along it's exposed side or the Pier must give way. The dangers then to which gorged ice subjects a Pier are.

1° Longitudinal thrust which is less than running ice subjects it to 2° Lateral thrust which every pier should be capable of withstanding although a combination of circumstances must coact for its occurrence. Under the conditions described a mass of ice of ordinary thickness (10-15 in) moving with a velocity of 3 or 7 miles upon these rivers respecting may come in contact with a pier along one side only. Whatever the momentum of the mass ~~[illegible]~~ its power to thrust the pier from its place cannot exceed that necessary to crush ice along the flank exposed at a rate corresponding to the velocity of the mass's motion. A series of experiments at Kansas City proved the crushing pressure for ice to be 450 lbs. per square inch.

Let l = length (inches) of pier-side exposed at given stage of water to the ice t = thickness of ice v = velocity of ice in ft per 1"

then $\frac{l \times t \times 450 \times v}{144}$ = foot pounds of resistance exerted in 1"

or $l \times t \times 450$ = resisting pressure a pier should afford.

(3) Masses of floating ice are frequently 50'×150' in area and ~~frequently~~ often as large as 500'×1000' moving with the velocity of the current.

the ice breakers are designed to plough through such fields of ordinary thickness at such rate of velocity. 3° Steamboats going with the stream are forced to maintain considerable speed in passing through draw-bridges. The long crib for protecting the open draw has in some case caused a current to strike across toward a channel pier. The difficulty of controlling a boat under these circumstances renders the strengthening of the channel piers a necessary precaution. The only danger is from descending boats (see dimensions of River Steamers under Regular Conditions).

4° Upon the Mississippi rafts of great size descend from the forests of Minnesota and Wisconsin. They are made up of parallel "strings" 16' wide extending the entire length of the raft and bound side by side; this construction permits the ready division of the raft into parts not too wide to pass between the piers. These rafts draw from 2 to 5 five feet and move faster than the current; about 3 miles an hour by day and faster by night (owing to deeper immersion: the air being heavier at night when cool); they are a greater source of danger than floating ice for they act with full effect of their momentum. Accumulations of drift timber by obstructing the river may subject a bridge to trial, but this is a rare occurrence upon these rivers. The methods of establishing river foundations now employed by engineers are,

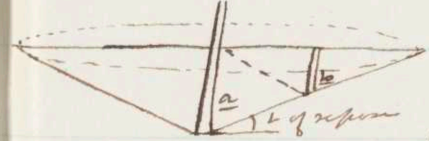
1° Piles and Columns of Support 2° Coffer Dam

3° Crib 4° Pneumatic tubes 5° Caissons 6° Curb.

1° When deep scouring action is out of the question piles have been employed, driven to a depth of from 25' to 35' and becoming columns of support when the bed rock is not buried deeper. Oak and Sycamore.

piles 50' long and 18" in diameter at the head, are employed generally in the West. The Mississippi bridges are generally founded upon piles, which can be trusted only exceptionally upon the Missouri. The supporting power of piles and tubes driven through the deposits is due to the frictional resistance afforded at their surface by the pressure of inverted cones of sand whose angle of slant = angle of repose of the material, the coeff of friction being in this case about 1/2. Hence other things being equal, supporting power is proportional to square of the depth to which the pile is driven, the resistance they afford to the driving weight proves this rule to be approximately true.

(See angle of repose = 3.).



They are sawed off at a depth by a horizontal circular saw and are usually driven at the bottom of foundation excavations made by some of the following methods. 2° Coffer Dams are frequently employed upon the Mississippi but are rarely practicable upon the Missouri. By their means piles are driven and a grillage or stone courses placed upon them or bed rock prepared: ~~or~~ any other method of foundation practicable may be employed. 3° Great timber cribs are employed to protect piers during construction and for founding pivot piers for draw bridges. When employed for permanent foundations they are adapted to the uneven river bottom and must be placed in position with all speed. 4° Pneumatic tubes are generally employed upon the Rhine as well as in Russian and Indian rivers where the circumstances are very similar to those under consideration. The expense of this method, the time consumed by it and the adoption of simpler expedients which make the employment of the pneumatic process readily available as an auxiliary has made the number of cases in this country very small. This process has not been resorted to upon the rivers named. 5° Caissons are used instead of Coffer Dams upon the Missouri; are sunk through the river bed which is excavated within, are sometimes pumped dry and ~~whether~~ are always made in a series of sections. Illustrations will be given of their various ~~[illegible]~~ methods of employment in founding the piers of Kansas City Bridge. They are also used to float entire piers to the seats prepared for them, upon which they are lowered by the admission of water or by suspending bolts attached to false works. In deep foundations the lower sections are not removed but usually filled with concrete. 6° Curbs are properly caissons without ends and perform the office of retaining walls, they are made of boiler plate and sunk by their own weight obstacles being removed by divers they are not to be pumped out but permit the use of suspended caissons at great advantage

The superstructure of all western bridges is exposed to very severe gales of wind, while destructive tornadoes are not infrequent. The great extent of open prairie country offers no obstruction to their gathering violence. 40 pounds pressure to the □ ft is the allowance usually made in calculating strains, but no bridge would withstand such tornadoes as have crossed the Mississippi; and of late years. The engineer is not constrained by natural obstacles alone. To protect and maintain the great system of inland navigation. laws have been passed imposing conditions upon all bridges over navigable streams

Upon the Mississippi every bridge must.

possess two spans of at least 250 feet and a draw of 160' in the clear. and if without a draw there must be 50' clear between lowest point of bottom chord and high water level. At St Louis special conditions imposed are: 1° that it shall not be a suspension bridge or a draw bridge with pivot or other form of draw and 2° that lowest part of the bridge shall be not less than 50' above high water at its greatest span 3° that it shall have at least one span of 500' in the clear or two spans of 350' in the clear of abutments. If the two latter spans be used, the one over the main steamboat channel shall be 50' above high water measured to the lowest part of the bridge at the centre of the span 4° no span over the water at low water mark shall be less than 200' in the clear of abutments. Bridging the Missouri was an unconsidered question and charters are granted upon ~~same~~ terms nor demanding such length of span or draw. Draw bridges are not allowed upon the Ohio. The dimensions of some Mississippi and Missouri River Steamers are

				Largest Steamer on Western Waters
Length over all	285	251	270	336
Breadth of Beam over all	61	72	74	96
H^t to top of chimneys	70	70	83	105.

Limestone only has been employed upon piers and foundations and the superstructure has in every case been brought to the points, ready for erection. The river channel is almost always found upon one side of the "bottom" and along the foot of continuous bluffs; this makes the approach to one end of the bridge necessarily long trestle or embankment while to avoid altogether or diminish the amount of cutting at the other end a curve is introduced beginning upon the last span of the bridge in several cases. Of all the conditions that, most rigorously imposed, is economy of construction

To sum up; the conditions are 1° Physical 2° Financial 3° Legal. I will now illustrate the general principles and practices already referred to, by the bridges now complete or yet under construction. They are at 1° Clinton 2° Davenport 3° Quincy and Burlington 4° St Louis 5° Kansas City. The St Charles bridge I have not visited.

1° Bridge upon line of the Omaha Extension of the Chicago and North Western Railway and between Fulton Ill. and Clinton Iowa. An island divides the river into two channels, the eastern of which is shallow, the western navigable. The eastern division of the bridge, approached by a long trestle work consists of 7 McCallum trusses of 200' span each; the western division of three Howe trusses of 200 feet span, between the 1st and 2d of which beginning at the West is a Bollman draw ~~of~~ 300 feet long. The stone used in the construction of superstructure was brought from Joliet. Ill. The pier is founded upon the. Piles were driven in the sand, sawed off, and upon them a floating caisson in which the pier was built was then lowered. This method was employed except for the draw pier which is built within a crib 440' long 40' wide and 44' deep. The form of the river bottom was carefully determined by sounding. The crib bottom was formed to fit the irregular surface and having been floated to its mid-channel position was filled with stone and sunk with speed. One corner has been slightly undermined making necessary the re-leveling of the turn-table plane. The draw bridge is moved by a steam engine placed in its centre and above the railway. Telegraph wires are carried over this draw, in the usual manner, by attachment to a pole standing above the turn table centre.

The turn table rests upon 36 conical wheels. The iron work including the Bollman draw truss was all furnished by the Detroit Bridge and Iron Works. 2 The Chicago + Rock Island railway is carried over the Mississippi opposite Davenport (Iowa) by a wooden bridge in two Divisions, one on either side of Rock Island.

Beginning at the West end there are

3 spans 250' each, Draw 284', 2 spans 250' each

Island then over eastern slew or minor channel

3 spans 150' each making total length of bridging 1984'. The surface of the bed rock is nearly horizontal across the river channels. The piers generally rest upon cribs with open ends which were sunk filled with rock at the pier sites. The trusses are all of the Howe pattern and lower chords are continuous. The chords and braces are of pine and of following dimensions.

Lower Chord	6 ties	7"x15"
Upper	" 6 "	7"x14"
Floor Timbers		7"x14

Braces scantling diminish from 12' 8" to 9' 6"

7 tie rods for first 3 panels then 5

~~Diminish~~ Diminishing from 2"1/4 to 1"1/8.

The upper chord is arched. and the overall 24'. Weight of each truss 300 tons. The chord pieces are keyed together and at junction of abutting ends  anchoring plates are let in and bound together.

Camber of the bridges is 3" to the span. To compensate for which the railway ties are made of diminishing depth from end to centre. All timbers employed in the bridge except ties and cross pieces are Burnetized. The wooden crib 350' long which protects the draw bridge causes the current which is very rapid in the channel to impinge against the end draw piers; steamers have struck these piers several times and ~~the~~ a number of suits have been brought against this bridge as an obstruction to navigation, it is soon to be succeeded by another with piers placed from consideration of the current not simply at right angles to the axis of the bridge.

Last spring the wooden draw weighing 250 tons was blown off its truck and ~~was~~ wrecked upon the crib and ice caused the second pier from the west end to break off 3' above the bed rock and shoved it 23' 8" from its place: the continuity of the lower chord caused the second span to move the east end of the pier 10' laterally so that one lower chord overhung the end of the pier. The ~~spans~~ trusses were drawn back to their positions and a temporary pier erected to replace the fractured one. Another pier has a vertical fissure through its sides and is strengthened by iron bands and bolts extending around it. This was the first bridge built across the Mississippi, having been completed in 1857. Its faults are all in its substructure. I am unable to give the dimensions of the piers and their ice breakers. The draw bridge is moved by two men. Howe Trusses are said by practical men to be impracticable for longer spans than these.

3° The bridges at Quincy and Burlington are upon the line of the Chicago Burlington and Quincy road and consist of Pratt trusses, entirely of iron and manufactured at Detroit. Both bridges are approached by railway upon trestle work, in first case at the West end in second at the East.

An accompanying tracing shows ~~the~~ a Pratt truss of 250' span in isometrical projection. The top chord and shoes or pedestals of the upright posts are of cast iron, all other parts of wrought iron. ~~[illegible]~~ No Cofferdams were used in preparing foundation ~~or [illegible]~~. at Quincy only 3 of the # piers rest upon rock. ~~Protected by~~ * Excavations were made by dredges piles driven and sawed off below the depth of scour and the piers resting upon a timber grillage suspended from false works were lowered to their places. For the foundation of the draw pier at Quincy 4 tubes of boiler iron 14' in diameter were sunk to the rock. vertical dredges

Two by columns of support

* as upon stated the scouring power of the river was taken advantage of.

4//

or divers being employed with. Steam syphons to excavate within the tubes. The cost of sinking them to the rock (about) 20ft was $750 00/100 each; when sunk to their final position concrete properly mixed (2 yds stone & 2 bbls sand 4 bbls cement well worked together) was lowered to the bottom in buckets and there packed by a diver in a proper manner. ~~The water was not pumped from the tubes and~~ Upon the concrete filled tubes courses of stone for the pivot pier were laid*. The 4 tubes are bound together by a timber caisson section, through compartments in which they were lowered, the interior being now filled with concrete. The draw bridge at Quincy is to be protected by a permanently fixed caisson ice-breaker between which and the draw pier a barge is to be moored, the advantage is economy. such arrangement being cheaper ~~than~~ a long stone pier or timber crib while equally effective. The ends of the draw, ~~span~~ length of which over all is 360' are, supported upon ~~two~~ cams, which are brought into action by turning a vertical screw, which acts upon ~~an~~ intermediate toggle joint. A ~~horizontal~~ hand wheel upon the shaft of the vertical screw is between the rails of the roadway and immediately accessible. The conditions being nearly the same for all the Quincy foundations and cost of Pratt trusses of different length of span being known, the solution of the problem, what length of span will be most economical was 157'. All spans then of the main bridge except those whose length ~~the~~ other circumstances determined are of 157'. Commencing at the West end the order of spans is this

250', Draw* 360', 250', 200'. 200'. 9 spans of 157' each

then are island from which the road is carried, at

* a heavy
[illegible]
rillage of timber
s imposed upon
the tubes cut
ff under the
water. The
tone piers rests
ith its inverted
one base
for distributing
ad upon a
s of concrete
within the
rillage.

* Two openings 160 ft in the clear.

same time crossing over the "bay" upon trusses # which latter, in same progressive order from West to East are 80', draw 190". 3 spans of 80' each.

The trusses and draw of the bay bridge are of iron and constructed under the Bollman patents (no lower chord). The 80' spans are all deck bridges, to permit a full view of the bridge while approaching around the curve.

4
250' = 500'
360
200' = 400'
157 = 1413
190
80 = 320
3183
Total length included is approximately 1 mile.

The iron for Burlington and Quincy bridges came from Troy and was shaped at Detroit.

The wrought iron rods and chords are subjected to a test strain # of 20000 lbs per square inch and are never exposed to greater working tension than 12000 lbs. There were no difficulties of magnitude to be overcome by original methods in either case; ~~their~~ time consumed in their erection has therefore been very short.

The tensile strength of iron is required to be not less than 60000 lbs per ☐ inch it has proved much stronger than this

Burlington bridge was begun Jan 1 '67 finished Aug 68
Quincy " " " Feb 1 '67 Sept. 68.

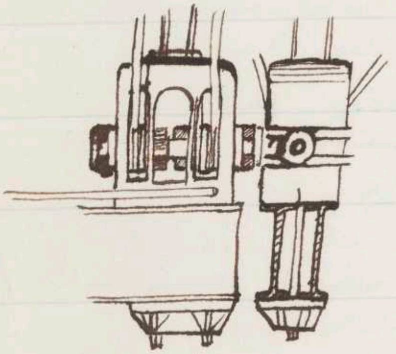
Burlington spans from W to E are 80' 250' draw 360' then 5 spans 250" each #

6 × 250' = 1500'
360' 360'
80' 80'
1940'
Total length

Referring to the isometrical view of a Pratt truss of 250' span. There are 15 panels and two end panels. For 157' span depth 22', for 200' span 24' for 250' depth 26'. They rest, one end upon simple cast iron plates the other, upon a friction truck. The upper chord is made up of a series of abutting ~~cast~~ hollow cast iron sections * each of a panel length (panel length is ½ depth of truss for 250' span is 13'). ~~[illegible]~~ ~~[illegible]~~. The inclined struts (60° inclination) at the ends and vertical posts which limit the panels are of wrought, built from segments under the design called Phoenix. They are formed of ¼" iron an hexagonal at ends of span and four sides at other points # they are made in Philadelphia. Raised flanges # fitting the interior of these posts prevents displacement when they are in contact

* The thickness of the shell increases as we approach the middle of the span. For 157' span the thickness ~~ranges~~ ½" ⅝" ¾" ⅞".

with the screw-bolts or cast iron "shoes". The top lateral bracing consists of struts formed of T iron
+ abutting against flanges upon the upper chord. and of ties of wrought iron which pass through the chord and are secured without. At the foot of each vertical Phoenix Post is a heavy casting of rectangular plan and elevation; two vertical webs divide the interior into three chambers which pass through parallel to the bridge axis. A strong



pin of wrought iron (2½ to 3½ in diameter according to position) passes through the dividing webs and by this the floor

beams are suspended, the ties and, links of the lower chord attached ~~held~~ and the bridge structure therefore held together. The lower chord consists of wrought iron, employing links of increasing section in proceeding from end to center panels. (the sections being ■1½ ■1⅞ ■2¼. for 157' truss). The tie rods one end of which is attached to the pin referred to are at the other end held fast by cast iron ears or other simple means of attachment to the upper chord. Each rail secured to ties, is directly over two longitudinal stringers which in turn rest upon transverse double T iron floor beams.*

15" deep and 17'6' long. These beams are suspended two and two by vertical wrought iron rods two at each end. Through the head of each of these suspending rods the pin referred to passes while nuts upon their lower ends [illegible] [illegible] maintain a strong cast iron bearing plate upon which the floor beams rest. The suspending bolts pass through the interval between the two beams. The number of chord links is ~~six~~ 3 upon the 250' span, two upon the 157' foot spans. in each chord at

*Phoenix beams

every point. The braces of each truss are inclined at an angle of 45° since the sum of two adjacent panels is a square. The bridge is capable of adjustment at any time by the screwing tighter or loosening of the braces by this means the camber can be ~~varied~~ increased. The lateral bracing ties beneath the floor pass through holes drilled obliquely through the shoe corners. Since only strains of direct compression act upon the Phoenix Posts there is no need of their being strongly attached to the jaws against which their ends bear. ~~When~~ the substructure is complete for one span piles ~~are~~ driven between these piers upon which a trestle is erected to the height of the top chord and affording ways for a travelling crane over all. The section of the top chord are first laid in position then the Phoenix posts are suspended to this in position. The shoes, floor beams and links are next added ~~then the~~ as well as the tie braces all of which are at once attached together by the wrought iron pins before described.

The erection of a span is accomplished very rapidly, ~~since~~ only the putting together of fitted parts simply connected is required and there is almost no riveting.

The spans are entirely discontinuous and are not in any way secured to the piers*. The draw trusses have arched upper chords and in the centre a depth of 36'; at that point there are octagonal Phoenix posts. The limestone of which the piers are constructed was brought from the Illinois River to Quincy and piers 8 feet in thickness have upon each side dressed facing 2' thick the ~~interior~~ interval of 4' within being filled with rubble. The piers are all protected by rip-rap piled about their base.

#The extremely ~~[illegible]~~ small surface exposed to the wind should be noted.

the West bank of the river north of the Quincy bridge has been protected by heavy rip-rapping. In founding and erecting the piers strong false works were employed; supporting travelling cranes for conveying dredge laying stone in position &c. Elevation of lower chord above low water is about ~~35~~ 25'. 2 steamers and ~~4~~ 3 barges for pile drivers & dredges were employed at Quincy. The batter of the ice cutter is 1 to 1. I am unable to give the dimensions of the piers and ice breakers.

*The factors of safety employed in the calculation of strength were 3 for the fixed and 5 for the varying part of the load. The erection of false works ~~&~~ by increasing the scour of the river at other points has had this effect that the section of the channel along the axis of the bridge is greater now exclusive of the piers than it was before their erection.

*he assumed
oad was
2800 lbs
r running
oot

Trains may be run through these bridges with undiminished speed and perfect safety. Two locomotives flanked by cars loaded with railway iron when at rest upon a 250' span at Burlington caused deflection of 2" 9/16; the camber being restored after the removal of the weight within 1/16. This was the first trial of the span. It is proposed to protect several of the more exposed piers by detached ice breakers a little distance above. Two of the advantages of these bridges are lightness and easy adjustment (Wt per running foot is about 950 lbs and with equipment 1600 lbs). The dependence placed upon cast iron hollow chords, flanges and ear pieces is a possible source of danger. The lightness of the piers is one of the points that first strikes a visitor but under all probable contingencies their strength is said to be assured. What I do not state I did not observe or note.

4° The project to bridge the Mississippi at S^t Louis was the occasion of specific legislation referred to, and has called out detailed plans from two companies chartered by the State of Illinois & Missouri, now happily combined. A Convention of the first western engineers assembled in S^t Louis* under the auspices of one of the contesting companies came to the following conclusions.

* August 1867.

The necessary length of bridge being not less than 1500'; the rock rapidly dipping toward the east from a point near the west shore where it was reached 23' below low water to a thousand feet east of that point its depth is 90' &c. The general circumstances peculiar to the Missouri River have been before stated, they are all experienced in this locality.

The conclusions endorsed by the engineers were, ~~that~~ it is safe and practicable to construct ~~a~~ bridge at S^t Louis with piers established upon either of the following plans.

1° Hollow cast iron piles* from 4 to 8' diameter driven by the pneumatic process or by means of syphon pump to the rock or with expanded base far below the scour of the stream.

* These tubes either to support a stone piers or to be extended up to the bridge seat.

2° Stone piers resting upon wooden or small iron pneumatic piles and lowered to a seat so founded, within protecting iron curbs as employed ~~upon~~ at Havre de Grace. The bottom course of stone being below the scour.

3° Stone piers built within iron or wooden caissons, the lower section being an inverted caisson and several lower sections ~~being~~ filled with concrete and sunk by the pneumatic or ordinary process of excavation. To diminish the weight it was proposed that the piers should be galleried. The alternative of 500' spans was rejected as not economical and the following division of spans agreed upon

St Louis Levee	264'
2 spans 368' each channel	736'
4 @ 264	1056'
E St Louis Levee	160'
	2216

The bridge is to be for general as well as railway use and the arrangement of cross section upon which the estimates were based is this. Four trusses with interval 14' in the clear between the two inner ones for the use of the three Missouri and three Illinois rail-roads, gauges, viz 4' 8½": 5'6": and 6'; four rails be laid down. The spaces between inner and external trusses to be reserved for highway and ordinary traffic and two footways each 8' in the clear to extend outside the trusses; width over all is then 75'. Grade of railways 87' above low water level from over land part way, then descending.

Entire length of bridge superstructure 5170' of approaches 3555' total 8725' necessary materials would build 10102' of superstructure of the same spans and 10663' of embankment of same average depth for a single track railroad or altogether nearly 4 miles in length.

Details of the assumed loads and formulae for these trusses accompany the report of the Illinois and St Louis Bridge Co. Wrought iron and steel were designed to be used ~~for~~ to resist strain of extension, cast iron to resist compressive strain.

The other projected bridge at present under construction ~~and~~ by the united companies of which Mr. J B Eads is Engineer in Chief. It is proposed to sink open caissons to the rock which will be exposed and a concrete base established for the piers which will be built in a water tight coffer or caisson and lowered upon the bear prepared, the same coffer or caisson being removed and again employed. The proposed spans.

arc; one of 515'* in the centre flanked by two of 497' each, the form of bridge being inverted suspension or ribbed arch. The bridge is designed after that across the Rhine at Coblentz and the material to be used in the construction of the superstructure is steel. The resistance of steel to compression is greater than to extension. The strength or resisting power of this material ranging according to experiment from that of the best iron to tensile strength of 250.000 lbs □ inch and crushing force of 400,000 □ in sustained. In the estimates accompanying the report the modulus of elasticity of steel was assumed to be

* Rise of centre arch one 1/10 the span and of the others 47' each.

144) 2232000 tons per □ ft
15500 " " □ inch = 31,000,000 lbs.

Safe strain of compression 12.5 tons and for tension 10 tons to the □ inch.

The arches to consist of 4 equal ribs. each composed of two circular members (upper + lower) connected by a system of diagonal braces: The distance from centre to centre of its members is 8';

The estimates for cost of the two bridges between the levees are placed below.

Truss Bridge	2 Trusses of 368' ($1622 per lineal ft)	$1.180.992.84
	4 " " 264' ($1000 " " ")	$1.056.000.00
	total cost of superstructure.	$2.236.992.00
Ribbed Arch.	1 span 515' ($1.233 per lin foot)	$63.5.318.75
	2 " " 497 ($1.233 " " ")	$1.225.602.00
		1.860.920.75

The very interesting report of Mr Eads contains all details of the projected steel bridge as well as the mathematical theory of the ribbed arch. I will quote from it hereafter a few interesting details.

" Each member (upper & lower) of each arch consists of two parallel steel tubes 9' in exterior diameter placed side by side. The members are to be braced from each other by a vertical system of cast steel bracing on each side at regular intervals of about nine (9) feet. These braces to be secured to conform like steel plates ~~upon the ribs~~ against which the sections of steel tubing will also abut and be secured by riveting. A horizontal system of bracing will extend from pier to pier between corresponding members in each arch.

Two centre arches of each span will be 13' 9½" apart from centre to centre. Outside arches 15' 1¾ from the middle ones. The railway structure is suspended between the two middle arches, is 13' 6' wide and 18' below the roadway which with footwalks 8' each in width makes width between railing 50'.

The roadway rests upon transverse iron beams 12" in depth supported by iron struts of + section resting on the arches at the points where vertical bracing is secured. Four parallel systems of longitudinal wooden ~~stringers~~ timbers serve to give stiffness to the roadway and retain floor beams in their places, they are in lengths of 9' feet each and rest within the flanges of the floor beams. The portion of the railway structure below the crown of the arches is suspended from them. The counter-bracing is altogether performed by the ribs themselves and there is no trussing property in the superstructure. As the greatest bridge yet

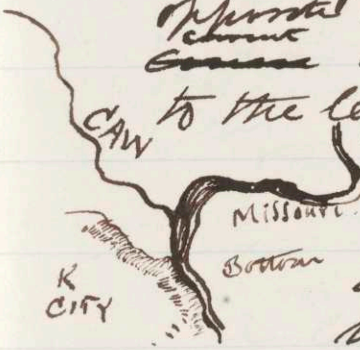
designed for either of the western rivers now considered it is a matter of especial interest.

I am better acquainted with the

bridge at Kansas City than any other and assisted by the accompanying drawings and tracings will give an account of that work.

5° Kansas City Bridge.

The K C & Cameron Railway Co (an arm of the Hannibal and St Joseph Road) required to cross the Missouri to reach Kansas City and establish connection with the Eastern Division of the Union Pacific R.R. and the projected (now progressing) K C & Neosho Valley R.R. which is to be continued to Galveston Texas. As there was no highway bridge across the river and as tolls (which would be far below the cost of ferriage) would go far toward maintaining the structure, it was determined to erect a bridge capable of being used by Railway and Highway purposes; the small number of trains daily which will be required for at least three or four years as well as the short time necessary for crossing a bridge 1500' long at speed of 5 miles an hour ~~would be [illegible]~~ (>4 minutes) made the employment of a common roadway for iron and other horses feasible, a watchman being on constant duty with gates and signals at command by which the possibility of accident through meeting of cars and carriages is prevented. At Kansas City and a point three miles below practicable situations for a bridge are found, but for the following reasons the K C location was chosen though a longer bridge was necessary. 1° As on the purpose of a city bridge it must be at the city 2° ~~[illegible] [illegible] located in separation to a point across the river from the town~~ 2° Materials could be more conveniently and cheaply obtained at the place first named. The location was therefore fixed at Kansas City. The Caw (or Kansas) River joins the Missouri 1½ miles west of the bridge site. The City is built upon a series of high clayey bluffs underlaid by limestone to a height of feet above the Missouri. The course of the Missouri opposite this city is to the east and as its ~~Course~~ current is ~~changed~~ deflected nearly 120° in direction to the left about two miles above the city the ~~current~~ channel at that point is on the south side or at the foot of the bluff. The nearness of the bluff assured the permanence of that river bank although the channel should continue as it was. The north river shore is a low alluvial bottom 12' or more above high water, but which would be removed with great rapidity by the Missouri should the channel shift.* By protecting the bank with rip-rap at the point of impingement of the axial currents the permanence of present conditions has been rendered probable. Preliminary work was begun in 1867 and $30000 (half furnished by the City) has been expended upon rip-rap.



Cost $3 per. cu yd.
slope 25' long
length of bank 10' avg
25 × 10 × 3 = 750
= 28 cu yds
× 2.8 per lin ft
= $8.4 per ft.

Soundings were taken as shown in tracing. Observations of current velocity and rate of fall as well as of ice phenomena were ~~taken~~ made and the course to be pursued in establishing foundations adopted. The height of the bluff upon the south shore made it advisable ~~that~~ to diminish the amount of excavation in the approach by an 8° curve ~~that~~ the axis of the bridge should make with the axis of the river an angle of 72° and that a short span upon the same end should

* The determination of high water level of 1844 was made from ~~the~~ the mean of a great many marks, errors being eliminated and corrections of computation introduced.

near ~~the~~ a small arc of the curve and ~~ve~~ make an angle of with the main bridge. For the same reason the shore span on west end of the Burlington bridge is ~~not~~ similarly placed. The arrangement of span adopted was, proceeding from the Kansas City side

1° Shore span over Pacific Railroad	70 ft
2° " reaching to channel	133' 6/10
3° Pivot draw span	362'
4° Main adjoining span	250'
5° & 6° Spans of 200' each	400'
7° Span reaching to north shore	177' 8/10

This made necessary the building of an abutment and two taper pillars for the south shore span and seven piers in the river as it existed at high water.

The law requires that piers shall be carried 10' above high water. These are 11".33 above that point. The necessary head room for the Pacific Road would have determined nearly the same height. Stone was found close at hand. Soundings showed that the depth of the rock increased in passing from the south to the North shore. The probability of ~~the~~ a future increase of the business of the road was considered in establishing foundations; ~~the~~ lower courses of masonry were therefore made of proper dimensions for supporting a double track railway.

The ~~Northern~~ approach of the bridge by the railroad is over 2300 feet of trestling beside which, the highway mounts, also upon trestle to the bridge end, at the rate of 4' in the 100. The method adopted in founding each of the river piers differed in minor features or modifications. I shall therefore consider ~~the~~ each foundation by itself.

Pier No 1 was to be established on the South side of the main channel where the rock, 23 feet below the surface of the water when the building of the pier commenced was covered by 2 feet of sand. ~~except [illegible] by the current~~. To protect the works a caisson was built of timbers 12"x12" thoroughly bolted and braced within as well as caulked and sheeted with plank.

Its dimensions were 60' long 18' wide 29 feet high. It was launched towed to its place 75 ft above the pier site and sunk transversely to the current, in August '67

It was placed and held in position by 4 wire cables, and, as desired deadened and diverted the current effectually. As the rock surface sloped rapidly to the north. The crib 70 ft long 20 feet wide and 28' feet high with which it was planned to protect the work was fitted roughly to the position it was to occupy. It was without ends and weighed 72 tons. It was floated to the position upon 4 barges. To guide it to the proper place and when sunk maintain it there 8 beams 60' long and 16" square, ~~built~~ formed of two pieces bolted together, through which ~~[illegible]~~ iron rods 65' long and headed by steel drills 2½" in diameter were lifted and let fall, were placed vertically in desired positions and in a few minutes anchored by the rods. The crib was now placed in position the guides removed for that purpose replaced and all firmly braced and secured together.

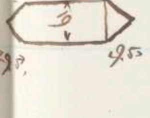
The crib was suspended by eight long screw bolts, a thread being cut for 20'. Three men
at each bolt lowered it at the rate of 25" an hour. A false bottom in segments was employed to regulate the first stages of the descent by the admission of water, this was afterward struck. In four days Sept 11th it rested in its place. With the ~~steam~~ water jet a diver removed

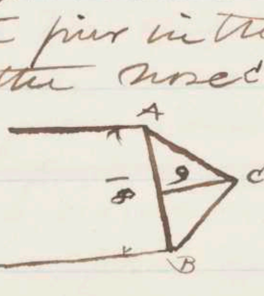
the sand pour beneath its edges in a single day. Sheet piling with ends sharpened to a feather edge was now driven around the crib then secured to the crib and a trench excavated around it by the water jet; in this trench a double row of bags, clay-filled was placed breaking joint clay ~~and~~ was thrust between and around them and a heap of clay 16' wide and 12' high was placed upon the bags around the whole circumference, this was covered with tarpaulin upon which clay and stones were piled. The precautions proved sufficient when the water was pumped out and the river bottom reached in three days. The great surface exposed and the depth of immersion subjected it to a total pressure of more than a thousand tons

circumference = 2×70' = 140'. average depth 23 ft.
2×20' = 40
180' total pressure =

$$\tfrac{1}{2}(23)^2 \times 180 \times 62.4 = \begin{array}{r} 23 \\ 23 \\ \hline 69 \\ 46 \\ \hline 529 \end{array} \quad \begin{array}{r} 62.4 \\ 90 \\ \hline 5616.0 \\ 529 \\ \hline 50544 \\ 11232 \\ 28080 \\ \hline 2970864.\ \text{lbs} \end{array} \quad \begin{array}{l} 2970464\ \text{lbs} \\ = 1485.+\ \text{tons} \end{array}$$

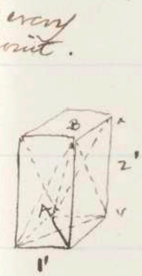
That the danger of this pressure drowning the workers might impend no longer than necessary work was pressed forward night and day. The pump kept the water down and the rock was exposed. The surface of the rock was smoothed and masonry commenced Oct 1 courses being full size of the crib* and so continued 15'. The horizontal section of each end of the piers is in every case a right triangle the hypothenuse being transverse diameter of the pier in that plane hence the advance of the nose C beyond a straight line AB joining the other vertices this afforded the masons a ready method of keeping their work true. The space between the exterior courses of





faced stone was filled with concrete, while the narrow interval between the inside of the curb and the pier was filled with the same. When the height 99 (15' above the foundation was reached) the dimensions of the courses was diminished to thickness 14' length of plane side 40' length of nose ∴ 7'. At this point filling in the curb ceased and at level 100' the ice breaker began. See diagram showing plan and side elevation of an 8' pier on accompanying sheet. The channel piers only differed from the others so far as masonry above 100' is concerned in their thickness, to compensate for the danger from striking of steamers the least thickness of channel piers is 8 feet* while that of others except No 2 is 7'. (The piers are designated as 8 or 7 foot piers according to their least dimension).

*The 8' piers are 1' thicker at every point.



The batter of the ice breaker faces is 6" to 1' therefore that of ice cutter is √2 to 2'. The ice breaker ends at elevation 116.00. was finished to that point Nov 22. The strength of these piers was determined by calculation of strains to which a scour of 30' upon one side alone, a moving mass of ice 15' thick bearing full upon the side and a striking steamer would expose them. The facing stones of the horizontal courses are doweled together and the interior is filled with rubble masonry. The stability of the pier is due to friction and tenacity of mortar which however is not relied upon to give necessary stability.

The upper portion of the curb was removed at 100 the lower remaining below.

The calculated thrust exerted by a mass of ice 15" moving 7½ miles an hour and striking under the most favorable conditions is 476 tons. The following and the general dimensions of 1. ~~Length on foundation 69/8 at surface 49'~~ and with a reduction of one foot in width at every point applies equally to all the piers but 2.

The round pivot pier whose diameter is 30'.

	Length Extreme ~~Len~~	Between Shoulders.	Starlings
L Water	51'	38½	12½ ~~19~~'
H Water	34½	26½	8' ~~12½~~
Top	40½	30½	10'
On Foundation	68	49	19.

The height of 1 is 62' contents 1234 cu yds.
The alteration of this pier to accommodate a double track road would consist in leaving away the facing rock from the foot of the ice breaker upward and the lengthening of the structure at each end. This addition could not all be made at one end on account of the pivot of the draw bridge being in the main axis of the bridge and the pivot pier cylindrical

Pivot pier No 2 has not yet been established. It is to be circular 30' in diameter at the top and is to be sunk in the middle of the channel. Its height will be 73' feet. A wood caulked and iron banded caisson has been built in ~~4~~ 2 sections. The lower section has a plate iron cutting edge. The whole caisson to which the sections will be added as it is lowered will be suspended by screw bolts from trusses sustained by false works. The masonry will not be laid within, upon the inverted caisson ~~as~~ while the lowering is in progress and the sand will be excavated beneath the edges by use of water jets. The depth of sand is not great and no difficulty is expected. A crib 70'×30' has been sunk transversely above to protect the work. When the sand has been removed from within ten feet of concrete will be laid within and under water. The caisson will then be pumped out and the laying of masonry courses begun. The draw will be protected by two ice breaker cribs 180' above and below respectively. with ~~2~~ smaller square cribs between centrally them and the pier. The upper section of the caisson will be removed.

Foundation of No 3. In Aug '67 driving of piles was begun depth of water 10'. of sand 23'. One pile out of every 4 driven was washed out with great regularity. The current caused them to sway thereby loosening them. Twenty piles were driven in a group about 70' above the pier for the establishment of a platform for instruments. When braced together the whole body swayed. To remedy this motion of the piles anchor rods were attached at one end by a pin bolt passing through a pile, this was attached before the driving of the pile hence, the other end being made fast afterward to an adjoining pile. The pin bolt weakened the piles and caused them to be broken in driving. An iron ring in two segments which could be bound about ~~a~~ pile was then adopted for the same end. This bracing was effective. The river removed much material at the upper end of the open caisson structure which was lowered slowly* but it was necessary to employ water jets and sand pump at the other end. A slight tilting it received in going down caused it to ~~tilt~~ bind when 2' from the rock. The facing course or shell of the pier had been built within to assist in forcing it down#. A platform was now built above and the caisson was heavily loaded at each end: this forced the caisson to the rock.

Material was dredged from the interior as it sank. The amount of material removed was considerably in excess of that displaced by the pier in every case.

* a temporary bottom was employed to enable the driving ~~effort~~ most available.

\# 270 lbs pressure for each superficial foot of surface was imposed. The thrust of the current was overcome by an anchoring wire cable attached to the caisson.

The diver found that between the edge of the lower section and the rock there were open spaces; one 10"×20'. Gunny bags filled with concrete were thrown into these openings from within to prevent the entrance of sand. The surface of the rock having been cleaned ~~the~~ concrete was filled in to the depth of eighteen feet.*(18')

#/ Laid under water by the diver

This was in March 68. 17' of water was then pumped out but as bad leaking followed and it was discovered that a vertical timber by which the ~~third~~ second section was bound to the pier had broken and that the joint between these sections which occurs just above the top of the concrete was not tight. The laying of concrete was then resumed and continued up 5'. Pumping out showed the upper part of concrete not to be perfectly sound. One foot was therefore removed ~~and the~~ two grillages of timber laid down. The timbers* of the lower grillage were laid 12" apart and transversely then a layer of concrete was laid down and beaten. Upon this (second timber above the lower grillage) timbers were laid at same distance apart and longitudinally. The grillages were employed to distribute the load of the masonry and the concrete was continued through, as described to give increased stability; for the coefficient of friction of stone on wood is 0.5 while that of wood on concrete is 0.7. The height of this pier from the foundations is 80'.# The courses of masonry are laid as before described, dovetailed horizontally and are of diminishing depth above the foot of the ice breaker.

8"×12"
☐

The cost of masonry is $15.25 here.

Two sections of the caisson form permanently a part of the pier. Rip-rapping placed about the upper end of this pier is removed to the lower by the current but this will cease when the second ~~[illegible]~~ pockets are filled.

In Sepr '67 piles were driven for false works of Pier 4. Depth of sand above rock was about 45' and of water 24'. Work was suspended for a time at this pier and six weeks later the sand had risen 22'. A crib was placed in position for sinking in October. In the spring when crib or caisson had been sunk 27 feet in sand the river scoured to a depth of 20' upon one side only, this cause the overturning of the caisson, its suddenness (2 day action) only permitted the saving of the machinery, dredges and engine. The caisson thus overturned and buried ~~sunk from~~ is such an obstacle to further works upon that spot that the arrangement of spans has been changed; the 250' span between 3 & 4 changing place with the 200' one between 4 and 5, this removes the pier site 50'. The method to be employed in founding the Pier No 4. has not before been used as here arranged but is an application of the modified caisson pneumatic process first used at Kehl bridge. The caisson represented in detailed sections in the accompanying tracing is erected but not launched. Piles are now being driven for the false-works according to the arrangement shown by plans. The lower section of caisson 4 is built of solid squared oak timbers strongly braced within, caulked and doubly sheeted upon the outside with 2' plank. The inner planking being diagonal the outer vertical. It is divided by transverse walls into 4 chambers. The ~~lower or cutting edge of the caisson~~ Walls of these chambers (except from the shoulders to the nose in the end compartments) are inclined 31° from the vertical and converge to 4 rectangular openings or wells in the top of the inverted caisson. The object of the wedge shaped lateral and transverse walls is to ~~make~~ facilitate the sinking of the caisson. Each transverse wall is principally trussed and its lower edge is 30" above the lateral cutting edge. Iron plating extends about two feet above these edges. The interior of each chamber is neatly planked (oak and black walnut) and caulked so as to render it air tight. The open space between the chamber and outer walls of the caisson will be filled compactly with concrete before the lowering is commenced. This will give weight and increase materially the internal strength.

When complete then each chamber will be communicated with by an independent well. To float this section to the false works a temporary bottom will be placed beneath, sustained in position only by the water pressure, by raising the caisson this pressure will be relieved and the bottom floated from beneath.

Upon the false works will be erected ~~#~~ 7 principal suspending trusses ~~each~~ of the design shown in plate. 24 long suspending bolts# two and two opposite will ~~suit~~ sustain the caisson and transmit the load to longitudinal stringers supported by the trusses.

By simultaneous action of men at each bar the work will be lowered uniformly.

In lengths 30'×2" (?).

It is expected that 80 water jets# arranged around the cutting edge will by loosening the material encountered prove as serviceable as when so applied to piles. The heads of all bolts coming to the outside are countersunk. Sections will be added in succession as the depth of immersion increases. The two lower sections are to be filled with concrete upon which courses of masonry will rest. The wells will be maintained open until the foundation is finished. Through them vertical dredges will remove sand from within. The great weight of the concrete and masonry increasing with the depth will overcome the friction of the sand. If no obstacle is encountered the pneumatic capacity of the lower section will not be called into service. Should buried timber# arrest the descent of the pier the well communicating with the chamber where the obstruction is found will have a cover and air lock being attached to the well ~~which~~ from which and the chamber water will be expelled by air. Workmen will descend and work in a depth of 30" of water passing matter excavated under the transverse wall into the adjoining chamber. Or the 4 compartments may be filled with compressed air the passage 30" beneath the transverse wall affording communication between them and the weight of masonry rendering loading unnecessary. A tube enclosing vertical dredge may be lowered through a well, its lower end immersed beneath the surface of water which will stand within at the same height as in the river and material may

7/8" diameter.

Trees 6' in diameter are buried in the Missouri bottom. There are no boulders.

be secured from the pneumatic chambers without an intermediate air lock. None of the advantages of the ordinary pneumatic process are not lessened by this, which is a far cheaper method. The lower edge is not fitted to the rock surface because borings are not trustworthy as to details of the rock face at such depths. When the rock has been laid bare and if unsound cut away to sufficient depth the chambers will be carefully filled with concrete, the wells pumped out and the pier made solid with rubble. The sections of caissons will not be removed. This is the most difficult foundation, its being necessary to penetrate at least 40' through sand to the rock.# The points of the process are, isolated, or communicating chambers with independent wells. The construction of the pier above the water and avoidance of men weighting to sink the caisson. The strengthening of the sections by concrete within and the perfect command of its rate of descent. The great advantage is its economy.*

Piers No 5. 6 & 7 are north of the river axis, where the main current is to the west, being a return eddy. The deposit of sand above the rock is in all these cases very deep and as the permanence of the present channel will make deep driving here out of the question, these piers were founded upon piles which in the case of 5 however are columns of support. The height of these piers above foundations is 5° – 66' 6° – 53' & 7° – 46'. and at ordinary low water dry

* The cost of constructing and sinking the Caisson will be about $40.000.

\# See accounts of Kehl bridge foundations.

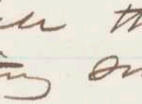
sand surrounds 6° & 7°. The case of foundation 5 does not differ materially from that of 3. The curb was lowered last February, being held against the current by wire cable attached to anchoring piles. The caissons were loaded by masonry lining within and having been ~~driven~~ forced down to the depth 80, more than 20' through sand. Piles are at this time being driven within ~~sand~~ a distance of 35' to the rock. They will be sawed off at the level 80 and concrete filled in resting upon a grillage. The resistance to caissons has been found to vary approximately as the square of the depth but ~~that~~ natural arches of sand by resisting or yielding make the increase in amount subject to irregularity. One of the 4 piles upon which an engine rested near the false works of No 5 suddenly sunk straight down without warning, the water rising at the same time several feet within the curb, as if a chamber in the sand had yielded and the water within forced under & into the curb. The piles driven for false works or foundations are 50' in length and of diameters 7" & 18" at ends. The driving hammers weigh from 1500 to 4000 lbs.

When foundations 6 & 7 were established the river was low and the place of foundation upon dry land. Coffer dams were erected with sheet piling and the sand within excavated by steam power about 10' at 7 and to a greater depth at 6. Five grillages of timber were placed upon the piles at 7 and two at 6. Upon these grillages courses of masonry were laid.

In laying the masonry horse power has been used for lifting stone. A steamer is employed to transport materials, two barges and caissons &c. The peculiar difficulties of this bridge are altogether in the foundations.

The Superstructure is a double triangular or Warren Girder in which the materials employed are wrought iron and wood. Wooden struts are employed for economy's sake as the accumulated interest of the difference in expense between the iron and wood will replace them every seven years while renewal will not be necessary oftener than once in 15 years. The spans are constructed by the Keystone Bridge Co of Pittsburgh. A plate giving elevation and two plans of half a 250' span forms a part of my thesis. Owing to the skew of the bridge the panels of the two trusses are not of same dimensions occurring in the same order

The top chord consists of 5 struts well keyed together and strengthened from the 5th panel to the centre by the addition of principal struts underneath, separated by a small interval to permit ventilation. The lower chord consists of four ~~ch~~ links of rectangular section upon which the floor beams rest directly.

A wrought iron pin which passes through the eyes of the links also ~~forms the a~~ gives attachment to the wrought iron ties upon either side of the wooden counterbraces and passes through the axis of the cast iron angle block against which the wooden struts abut. The abutting surfaces of wood & iron are ~~cut~~ in form of dihedral planes . this holds the strut to its place and tends to prevent crushing & spreading of the foot. The difficulty of making a satisfactory fit is an objection. The dimensions of chords ties and braces are marked upon the

Plates. Iron when the load is suddenly imposed and removed is subjected to 8000 lbs per ▨ inch when run gradually to 10000 ~~lbs~~ and never to more than* 12000 lbs. While the specification demands a tensile strength of 60000 lbs actual strength has proved to be 84.000 lbs per ▨ inch, All work of the Keystone Bridge Co enjoys the use of Linville posts and the upset eye bars. The draw 360' long is to be a Pratt Truss. the posts being upon the Linville pattern. These posts are built of wrought segments not riveted close together but with thimbles interposed through which the rivets pass. These thimbles increase in length toward the middle and a swelled form is given to the post . By this means large diameter is secured with small weight. The posts admit the passage of counter diagonals without cutting away the material of the ~~p~~ strut. The arched upper chord of the draw is to be built of an upper and lower plate between which are placed ~~two~~ two channel and two I bars. .

* ~~Changes at the ends to 10000 and in middle to 12000.~~ This to 12000 at ends 8000 in middle and 10000 in intermediate part

To accommodate the highway ~~and footwalk~~ the bridge will be planked in this way. Upon the longitudinal stringers 1½ planking placed diagonally then tarred felting, another layer of planking of same thickness placed diagonally in the contrary direction then Nicolson Pavement. A sidewalk will be supported by beams forming extension of floor beams on the west side beyond the truss. The ends of the chord eye-bars or links are upset in a manner which gives such form that after the hole for the pin has been drilled the cross section of the solid metal through the axis is the same as at intermediate points in the bar length. The end is also shaped so that ~~breaking~~ tearing will occur elsewhere as soon as beyond the eye  The short shore span is an open, simple iron truss. Only the pier spans of the bridge at either end have yet been erected.

The upper chords will be roofed independently, a protecting curtain being extended low enough to protect the timbers of the chord from rain while free ventilation is secured.

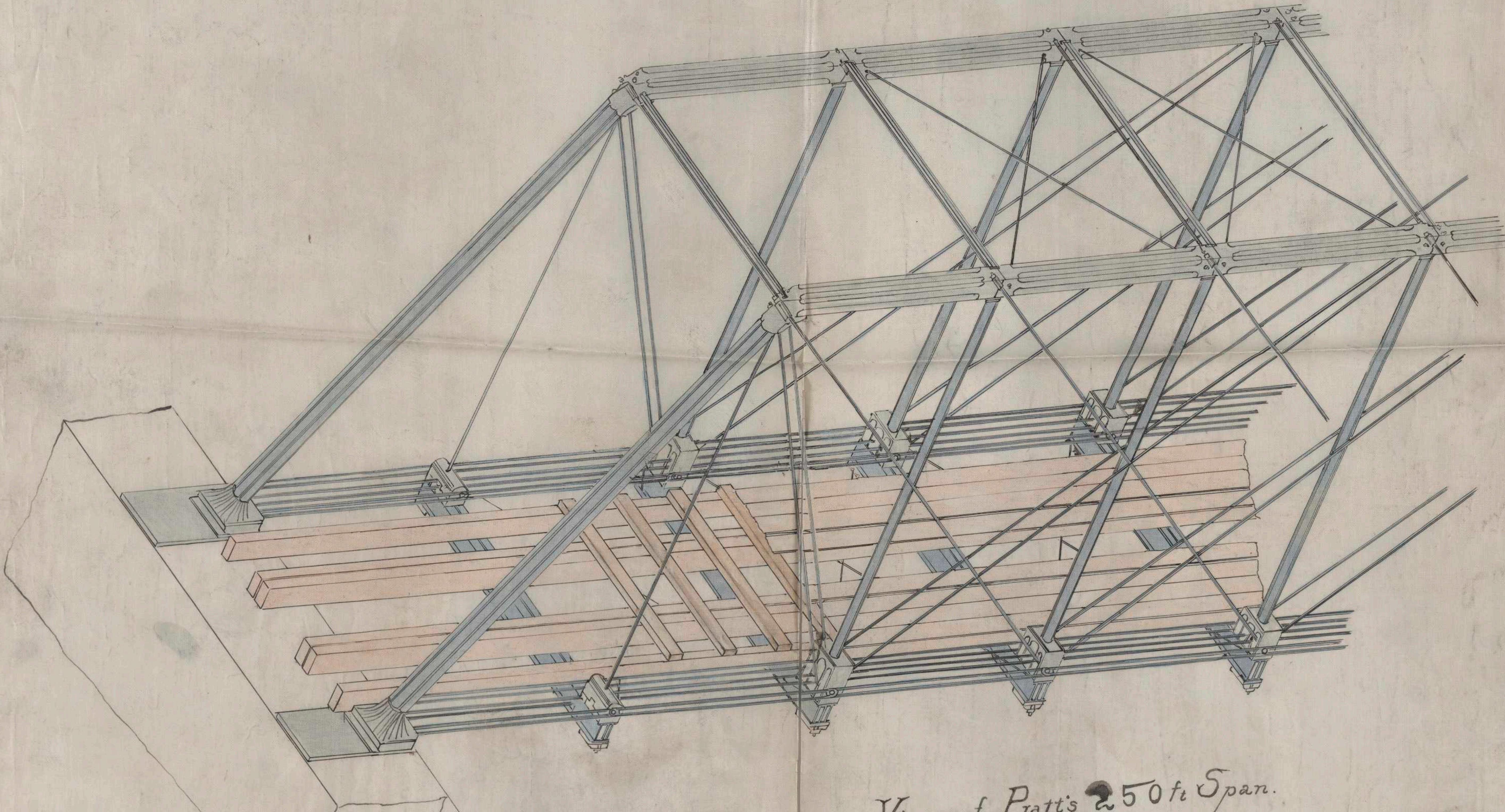
Much could be learned from such a work as has never yet been published about American bridges. There are great works and greater yet to be. May the Class of '68 add to their number and let the literature take care of itself.

The End.

Kansas City Mo
Aug 28/68.

F R Firth.
of Class of 1868.
Mass Inst of Technology.

QUINCY BRIDGE.



Isometrical View of Pratt's 250 ft Span.
Scale 6' = 1".

Accompanying
Thesis by
F R Firth
Aug 1868.

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