DESIGN AND CONSTRUCTION

of

DARDANELLE BRIDGE

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PREFACE

Two principles will serve as guides in the writing of this thesis to partially fulfill the requirements for a professional degree in Civil Engineering.

First: The primary purpose will be to preserve by a written record the experiences acquired during the construction of this bridge, more especially the experiences with the new methods and devices that proved successful.

Second: It shall be written as simply and completely as possible in order that the person with a small amount of construction experience may gain some knowledge from reading it.

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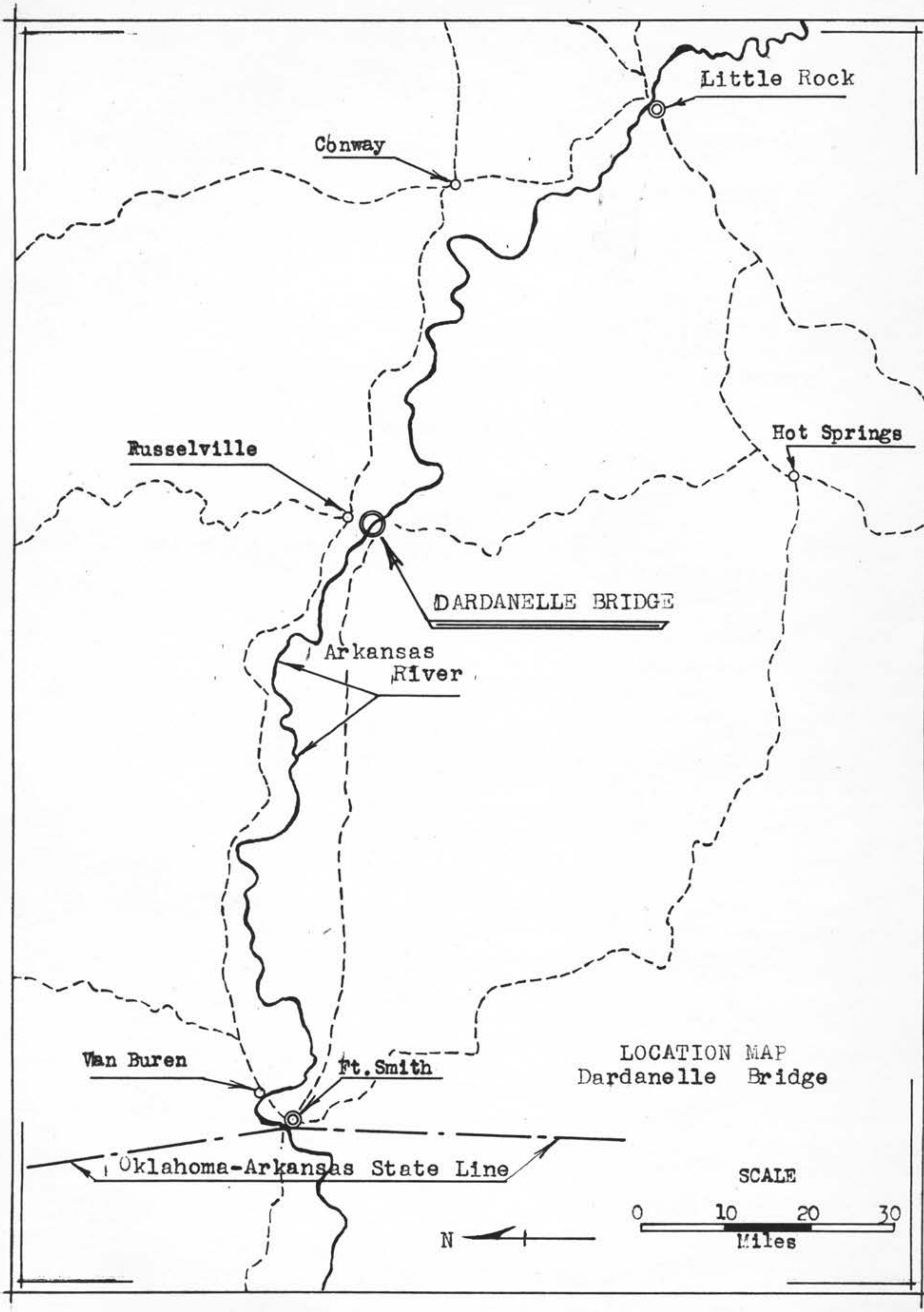
CHAPTER I

INTRODUCTION

Early river traffic in the United States caused the founding of towns along the rivers and in some cases these towns became somewhat isolated with the advent of railway transportation. Dardanelle, Arkansas, located on the Arkansas River about half way between the western boundary of the state and the capitol, Little Rock, was so affected by railway construction. The nearest station was at Russellville, four and one-half miles away and on the other side of the river. For a number of years a ferry boat was the only means of crossing the river and at low water stage, routes for crossing and suitable landing points were difficult to find. This ferry boat service was augmented in later years by a pontoon bridge reputed to be the longest in the world. At low water, the pontoon bridge was very satisfactory but at the high stages it had to be removed because floating logs would destroy the pontoons.

This combination of pontoon bridge and ferry boat was not entirely dependable and with the advent of automobile and truck traffic the need for a more dependable method of crossing the river was emphasized. The building of a branch railroad from Russellville to coal mines on the opposite side of the river from Dardanelle, terminating at a station directly across the river, further emphasized the need for a more satisfactory method of crossing the river.

Because of these factors people on both sides of the river realized the need for a bridge and recognizing the merits of a free, instead of a toll bridge, voted on June 5, 1925 to bond themselves that this bridge might be built.



LOCATION MAP
Dardanelle Bridge

After the voting of the bonds work was begun on preliminary surveys. All feasible locations were considered and the limitation due to points at which the south end might be placed made the Union Street crossing the most desirable. At this location the river bluffs were about the same elevation as the roadway would be on the completed bridge. (This elevation was determined by the elevation of maximum high water since the floor of the bridge must be above high water.)

The distance across the river was measured and the river bed was sounded. The soundings consisted in determining the elevation of each strata of material particularly bed rock, and in order to be assured that solid rock had been encountered, a core drill was used. (Core drills cut out and remove a small cylinder of the material through which they pass.)

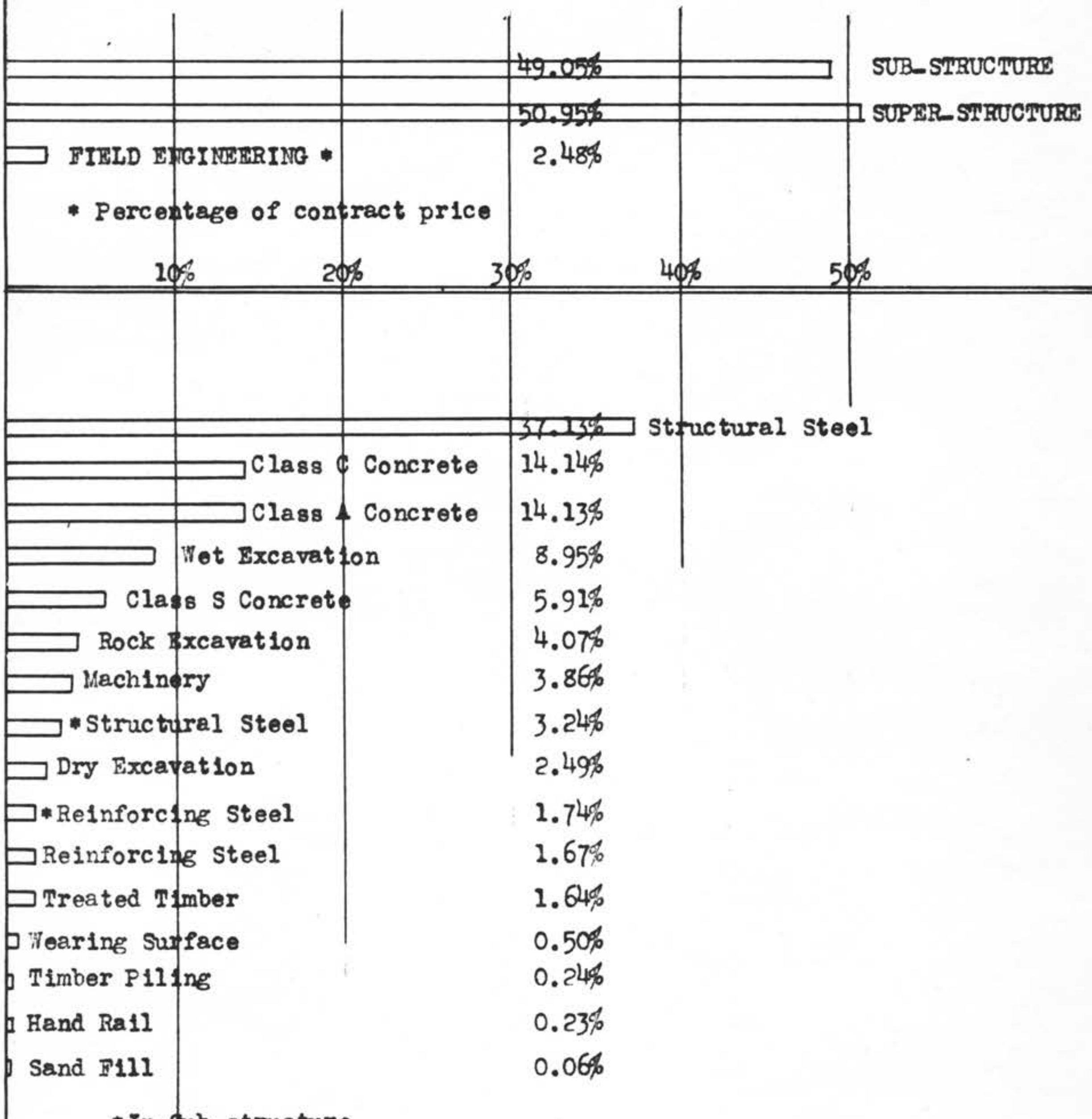
With the information obtained from the surveys, preliminary designs were made. The various types of bridges were considered and one at a time types were found impractical or uneconomical. Since the War Department (The War Department has jurisdiction over all navigable streams and all bridges across such streams must be approved by them.) classes this as a navigable river, provision had to be made in each bridge designed for river traffic. A bridge high enough above water may meet that requirement or one with a moveable span that will clear the channel. Since the south approach of the bridge was in town, no long grade could be used to rise from the natural ground level to the bridge level, this eliminated a high bridge. A concrete arch bridge was not economical because of the depth of foundations.

After considering the above factors, a detail design was made of a bridge composed of steel spans with a swing span all supported on concrete piers. One criterion used to determine the desirable number of piers and spans was that the cost of the superstructure should equal the cost of the substructure. (This principle is an accepted criterion of design but it is not easily applied since the cost cannot be accurately estimated until the design is nearly complete. It is interesting to note the accompanying graph on page 5 of the cost of the various parts of this structure and the relation between the cost of the substructure and superstructure.)

The design as completed consisted of seven two hundred fourteen foot-six inch simple truss spans with a sidewalk on one side, a three hundred sixty two foot swing span, and four forty foot reinforced concrete deck girder spans. The foundations consisted of nine reinforced concrete piers with two rectangular shafts below low water level and two rectangular columns above low water connected by a web wall; (see page 6) a circular pivot pier for the swing span and two small concrete piers under the north approach span with "elephant ear" abutments at each end of the bridge.

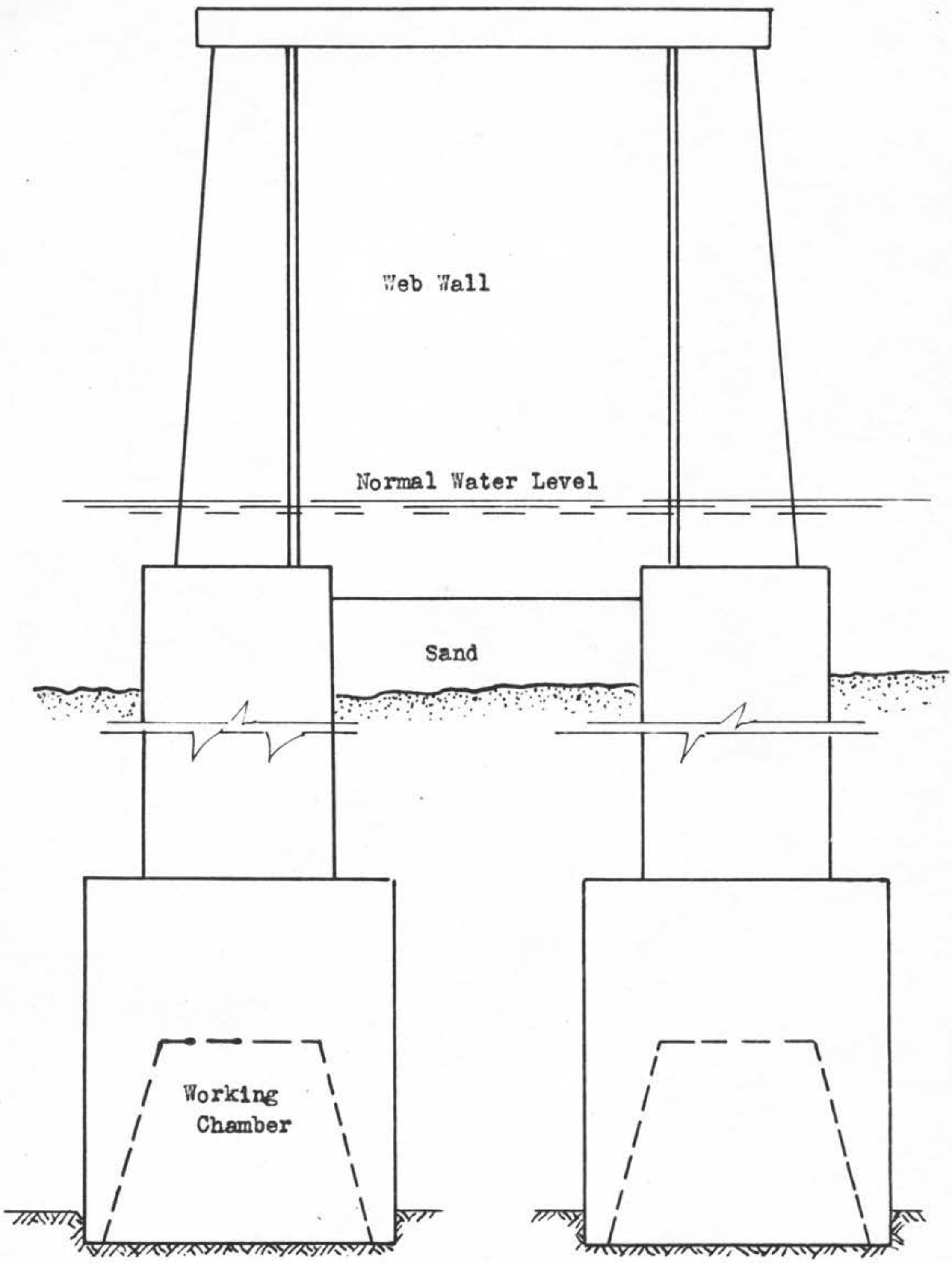
This structure as described was advertised for bids but when the bids had been opened each was above the estimated cost so all of them were rejected. A number of the contractors bidding at the time favored a solid pier below low water and they were of the opinion that the final cost of such a design would be less than the one used.

The design was revised in this manner and the structure again advertised for bids. The bid price for this design was higher than the previous one and all bids were again rejected. The plans were studied with the information obtained from the two groups of bids and alternate plans were submitted, one for open dredging of the foundation and the other pneumatic piers of the original type. This time the Lakeside Bridge and Steel Co. who had not previously bid submitted the lowest bid and they were awarded the contract on November 18, 1927.



DARDANELLE BRIDGE

Cost in percent of total



RIVER PIERS

Following the awarding of the contract and before the start of actual construction operation on November 30, 1927, the river reached flood stage and the current of the main channel changed from its usual location along the south bank and cut into the bank at the north approach to such an extent that a revision of the approach spans was advisable. The three forty foot reinforced concrete deck girder spans were replaced by two sixty foot spans of the same type. It seemed reasonable to believe that the river might again cut into the bank and endanger piers supported on piling. Accordingly, a pneumatic pier was designed but it differed from the other pneumatic piers since it carried only the sixty foot approach spans while they supported the two hundred fourteen foot steel spans.

CHAPTER II

CONSTRUCTION OF SUB-STRUCTURE

The first dirt moved in the construction of the bridge occurred on November 30, 1927. At that time the north abutment was begun. This unit of the foundation did not extend to bed rock but was supported on wood piling cut off at low water elevation to insure their permanency. (Wood if kept under water does not deteriorate.)

A cofferdam of steel sheet piling was driven to enclose this footing and the area inside excavated to a point one foot below the desired elevation of the concrete. It was estimated that when the wood piling were driven for this footing that the ground would swell enough to bring it up to the proper level. This is a difficult thing to estimate because types of material react differently. In this type of sand the swelling resulting from driving the piles brought the surface up six inches.

There is considerable question in the writer's mind of the necessity for estimating the swelling of the substrata due to the driving of piling. The theory at the time was that any material placed in the cofferdam to bring it up to grade after the piling were driven would be less compact than the natural material and thus would permit settlement which might cause cracking of the concrete footing. Of course it would be impossible to excavate after the piling had been driven due to lack of room. It seems logical that a small amount of material if placed in water to bring the footing to grade would not settle sufficiently to cause serious cracks since the entire weight of such a footing would be supported by the substrata in all probability before an initial set had occurred in the concrete.

One of the problems encountered in driving piling is holding them in their proper position. A novel method of accomplishing this was employed. Two tempelates were used, one near the top of the cofferdam and one near the bottom. (See Figure 1) They were very effective and the final position of each piling was remarkably close to its specified position.

Since the footing for this abutment was below natural ground water level and since the sheet piling forming the cofferdam did not penetrate to bed rock, it was not possible to pump the water out without some impervious layer of material in the cofferdam. This impervious strata is obtained by placing a layer of "seal" concrete; that is, a layer of concrete is poured through the water standing in the cofferdam and it is supported on the sand in the bottom of the cofferdam. This process of pouring concrete under water requires special care and since there are a number of methods that can be used it is probable that the contractor should be consulted to determine which method he has used most successfully. The most satisfactory method will depend to a large extent on the skill and experience of the workmen. (See Figure 2)

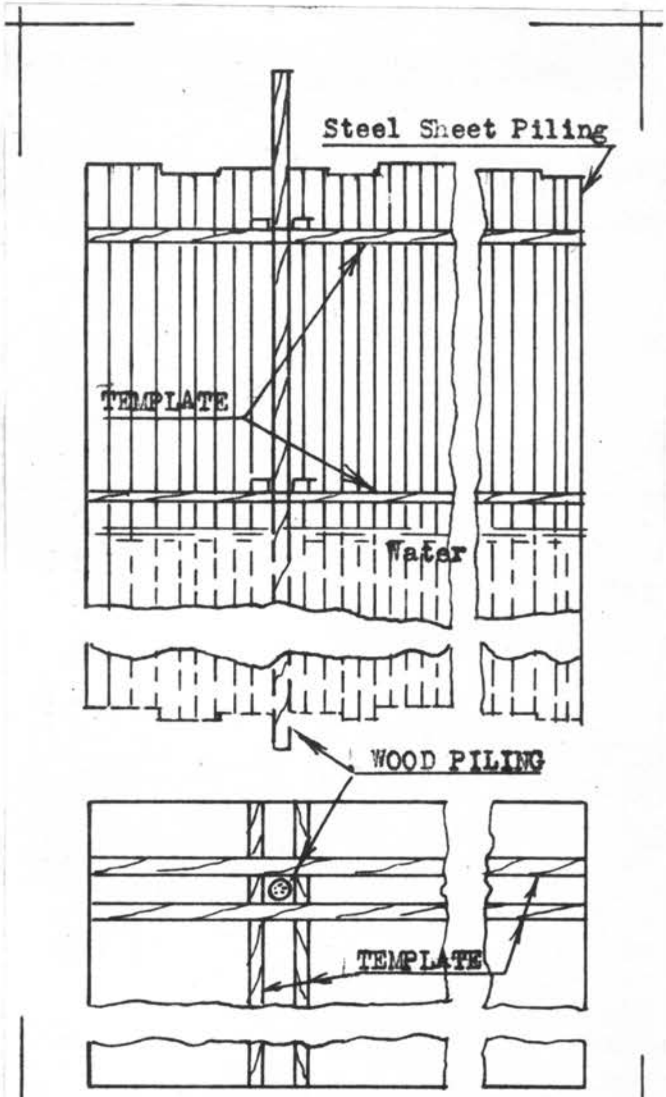


FIGURE 1

The tremie method was used here. A tremie consists of a pipe six to ten inches in diameter with a funnel-like hopper at the top. A batch of concrete is dumped into the hopper and as it falls through the pipe below, it forces the water out thus leaving a column of concrete in the pipe. (See Figure 3) Batch after batch is poured into the hopper which forces the concrete in the pipes out the lower end thus placing a layer of concrete under water without washing out the cement and sand and destroying the effective mixture. The theory of the tremie is perfect but its operation must be in experienced hands. Unless the concrete is mixed wet enough it will not flow freely enough to act as a unit and force the water out of the pipe. The result is that the water is only partially displaced and the concrete is dropped through water thus destroying its value. Some foremen wad up a sack and stick it in the top of the pipe so that the first concrete will force this sack ahead of it and thus displace all of the water. This method will not always prove successful. Others place a flat board over the lower end of the pipe with another piece cut to fit exactly inside the pipe and nailed to the first board. (See Figure 4) Two wires are fastened to this "plug", one extends up through the pipe and is pulled tight to hold the plug in

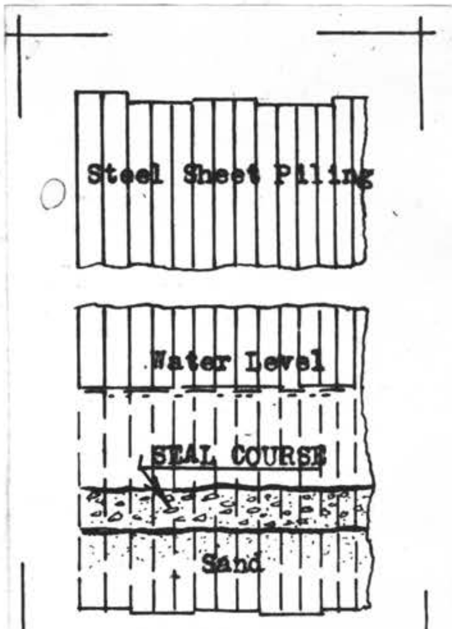


FIGURE 2

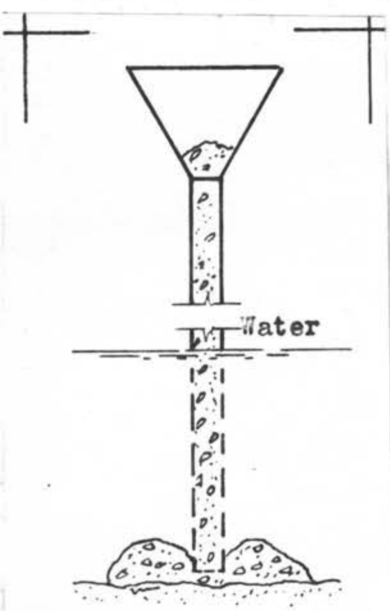


FIGURE 3

place and prevent leakage, the other wire outside the pipe and after the operation of pouring has been successfully begun the board is pulled up to the surface by means of the outside wird. In inexperienced hands the tremie method of pouring concrete under water is not satisfactory.

It must be born in mind in a footing of any size that it will be necessary to go through this initial process with the tremie a number of times since the bracing will make it impossible to move the tremie to all parts of the footing without lifting it above the water surface to clear the bracing.

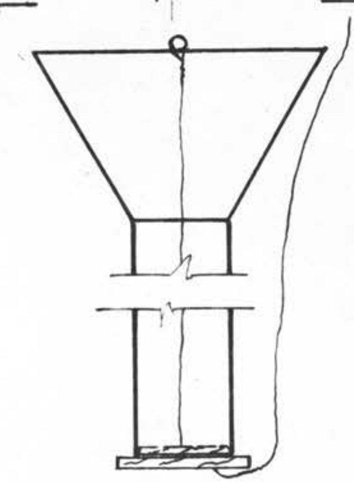


FIGURE 4

Due to the experience of the contractor's men in this case the tremie method was successful and an excellent seal course was obtained. One precaution taken to prevent failure of the seal was to make the surface of the sand in the cofferdam as level as possible before pouring began. In this case an air jet was used consisting of a small pipe about three-eights inch diameter with the end bent at right angles to the main part. (See figure 5) This was used to feel out the high spots which were immediately leveled off by means of compressed air forced through the pipe.

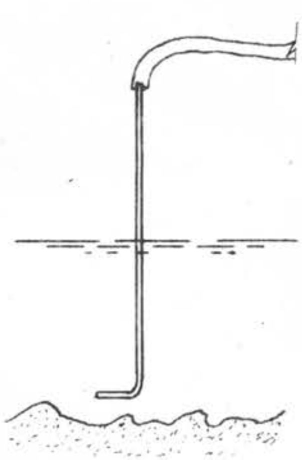


FIGURE 5

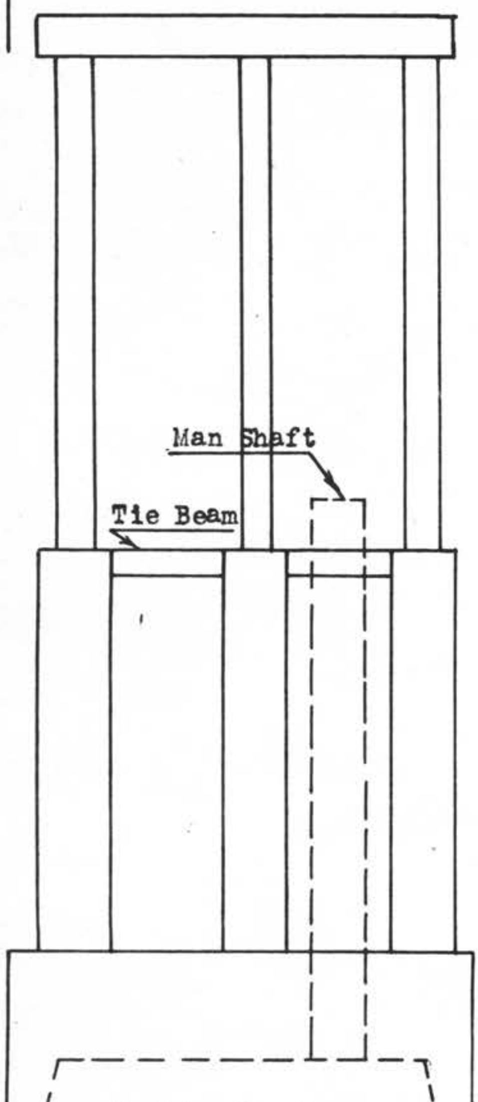
The proper thickness for the layer of concrete to seal a cofferdam was the subject of considerable argument. It must be borne in mind that the pressure of the water under this seal may cause a failure if there is any thin section or if there is'nt sufficient thickness over the entire area. The failure of the seal in one spot means the loss of the entire seal because it cannot be patched satisfactorily and either the old seal must be removed or a new layer about as thick as the previous one placed on top of it. As a rule the contractor will not be permitted to place a second seal on top of the old one as it will raise the footing so high that the wood piling will not be under water continuously.

Due to the seriousness of the failure of a seal the general practice is to place sufficient concrete in the seal to overcome the hydrostatic pressure by the weight of the concrete. That is; for every foot of depth below water level, a layer of concrete (62.4 ÷ 150) feet thich will be placed.

It seems that a less expensive and equally effective seal might be designed since any great depth means a large cost for this item.

After the seal course had been in place for forty-eight hours, the water was pumped out and the piling were cut off to the proper elevation, forms constructed for the footings, reinforcing put in place and the footings poured. The columns, cap, and wings walls were all constructed in the usual manner and offered no items of special interest.

The north approach as has been previously mentioned was revised after the contract had been let and a small pneumatic pier replaced the piers supported on wood piling. It was not considered advisable in the design of the pier to follow the general plan of the other pneumatic piers. This pier supported a three girder reinforced concrete deck girder and therefore had three concentrated loads to support. Since these girders were eight feet center to center it was not practical to sink separate cylindrical cassions under each column to support the



Elevation

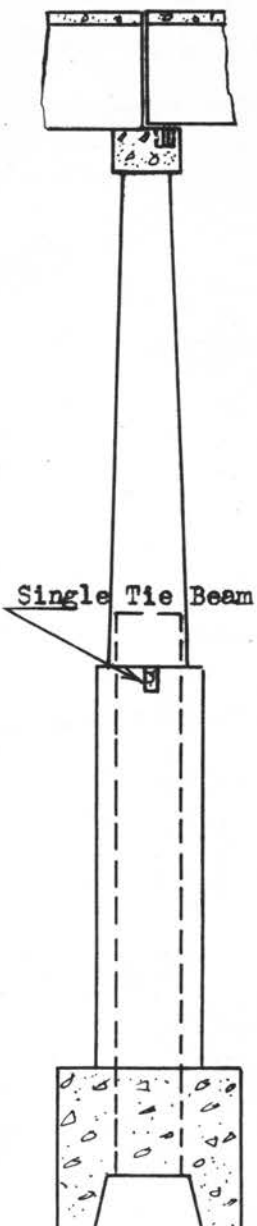


Figure B

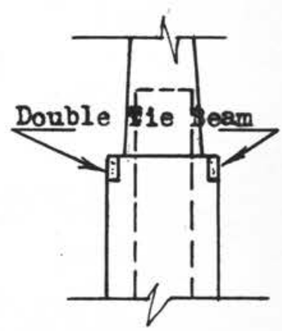


Figure C

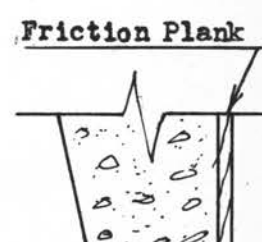


Figure A

DETAILS OF
SHORE PIER

superstructure. Due to this fact a solid base was designed which contained the working chamber for this pier. (See Page 13) Because of the three columns above this "block" it was not possible to place the "man shaft" at the center of the working chamber (the tube through which the workmen go to and from the working chamber) as is the usual custom where only one shaft is used. The blow pipe, air, and water lines were placed near the other end of the working chamber from the main shaft.

Since the entire working chamber was to be made of concrete it seemed advisable to make the "cutting edge" rather blunt or it might not stand the strains to which it would be subjected. (Fig. A Page 13) In order to further protect the cutting edge, a fifteen inch channel was used with the legs turned up. In order to provide smoother movement of this cassion, the channels were allowed to project outside the concrete such a distance that "friction" plank could be inserted between the channel and the concrete. This broad cutting edge was very satisfactory as far as the strength of the pier was concerned and made an excellent surface on which the pier was "landed", but it was the cause of a lot of trouble during construction. If at any time there is inequality of pressure on the sides of a cassion, there is a tendency for the cassion to move out of position also if the cutting edge strikes a hard material at one point while the remainder of the cutting edge encounters soft material, there is a tendency for the cassion to be forced sidewise, especially at the time it drops after material has been removed below it. Such were the difficulties encountered with this cassion; also, when down a comparatively short distance a log was found that laid across the cassion. With the broad cutting edge it was necessary to dig back under the cutting edge such a distance that the log could be cut outside the walls of the cassion. If this log had been encountered at some deeper point, a great deal more difficulty would have resulted. To undermine a cassion is to invite trouble in the form of a "blow in"; that is, the sudden in-rush of sand and water that may cost the lives of an entire crew.

Due to the effect of unequal pressure, as mentioned previously, a pneumatic pier to be sunk on the river bank will be forced toward the river by the unequal pressure. This pier was placed six inches out of position away from the river which was not any too far as the pier moved about eight inches toward the river.

One of the problems that confront the engineer on this type of work is an accurate and rapid method of determining the position of the bottom of a pneumatic cassion. On this cassion lines were constructed at right angles to the cutting edge on the center line of the pier at right angles to the center line of the roadway. Distances above the cutting edge were also marked off along these lines. This method was satisfactory for a shallow pier only, because each time these lines were extended, as the pier was built during sinking, an error resulted and this error would have soon become large if the pier had been very deep. A final check was made by hanging a plumb bob in the man shaft thus determining the exact position of the cassion.

Under similar circumstances it would seem advisable in the future to place rods at the four corners of the cassion with distance marked off on them to obtain better day to day information on the position of the cassion.

The "block" was poured and a week later sinking began. No special difficulties other than those previously mentioned were encountered. One error was made in the design that was not serious but in future designs it would be avoided. At a point two feet above low water, the three columns were to be joined by a single beam on the transverse center-line of the pier. (Fig. B, Page 13) At the time this pier was sunk the water level was above this point which brought up a problem regarding the construction of this beam.

It was not possible to put this beam in before the cassion reached solid rock and the working chamber had been filled because the man shaft was in the way. If the beam was not constructed until the cassion had been completed the beam would be below the surface of the water and a cofferdam of some description would be necessary to make its construction possible.

Instead of the single beam, two beams were built at this level such that the man shaft was between them. (Fig. C, Page 13) This was an improvement over the single beam as it made the columns stiffer as the result of a more rigid tie between them.

Most specifications require that a cassion shall be sealed in two separate pours of concrete, the first one to fill the working chamber to an elevation about one foot from the roof of the working chamber. This did not seem a desirable proceedure especially with this cassion since the working chamber was long and narrow and the man shaft was at one end with no shaft at the other. Men stayed in the working chamber during the first part of the pour, moving the concrete back to the far end, then when the chamber was so full that further work was impossible, the men were removed and concrete poured as rapidly as possible until it extended about five feet up into the man shaft. This put a hydro-static pressure on the concrete in the working chamber and forced the material back to the far end. This fact was checked by opening the valves on the water line, blow pipe, and air line momentarily as each batch was deposited. Before the last concrete had been poured mortar was coming out these pipes which proved that there was concrete up to the roof of the working chamber at that point. Air pressure was maintained on the cassion until final set had occurred in the concrete in the working chamber.

It seems logical that better concrete would result if the air pressure was gradually reduced and water pumped into the man shaft until the water was level with the water outside thus preventing the water from being forced into the cassion from below and eliminating the possibility of air being forced out through the concrete.

The remaining sections of this pier were constructed in the usual manner without any occurrence of special interest.

The design of the piers supporting the simple steel spans was revised below the water line from two rectangular shafts, about eleven feet square at the bottom reduced to nine feet square section in the upper part, to two cylindrical shafts, the lower part eleven feet in diameter, the upper nine feet six inches in diameter.

A number of factors contributed to this change. In the rectangular design the working chamber would be rather small since the walls slope in order to give sufficient strength to the cutting edge; also the rectangular type of cassion is subjected to cross-bending as a result of the hydrostatic pressure on the walls. This may require walls of considerable thickness. The deciding factor in this case, however, was based upon the contractor's desire to begin operations as soon as possible and with the rectangular shafts it would be advisable to construct the cassions of wood on the job, but the cylindrical type could be made of steel in the contractor's fabricating plant and shipped to the bridge site ready for use.

Since the specification required that the final position of the cassion must be within two inches of its plan position, it was necessary to take precautions to start them in the correct position and hold them close to it. A cassion may be forced out of position by one edge striking a log or unequal pressure on the sides may tilt it and cause a serious shift of the base.

In order to eliminate the trouble resulting from striking a log in the upper layer of the sand, each time before a cassion was placed in position the upper stratas were explored with a clam-shell dredge as far down as possible, following this operation a dock was built in which the cassion was placed.

This dock consisted of a frame constructed by driving four piling in such position that two sets of horizontal members could be attached to them to serve as guides for the placing of the cassion and support it laterally during sinking. (See Figure 6). In order to obtain the most value

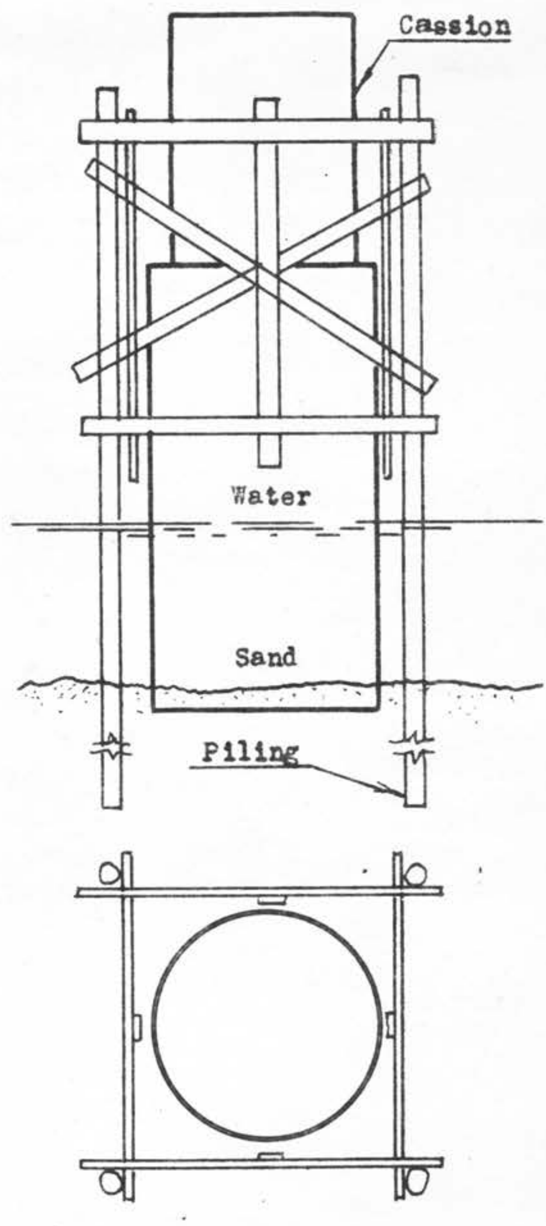


FIGURE 6

from these guides, vertical members were placed on the horizontal struts thus preventing the catching of the cassion on the struts. These verticals were so spaced as to leave about one inch clearance on each diameter. This system proved very effective and had the psychological value of eliminating the fear of the cassion tipping over with probable loss of life resulting from that occurrence.

It is necessary that the position of the cassion be determined once or twice a day during sinking in order that the foreman may know which way to shift it as it is sunk. Large cassions that have two shafts may be easily and accurately checked by plumb lines in the two shafts, but the small cassion with one shaft offers more difficulties. Because of careful fabrication, the man shaft was in the longitudinal center line of the cassion. To determine the position of a cassion, first the position of the top of the man shaft was determined, then the tilt of the man shaft was obtained by means of a carpenter's level held along theside. With this information and a record of the distance from the cutting edge up to the top of the shaft, it was possible to compute the position of the cutting edge. While the computations are quite simple, it is easy to become confused in interpreting the information which might prove costly.

One of the problems that confronts the engineer in checking the cassion was solved in a satisfactory manner on this job. As a rule it is impossible to place a transit at any point in the shore to check the position of the cassion. Because of this fact it is generally necessary to set the transit on the tramway to do the checking. Since the tramway is connected to the docks on which the hoisting engines are set and since the tramway is generally used for the transportation of all material to and from the river piers, it is nearly impossible to find a time when the tramway is not being shaken by the operation of some machine. In order to obtain results with sufficient accuracy to depend upon, it becomes necessary to stop all operations while the cassions are being checked. This lost time is expensive to the contractors and puts the engineer at a disadvantage in case he wishes to check a result that is doubtful.

To eliminate these troubles a small dock called an "engineering tower" was built in the transverse center line of each pier and at a point sufficiently far down stream to clear the tramway. (See Figure 7) In order to get onto the tower a board was placed from the tramway to the tower but to eliminate the transfer of vibration to the tower, the board was blocked up so that it would just clear the tramway. Thus, it was possible to check any cassion at any time without interrupting construction operations.

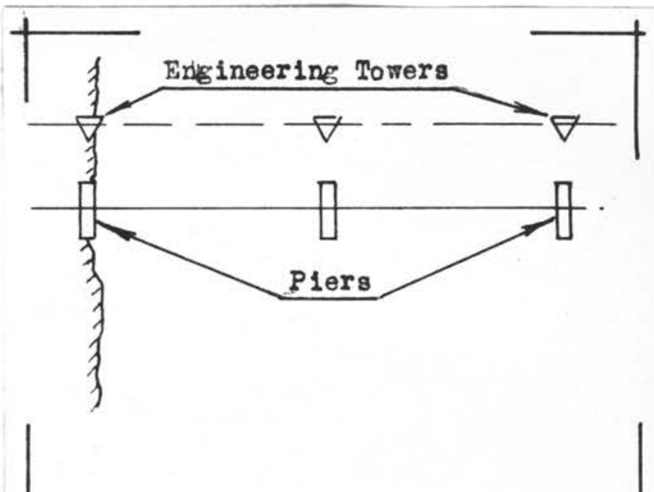


FIGURE 7

The web wall between the two columns extended to a point below low water which introduced a problem of construction. The lower section of this web wall joined onto the cylindrical surface of the cassion and made the problem of unwatering the form for the section difficult. After all the factors had been considered, it was decided to build the forms and force them down into place; then after all the openings at the ends of the forms had been plugged, the first part of this concrete was poured by the tremie method described previously.

In this design the columns above the cassions were rectangular in cross section and battered on three faces. This type of column is easily formed but in any river carrying "drift" it seems that quite often some of the drift lodges on this type of pier. A triangular up-stream face is not much better, however, the circular face apparently catches least of all. This type is expensive to form especially if the columns are to be battered.

Due consideration should be given the matter of placing the upper part of a pier in its exact position. If the top of the cassion is not enough larger than the bottom of the upper columns, then if the cassion is out of position its maximum permissable distance it will be impossible to place the upper pier in its correct position. The thickness of forms should be remembered when considering this problem.

With the engineering towers previously mentioned it was possible to check the distance between piers and thus establish accurately the location of each pier. Since the piers were so accurately located it was possible to set the anchor bolts in the top of the piers that hold the masonary plates for the steel spans. It must be born in mind that no matter how accurately work is done there will be some error in each part and if those errors happen each to add to the other that the final error may be rather large. Accordingly, the anchor bolts were set in four inch pipe, thus making it possible to move the upper part two inches in any direction. (See Figure 8) This adjustment proved ample as in no case was it necessary to move the bolts over one half inch.

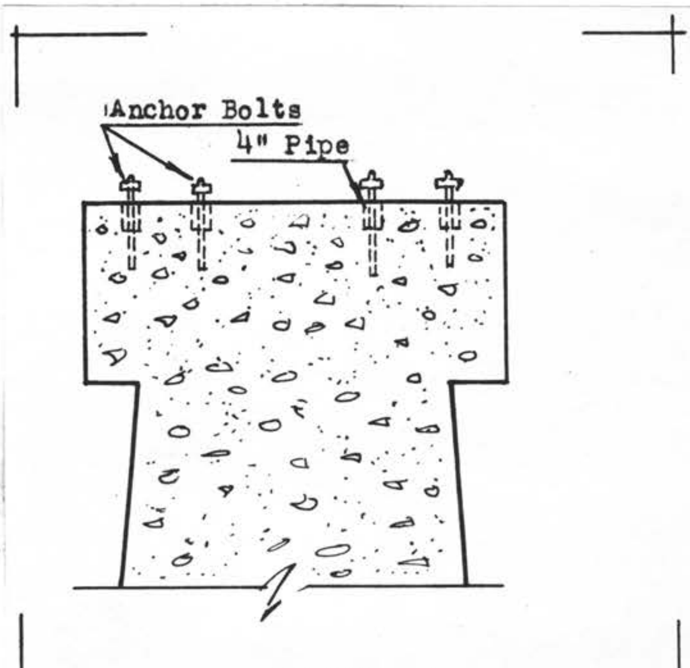


FIGURE 8

The pivot pier in the original design was circular in cross section but varied in size at different levels. It was finally constructed in this manner, but only after a great deal of discussion. A cassion should have as smooth an outside surface as possible or the vertical movement of the cassion will be interfered with during sinking. A circular cassion is difficult to form of wood and since the construction will take considerable time and as this size cassion is too bulky to move into position after it is constructed, there is considerable risk from high water destroying all that has been done. The construction of this cassion of steel was rather expensive and in addition there was the problem of supporting the concrete over the working chamber since the clear span was about eighteen feet. A number of plans were considered and finally the cassion was built of steel with light I beams welded to the roof of the working chamber. These beams were strong enough to support a layer of concrete about eighteen inches thick which would then serve as a support for the remainder of concrete. Since this first layer of concrete had a high stress, it means that the cassion would have to stand for ten days or more in order for the concrete to attain the necessary strength. With a cassion of this size, high water would be very dangerous. If the water should undercut the cassion on any side it would tip and either get so far out of position as to make it impossible to bring it back or tip it at such an angle as to make sinking impossible. Instead of using the ordinary cement, a new type at that time was used called "quick hard" which developed its strength in a much shorter time than the old type.

The cassion was placed in position and the first section of concrete poured. In order to have assurance that the concrete had sufficient strength before it would be required to support the load placed on it by pouring the remainder of the concrete over the working chamber, sample cylinders were taken and one at a time these were tested at intervals of twelve hours until they had reached the required strength. As soon as the required strength had been attained, the contractor was to be given permission to go ahead with the second run of concrete.

A few hours before the contractor could have proceeded with work on this cassion, the river began rising and reports from up stream indicated that it would reach flood stage.

The contractor was thus confronted with the problem of protecting the cassion from the flood. In order to prevent the undercutting of the upstream edge, a barge load of sand bags was anchored by the cassion and a watchman stationed at the cassion to report any indication of undercutting. A layer of sand bags was placed around the cassion and as soon as any were displaced by the stream others were dropped into position.

This scheme proved effective as the cassion was held within a few inches of its original position but during this same flood a cassion in a similar condition on a bridge downstream moved a number of feet.

This pier was not constructed immediately following the completion of the other piers in the river. As a result of floods the tramway leading from the north shore where the concrete plant and compresser were located was destroyed. Since the distance from the compresser plant on the north shore was too great for the compresser to furnish the volume of air necessary for the sinking of the pivot pier, it was either necessary to set up the plant on the south shore or place it on a barge. Since the installation of the plant on the south shore would make it necessary to again dismantle the plant at the end of the job and with the barges already constructed for use in steel eraction, it was decided to delay this part of the construction until the steel was in place then set up a concreting plant on one barge and the compresser on the other. This arrangement eliminated losses of air and power in long lines between compressor and the cassion, but due to the movement of the barge it was necessary to use a flexable connection in the air line.

Operating from a barge offers a number of advantages chief of which is the elimination of flood hazard to equipment. In a few hours all equipment can be removed from the river and immediately following a flood operations can be resumed. In most streams, however, the water does not remain at sufficient depth so that the barge can be floated to all points where work must be done.

The problems involved in the sinking of this cassion did not differ materially from the others. When the cassion was finally landed on rock, the cutting edge was not strong enough and it bent, thus making it a little difficult to hold the cassion reasonably plumb. It was possible for a number of people to remain in the working chamber during the process of sealing and it was particularly interesting to note the action of the concrete dropped through the bucket lock as the concrete fell to the bottom. There was no great amount of segregation of the aggregates, a matter often argued by engineers. It is probable that the shaft through which the concrete falls has some effect in preventing segregation, also, the air pressure may have a little effect. Here, again the seal was completed in one continuous pour with concrete finally extending up into the shafts of the bucket lock and man shaft thus placing a hydrostatic head on the concrete in the working chamber and forcing it up against the roof of the working chamber.

The upper part of this pier was built by using steel forms. These forms were used over and over again; one set being placed on top of the other. As the forms were filled the lower set was removed and placed on top when the concrete in the lower set developed sufficient strength.

Careful construction of these forms and efficient use made them a very satisfactory type.

The cap of this pier was rather difficult to construct due to the sloping inside surface as shown in Figure 9, which should be eliminated in future designs.

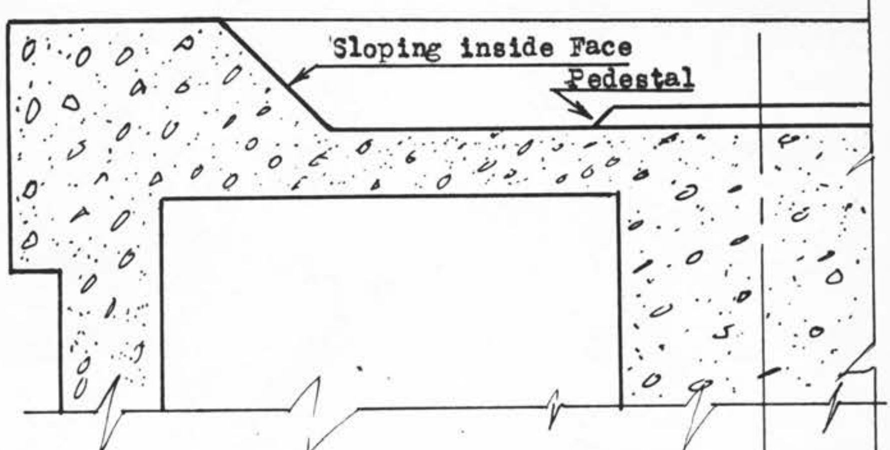


FIGURE 9

The center bearing for the swing span was not set on the cap as originally planned but a small pedestal was poured after the pier was complete. With such a pedestal it was possible to bring its upper surface exactly to elevation and make it exactly level, thus making it unnecessary to place grout under the center bearing casting.

The last pneumatic pier to be constructed was on the south shore at the foot of a steep bank. Any pier in such a location will be difficult to build but the unequal pressure on a cassion in such a location is especially serious.

Since the contractor had sheet piling on the job for the construction of the north abutment, he decided to use it again to protect this pier. A rectangular cofferdam was built around the points where the two cassions were to be built and they were sunk inside this cofferdam. No occurrence of special interest was encountered in the sinking of these cassions. The upper part of this pier was revised to reduce the earth pressure on the bank face and increase the strength of the pier to withstand that pressure.

Instead of the web wall being carried down to low water which would have been a number of feet below the dirt line, it was carried down to about the elevation of the dirt so that the dirt would flow through between the columns instead of throwing a heavy load on one side of the pier. The pier was strengthened by placing enough reinforcing in the column face next to the bank to develop its full strength as a cantilever beam.

The last unit of the foundation to be constructed was the south abutment. This abutment was back at such a distance from the river that the surface of the ground at this point was level with the bridge floor. As a result it was about fifty feet from the ground level to the bottom of the footing. The sheet piling were not long enough to build this abutment in the usual manner of driving them to form a cofferdam and excavating the inside without affecting the dirt outside. An open pit was first excavated about twenty feet deep allowing the dirt to form its natural slope; then at the bottom of this pit the cofferdam was constructed and braced somewhat more strongly than other cofferdams. The material was excavated to the proper elevation (this time set at six inches below the footing level) and preparation made to drive piling. Due to a layer of boulders found just above the rock strata on the pneumatic pier forty feet to the north, it seemed advisable to insure that the piling would penetrate this boulder strata and enter the shale below. A steel tip was considered desirable and a special type used by Mr. J. E. Kirkham, South Dakota's Bridge Engineer seemed best. These points consist of a seven-eighths bolt with the head removed driven to the tip of the pile. (See Figure 10) A nut with an "o-gee" washer is placed on this bolt and the pile tip cut to a blunt point the diameter of the washer. About eight or ten inches from the end of the pile a steel ring is driven snug against the pile, the ring being an inch or so smaller in diameter than the full size of the piles.

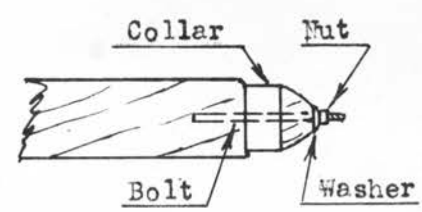


FIGURE 10

The effectiveness of these tips was proven by computing the elevation of the pile tips which were in each case at the elevation indicated for the bed rock.

The elevation of the sand in the cofferdam was correct when leveled off following the driving of the piling.

Due to a change in the personnel of the contractor's crew, the tremie method of sealing this cofferdam was not used. A clam shell bucket was used as a container to lower the concrete thru the water to the bottom of the cofferdam. It is essential that this method shall be applied only by men skilled in its use. The clam shell bucket should be in good condition or mortar will leak out. The batch of concrete is placed in the bucket or enough of the batch is placed in the bucket to fill it within about two inches of the top, then the bucket is lowered slowly into the water until it is submerged. After it has been submerged it may be lowered more rapidly until it strikes bottom. After the bucket comes to rest on the bottom, it is opened slowly and the concrete is deposited in the desired position.

This method of sealing permits the use of stiffer mixtures of concrete than the tremie method. The concrete must not be mixed so stiff that it will not spread out when it is deposited. The man operating the hoisting engine must be well trained or the mortar will be washed out of the batches. It is well to place a mark on the cable lowering the bucket so that the engineer may gage the position of the bucket as it is lowered. All sudden changes in motion tend to cause washing of the concrete. The concrete is leveled off by proper placing of batches and spading with long handled spaders.

Here again an excellent seal was obtained but by a different method than the one used at the north abutment.

The remaining portion of the abutment was built in the usual manner with the exception of the back wall. The back wall was made sufficiently thick so that an eight inch corrugated iron pipe could be encased. (See figure 11) Cast iron grate drains were placed at each gutter and the catch basins were drained by these pipes to the center of the roadway where a pipe was placed along the center line of the roadway attached to the underside of girders and extended far enough toward the river that the water would fall directly into the river. This method of disposing of drainage water prevents the erosion of the fill around the abutment which is always a serious matter and no type of paved ditch on a steep slope seems satisfactory.

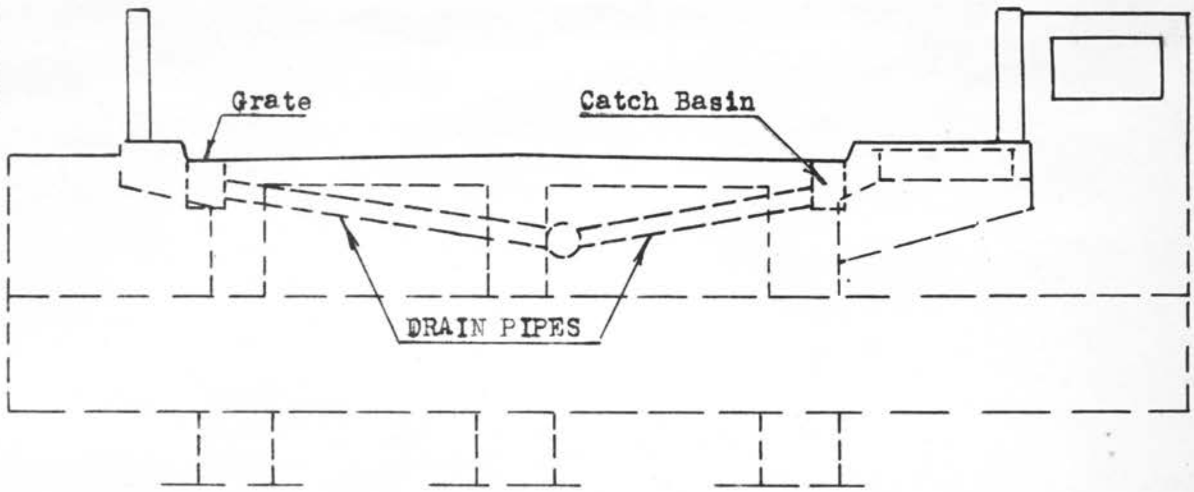


FIGURE 11

CHAPTER III

SUPERSTRUCTURE CONSTRUCTION

The first part of the superstructure to be built was the sixty foot reinforced concrete deck girder spans at the north end of the bridge. To add to the ordinary problems of construction, these spans were on a vertical curve, and it was necessary to lay out this vertical curve by varying slightly the depth of the stem of the T-beams. After the forms had been built and blocked up to obtain a satisfactory camber, the reinforcing steel for the beams was put in place. Due to the size and length of the main reinforcing bars, it was impossible to shift them around to any great extent after they were in place. This fact caused some difficulty during the placing of the transverse steel in the slab. The large hooks on the ends of the girder reinforcing, interferred in many cases with the placing of the slab steel in its proper position. In future designs it would seem that the hooks on these large bars might well be eliminated and the bar extended out parallel to the surface of the slab making sure that the horizontal part of these bars are at the center of the slab, thus preventing any interference with the slab reinforcing.

The usual methods of supporting the slab steel were used, and as usual difficulties were encountered in maintaining this steel in its proper position. The concrete was placed by means of a tower and system of spouts. This method was satisfactory since this part of the bridge was adjacent to the concreting plant.

One error made in the design was the use of short hooked rods as anchors to attach the sidewalk beam to the bracket supports. In order to prevent cracking of the beams when they deflect, there must be provision for movement of them at the supports. In order to provide for this, straight rods wrapped with tar paper were used as anchors.

Due to the length of these spans, it seemed advisable to provide a positive expansion device, and accordingly the type used as shown in Figure 12 was used. This expansion device is difficult to place and a definite method of procedure should be worked out for its installation by the design office. Just how to construct the girders in such a manner that they will not be in contact with the cap of the pier is not an easy problem to solve. Wedges were used in this case and they accomplished the purpose for which they were used but they were not entirely satisfactory.

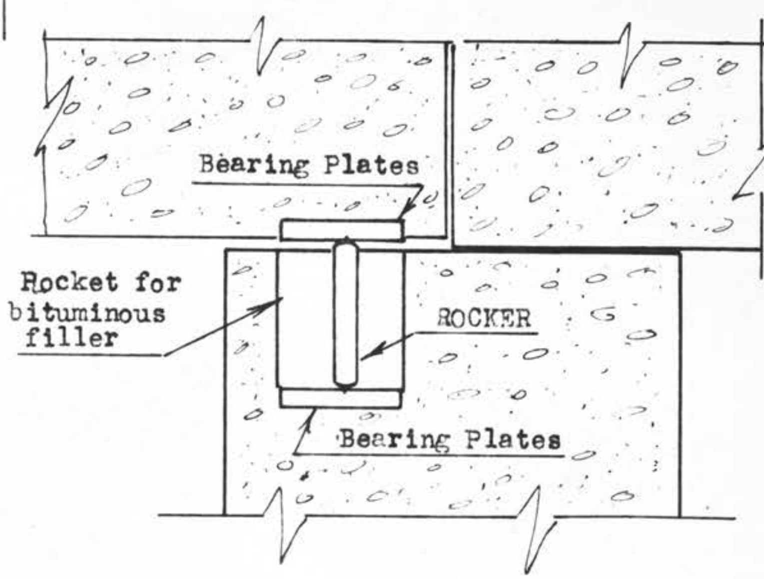


FIGURE 12

This type of expansion device was placed in a pocket in the cap of the pier and since this pocket might become filled with foreign material, the design called for a bituminous filler which must remain free flowing at all temperatures and must not contain corrosive ingredients that would deteriorate the expansion device.

One essential requirement not set forth in the design was that the bituminous filler should have a specific gravity of more than one. The material used did not meet this requirement and as a result, water ran down into the pocket during the pouring of the girders displacing the bituminous filler which ran down over the surface of the pier. This, of course, did not affect the strength or the durability of the pier, but caused an unsightly appearance.

The sidewalk on the down stream side, being of a thin section, was constructed entirely separate from the rest of the span in order to provide for differences in expansion.

The finishing procedure for the roadway was exactly the same as that used later on the steel spans, and will be described as part of that phase of construction.

The hand rails on this part of the structure were concrete posts and pre-cast concrete rails.

Most of the structural steel on this bridge was erected in a different manner from the usual method of building false work between the piers, and erecting the steel in its final position. This method involves the expense of purchasing sufficient material to support at least two spans, and the expenditure of the necessary funds to erect this false work, and upon completion of the erection of the steel, to remove this same false work.

Added to these items of expense is the hazard of a flood which may in extrema cases not only destroy a great deal of the work, but may carry away considerable of the false work material and in some cases, drop part of the structural steel into the river.

The Arkansas River at this point has a record of having reached flood stage every month in the year, thus there was no time of the year that the contractor can feel reasonably safe for the erection of steel by the usual method. It was therefore proposed that the steel should be erected on false work along the bank of the river and floated into its final position on the piers by means of barges. This proposal at first seemed rather fantastic and spectacular, however, it had so many merits that a thorough study of it was begun. In order to support these spans and maintain their stability during the transfer from the shore to their positions on the piers, it was decided that two barges, each forty feet wide by ninety feet long and six feet deep, would be used. These barges each contained 190,000 feet of timber, five tons of hardware, twenty-five bales of oakum, and their total weight was approximately 120 tons.

An examination of the river's bed at this point indicated that in order to have sufficient water above the stream bed at all points to navigate the barges, that the river must be above the six foot stage. From that stage up to the twelve foot stage would be the limits during which floatation must take place. Above twelve feet the current would be rather swift and considerable drift would be running that might interfere with the operation of the barges.

After the barges were constructed, three bents of false work were constructed on each barge in such a position that they could be placed under three panel points of the spans. After the steel had been erected on the false work on shore, it was partially riveted, then swung and moved off of the false work by placing the ends of the spans on flat cars operating on two parallel tramways that extended out into the river.

After the spans had been completely riveted, they were ready to be floated into position. The procedure of floating consisted of four distinct steps. First, the barges were brought into the correct position between the two tramways and they were partially scuttled by opening ports in the bottom of the barges. The amount of water permitted to enter the barges was sufficient so that when the water was pumped out, the barges would lift the 176 ton span free of its end supports on the tramway. As soon as the span was free of its supports, the second stage began which was the movement of the barges out into the river and down to their proper position between the piers. A detailed discussion of this will be found under special problems in the next chapter.

After the barges were in place between the piers, the third step began. The ports were again opened and water allowed to enter the barges until they had landed the steel span on the piers. The fourth step, the barges were returned to their original position between the two tramways and the entire procedure repeated. The whole process of loading, floating into position, unloading, and returning the barges required about six hours, thus reducing the flood hazard of erecting steel from about eight days to a little over six hours.

All of the simple spans on this bridge with the exception of the one adjacent to the south bank, were erected in this manner. The one on the south bank was erected in the usual manner since it was necessary to use the barges in the construction of part of the foundations for that span and the swing span.

The steel span at the south end of the bridge was erected on false work placed between the two south piers, and some of the hazards of steel erection in this manner were encountered which indicated the wisdom of the decision to float most of the steel into place.

At the time of year this span was erected, there was the least possibility of floods, however, two occurred which might have been serious if the false work had been out in the main channel of the stream instead of adjacent to the shore.

The erection of this steel required about eight working days.

The swing span was also erected on false work but due to the nature of such a span it was unnecessary to place false work under every panel point since the first half could be erected on false work and the last half partially cantilevered.

One of the initial problems in the erection of the steel for the swing span was the placing of the center girder. A great deal of the machinery had been assembled at the fabricating plant and attached to this girder. As a result, the total weight of the assembled unit was about twenty-five tons. Since the north section of the bridge had been erected and the floor poured, it was possible to bring this girder over the roadway up to the north end of the swing span but from that point to its final position on the pivot pier it had to be transported over false work. This made it necessary to have much more rigid false work than would have been necessary otherwise.

One difficulty was encountered in the erection of this span which might not occur in most other bridges unless the spans adjacent had been erected previously, as was the case with this structure. When the swing span had been blocked up sufficiently to provide the proper camber, and the steel put in place, the end latch interferred with the end floor beam on the adjacent simple span. After the camber blocks had been removed, the span deflected and there was no further interference of this kind.

The assembling of a great deal of the machinery on the center girder is an advisable procedure, however, in this case, the machinery interfered with the riveting of the bottom chord where it attached to the gusset plates on the center girder and it was necessary to use turn bolts in a few places.

The construction of the concrete floor on the simple span was simplified by the sidewalk cantilevered from one of the trusses. This made it possible to run the "dinky" track on the sidewalk and thus pour concrete at any point on any of the spans, and to pour the full width of the roadway at all points.

After the roadway had been completed, the track was shifted onto the roadway and the sidewalk poured.

As has been previously mentioned, difficulties arise in the proper placing and maintaining of reinforcing steel in floor slabs. This problem was solved by assemblying the steel in the usual manner, but it was maintained in position by use of concrete briquettes placed under the top longitudinal reinforcing bars in the manner shown in Figure 13. These briquettes were precast with wires embedded in them, and after the steel had been tied in its proper position, the entire

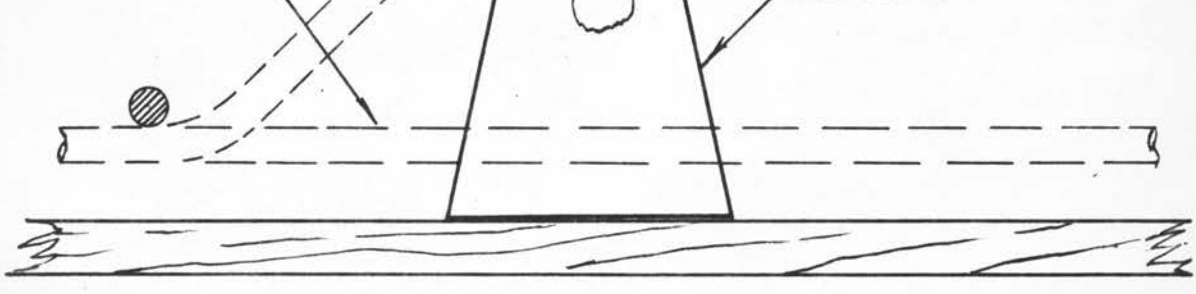


FIGURE 13

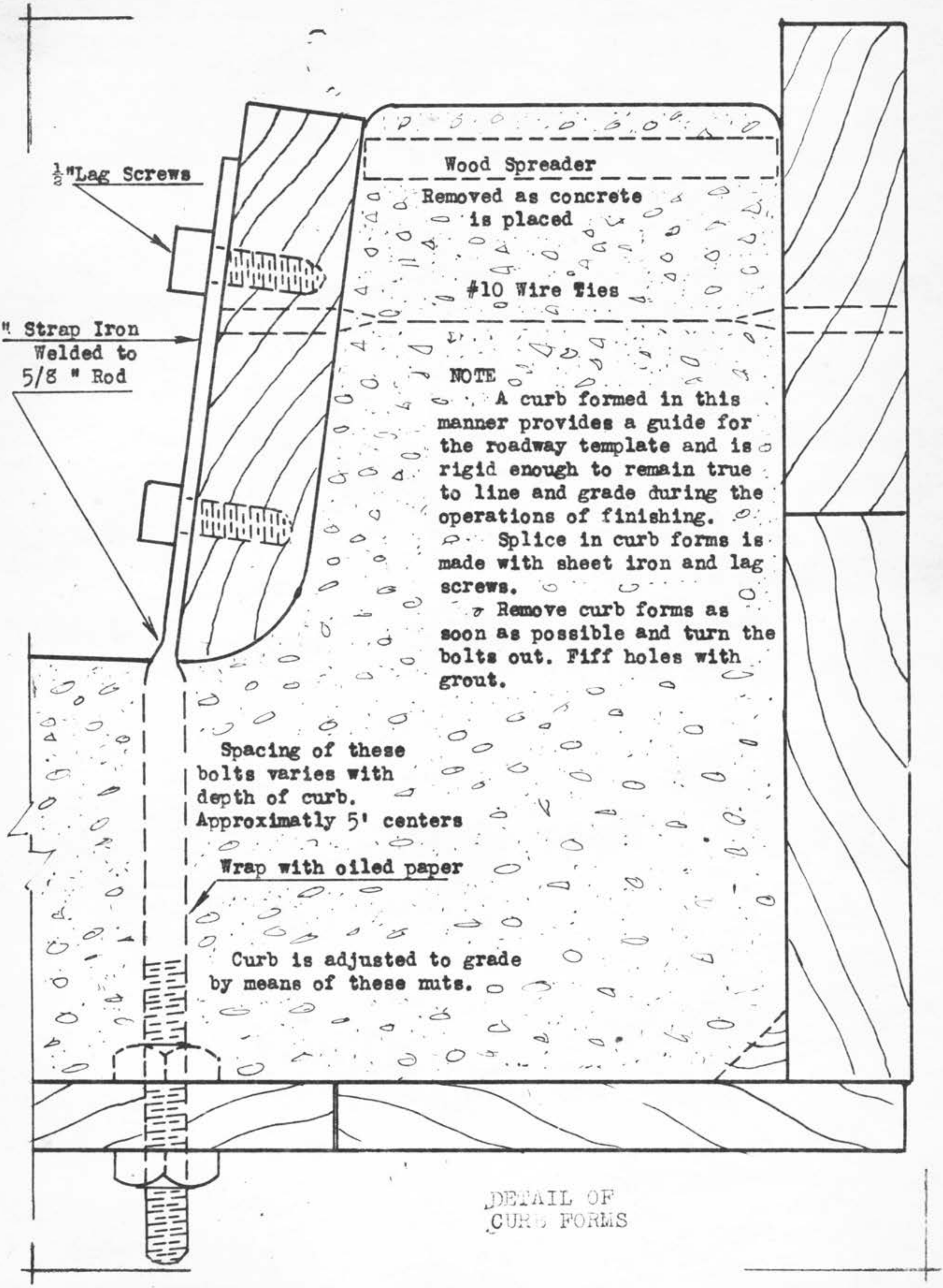
mat was lifted up onto these briquettes thus making a rigid mat of steel on which workmen could move about without causing the usual displacement of the steel.

The spacing of these briquettes will depend upon the size of the bars used, however, a few trials will soon indicate the desirable spacing.

The concrete was brought out onto the spans in buckets placed upon dinky railroad cars, and a short chute placed underneath the bucket was used to distribute it over the roadway. After the concrete was dumped, it was struck off to grade by means of a heavy transverse template supported at the ends by the curb forms. Following this template was a lighter template operated in the same manner which brought the surface to exact grade. The surface was finished by long-handled floats, longitudinal template, and belting. The longitudinal template was a flat board about ten feet long operated by plow handles attached to it at each end. It prevented abrupt breaks in grade at any point along the roadway and the belt gave the roadway a final uniform finish. This system of finishing the roadway of a bridge is the most satisfactory yet experienced, since it produced a smooth surface for traffic. This method is only satisfactory where a design of the curb forms has been properly made, that is, the curb forms must be sufficiently rigid to withstand the load placed on them as a result of operating the templates.

On page 38 is a sketch of the curb forms used on this structure. These forms are rigid both vertically and horizontally, thus not only making possible the use of this method of finishing the floor, but also guaranteeing a curb uniform in thickness, and of almost perfect alignment. It is necessary in the use of these forms that they be removed as soon as possible in order that the finishing work may be completed.

The sidewalk was reinforced by small bars and because of the



DETAIL OF
CURB FORMS

thickness of the section, some cracking occurred over the supports. This cracking was not serious, however, it is well to always hook the ends of reinforcing bars, especially in short spans, to prevent excessive cracking.

At the points in the sidewalk where the plumb posts and the diagonals passed through it seemed advisable that a hoop of reinforcing steel be placed around these openings in order to avoid possibility of cracks starting at these points.

After the concrete work had been completed, there was some noticeably high and low places in the steel hand rail along the sidewalk. Because of the way this hand rail had been detailed, it was not convenient to adjust it to make a uniform vertical curve on each span, and special care should be given to means of adjusting such a hand rail on future designs.

The floor of the swing span was constructed of 2" x6" creosoted timbers placed on edge with a wearing surface of Alabama rock asphalt. Since these timbers were straight and the floor was to have a crown that had been included by detailing the position of the stringers such that the center ones were higher than the outside ones, some difficulty was encountered in pulling the ends of the 2" x 6"s down against the stringers.

It is questionable whether this initial stress is advisable, especially in creosoted lumber, and it might be advisable to construct the crown entirely by varying the thickness of the wearing surface instead.

Since this span had a sidewalk cantilevered from the down stream truss, it was necessary to counterbalance the span by a concrete beam near the up stream truss. (Without a counterbalance the load on the center bearing would have been eccentric making operation of the span difficult.) The position of this counterweight was such as to interfere with the placing of the roadway drains on that side of the roadway, however, no difficulty was encountered in solving the problem of drainage, and this fact is merely mentioned to call attention to such a problem in future designs.

The painting of steel, as a rule, does not receive much attention in bridge construction, and the theory of paint seems to be least clear of all the problems confronting the engineer. On this structure the specifications required two coats of paint, an initial coat composed of blue lead and zinc oxide, and a second coat containing the same materials but in sufficiently different proportions as to cause a marked change in color that would enable the inspector to tell when any points had not received the second coat of paint.

Due to an error on the part of the contractor, a supply of paint was obtained which contained nothing but blue lead and some of this was used before the error was noticed. It was argued at the time that the blue lead was a pure paint and that the state was receiving a higher quality of paint at no additional cost. Since no information could be obtained to indicate that the blue lead would be more satisfactory, the contractor was required to provide paint that met the specifications. He was given permission to mix the necessary proportions of zinc oxide with the blue lead that he had on hand.

It was interesting to observe the actions of these two paints when subjected to the weather. In a comparatively short time the pure blue lead paint began to chalk, that is, the surface seemed to dry out and by rubbing your hand over it, a powdery flour came off, while the paint containing zinc oxide dried with a glossy, tough, enamel-like surface, and at no time within the same period did it show any tendency to deteriorate.

It is essential in painting such a structure that the contractor be given permission to paint the inside of the top chords, especially near the joints before erection, as these points are very difficult to reach after erection, and consequently less satisfactory workmanship is obtained. Care should be taken in the painting of large surfaces that will be in contact after erection if they are painted with too heavy a coat of paint, then at the time they are riveted, the heads of the rivets will burn the paint in their immediate vicinity thus leaving surfaces that are not smooth, and making it very difficult to obtain tight rivets.

After the swing span had been erected and the floor placed, it was noticed that the deflection at the ends was only about one-half of that expected, and as yet, no satisfactory explanation of this matter has been provided.

The approach span at the south end of the bridge was the last unit to be constructed. This span was originally shown as level and the grade approach sloped from the street down to the end of this span. At the time the bridge was completed, there was a short distance between the street and the bridge which was not paved and it seemed likely that a great deal of material would be washed down and deposited on this approach span. Eventually some of the dirt might be carried out to the expansion device under the steel trusses. A great deal of this could be prevented, of course, by providing proper gutters at the ends of the bridge which would have had to be constructed on the loose fill. Almost any type of construction placed on a loose fill will crack or move about leaving openings in the joints through which the water will escape to erode the fill around the gutters. In order to avoid these unsatisfactory results, it was decided to bring all of the drainage of the approach span and approach fill to catch basins in each gutter at the abutment. These catch basins, as have been previously mentioned, were drained by pipes extending from them to another pipe at the center line of the roadway. This second pipe was attached to the lower side of the approach span and extended along the center line of the roadway far enough out toward the river so that the drainage water would be discharged directly into the stream.

In a structure of this size, a better general appearance will be obtained by varying the elevations of the various piers so that the entire structure is on a slight vertical curve. This vertical curve should be worked out to harmonize with the final camber of the spans.

The steel on this structure, which was fabricated by the Lakeside Bridge and Steel Company, was accurately done and in no case was there any difficulty encountered in fitting it up or in riveting. The workmanship on the structural steel was as high class as could be obtained.

CHAPTER IV

SPECIAL FEATURES OR PROBLEMS

During the design and the construction of every structure, problems of special interest are encountered. The use of engineering towers as an aid to rapid and accurate checking of the position of the cassions was an excellent solution to one construction problem. These towers were built independent of all other temporary structures thus preventing the normal activity of construction from affecting them. They were built with three piling as supports and a triangular platform as a working surface. These towers were placed on a line parallel to the bridge and at a distance down stream sufficient to permit a tramway between them and the cassions for the piers.

As soon as a tower had been constructed, a line parallel to the bridge and at a definite distance from the bridge was marked off on the working surface; then the proper distance from the previous pier was obtained by measuring with a chain from the previous tower. The exact position of this point was not determined until a number of measurements had been made.

The proper location of these points on the towers involved the calibration of the chain for a special condition of support or it would involve the computation of the effect of sag and the elongation due to pull. After some consideration it was decided to eliminate the computation of the reduction in length due to sag and the increase in length due to pull by determining the necessary pull to elongate the chain an amount equal to the reduction in length due to sag. This was determined experimentally by laying off a distance on the ground equal to the distance between the piers. This distance was correct because the chain had been calibrated when supported in the manner used. The chain was then lifted free of its supports and the zero mark held directly over the proper point on the ground. The amount of the pull was determined by a spring balance to bring the proper point on the chain over the other point on the ground; then the chain was ready for use on the towers.

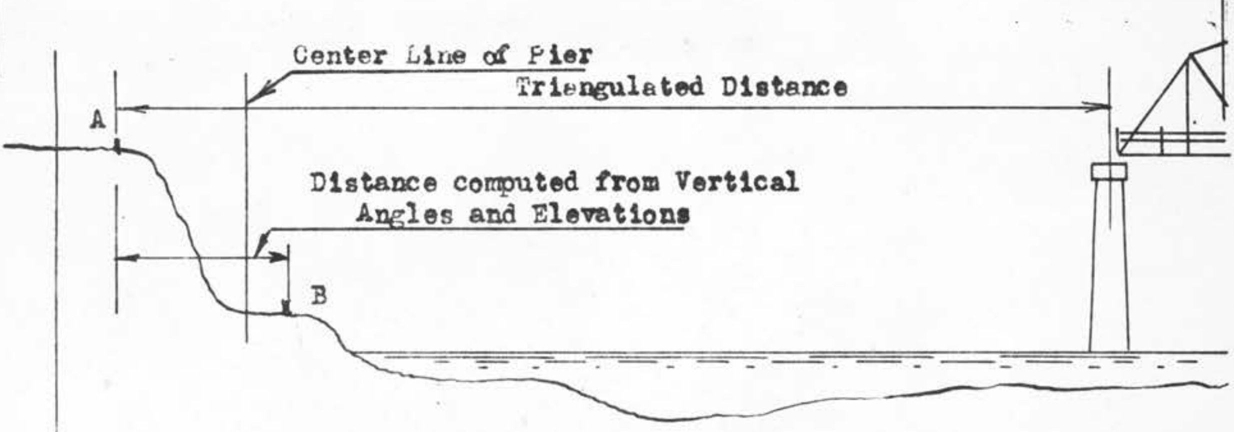
In order to prevent the transfer of vibration from the tramway to the towers, the board connecting them was nailed to the tramway but not to the tower and by inserting a wedge under the board at the tramway end, it was lifted free of the tower except when some one was on the board.

A problem that could not be solved by reference to available publications was the required lapse of time from the pouring of concrete in a cassion until air pressure might be applied and sinking operations begun. This is an important matter to the contractor because the longer the time required, the greater the hazard of loss due to high water. Normally, sinking was permitted to begin at the end of 72 hours but due to delays in some cases there were cassions that were not disturbed for a week. It was interesting to watch for any apparent differences in the action of the compressed air on these cassions. In no case was there any apparent difference in the action on the concrete.

The first construction operations on the bridge were at the north end and progress was toward the south. Construction operations for the first few piers were carried on from a tramway. Later, the high water destroyed this temporary structure and the remainder of the work out in the river was done from barges. Before all the piers in the river had been constructed, a prolonged period of high water made it advisable to begin operations on the south bank of the river.

In order to locate the pier and abutment properly on the south bank, it was necessary to determine accurately the distance from the completed pier nearest the south bank to a point on the south bank. The usual procedure is to determine the distance between points on opposite banks of the river by laying off a line on one bank perpendicular to the center line of the bridge and then by the measurement of angles and distance along the line to compute the distance between the two points. Local conditions made this impossible but the distance from the pier in the river to a point on the south bank was determined by this general method. It was an easy task then to locate the abutment but the pier on the south bank which was located nearest the shore line was at the foot of a steep bank. In order to determine the position of the pier, it was necessary to use an unusual method.

As shown in Figure 14, point "A" was located at the top of the bank and the stake "B" was set near the water's edge, then the vertical angle was measured and by running a line of levels between these two points



METHOD OF LOCATING PIER ON SOUTH SHORE

FIGURE 14

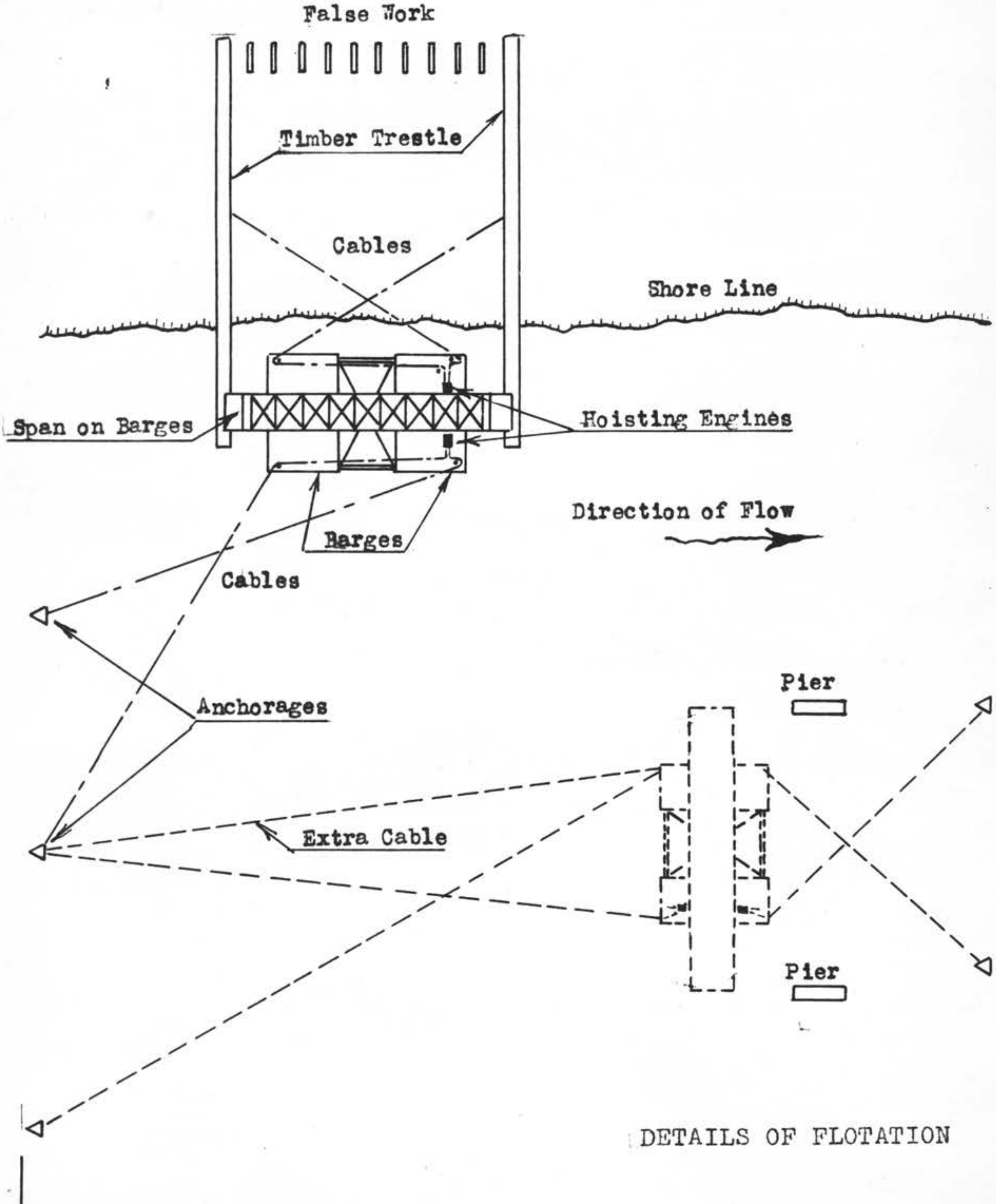
their difference in elevation was determined; with this information, the horizontal distance was computed and the proper location of the pier determined.

Other problems such as the rapid variation in the bulking of sand placed on barges might be mentioned but these are problems common to many construction projects. The method of erecting steel on this project was unusual and the details of the method will be discussed.

The simple spans on the bridge were erected by assemblying them on false work located on the bank of the river. They were then moved off of the false work by placing the four end panel points on narrow gage cars that operated on the railroad tracks placed on the timber trestle runways at each end of the spans. These trestles were extended far enough out into the river so that the spans could be placed over barges that were used to transport the spans to their final position on the piers.

The general sketch on page 47 will show the position of the single set of false work used for the erection of all spans. As soon as a span had been assembled, the bottom chord was riveted and that span was moved off of the false work. The work of assemblying another span was begun while that span was being riveted. As soon as a span was completely erected, it was painted and could have been immediately transported to the piers.

The usual time for the assembly of a span of this size in its final position on the piers is six to eight days and it requires eight or ten men to transport the steel and erect it. The method used on this bridge made it possible to assemble a span in as little as twenty hours with five workmen. Another saving incidental to this method was the reduction in the tools, rivets, and bolts lost since all of them that were dropped



DETAILS OF FLOTATION

could be recovered.

When the river had reached a proper stage (between seven and eleven feet) the floating of the spans into position was begun. As shown in the sketch, anchorages were constructed at points upstream from the erection yard. These anchorages consisted of three piling driven in a cluster with the tops lashed together and attached by cable to such a point on a single pile to be driven twenty or thirty feet upstream that it would be well below the stream bed when that pile was driven.

The first step in the actual flotation was placing the barges in their proper position along shore so that the false work on them would be in correct position to support the desired panel points on the spans. With the barges thus located and properly tied together, they were partially scuttled by opening valves in the bottom. It was necessary to allow sufficient water to enter the barges so that upon its removal the barges would lift the spans free of their supports. The spans weighed three hundred fifty two thousand pounds and it was therefore necessary to allow at least five thousand six hundred and forty cubic feet of water to enter the two barges. The time required for that quantity of water to flow through the four, eight inch valves in each barge was estimated by determining the head on the openings due to the depth to which the barges were submerged by their own weight. Since each barge weighed about one hundred and twenty tons, the bottom of the barge was about one and two-tenths feet below the surface. The computed time of submergence by the use of the valves only was four and one-half hours. This time was reduced by pumping water into the barges also.

As soon as the barges were filled, the spans were moved into position and blocking placed between the false work on the barges and the lower cord of the span. The water in the barges was then removed by pumps.

At first thought the problem of pumping seems incidental but a few hours saved in any step of these operations may be vitally important. Any marked change in the river stage as well as a storm may make operations impossible; also during this process of pumping, no other work can be done and an entire crew is idle. If the water was to be removed in approximately three-quarters of an hour, it would necessitate a pumping capacity of about 1000 gallons per minute. In addition to a number of small pumps an eight inch sand pump was used and the unwatering of the barges required about a half hour.

The power for operation of the barges was furnished by two three drum hoists installed on one of the barges. One hoist operated the downstream cables and the other the upstream cables. The initial position of the cables is shown by the dash-dot lines. When the barge had been swung out into the river so that it was parallel to the line of piers, the downstream cables were changed from their first position to the second where they were anchored to the pontoon bridge towers. The upstream cables then were gradually let out and the downstream cables taken up until the span was in the proper position over the piers. Due to the manner in which the cables were arranged it was possible to move the barges in any direction that might be desired. By hanging a plumb-bob on the end floor beam, the span could be spotted exactly where it should be. The barges were again partially scuttled and the span landed on the piers. The barges were then returned to position along the shore and the entire process repeated.

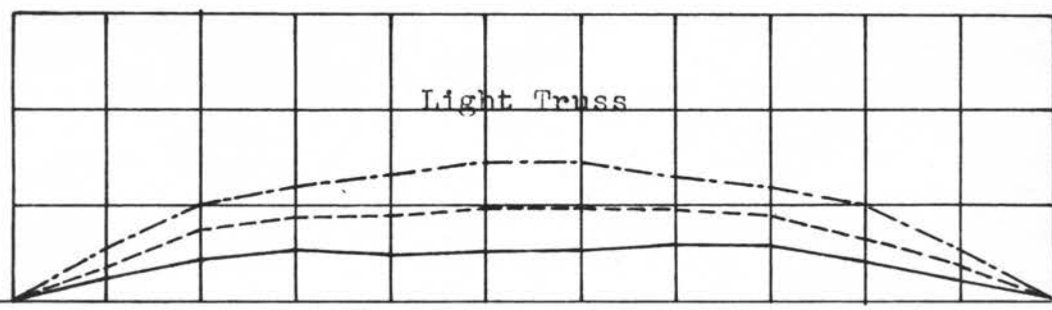
It will be noted that three upstream cables were used. This was partially a safety factor in case of breakage but was primarily necessary due to movement of the barges out into the river for spans farther from shore. One cable at a time could be removed from its anchorage and attached to an anchorage farther out.

At first thought it would seem that the water used to submerge the barges while landing the spans on the piers could remain in the barges and after the barges had been returned to the bank that they would be ready to load again. This was the original plan but considerable difficulty was encountered with them submerged that much, especially when they were turned broadside to the current in bringing them to shore. It was therefore necessary to pump most of the water out after the barges had been unloaded.

The entire operation required about six and a half hours; one and a half hours to load the span, one and one half hours to float the span into place, one and one half hours to unload the span, and two hours to complete the operation by returning the barge to the shore. It therefore reduced the hazard of flood damage from about eight days to six hours.

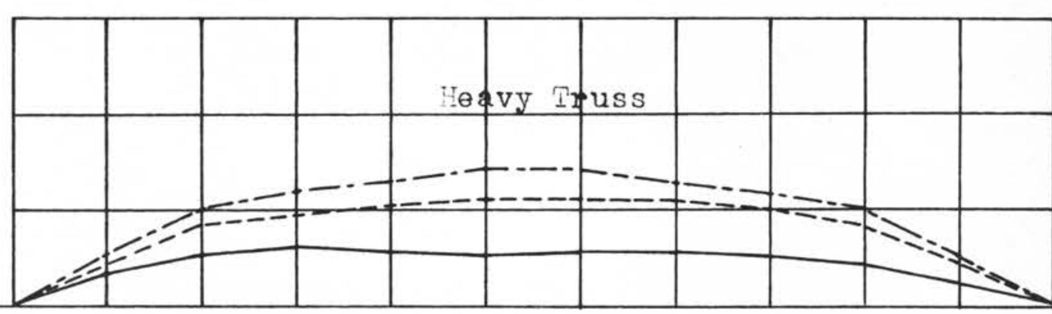
The camber of steel spans has always been of interest to the author. It has always been a question as to what the final position of the lower chord points will be after the truss is placed in use. Due to the uniformity of erection conditions, that is, six spans were erected on one set of false work, it was felt that a rather thorough check could be obtained on the amount of camber lost when the span was swung and the amount lost when the floor was constructed. On page 52 is a graph of the initial camber, the camber after swinging the span and the camber after the floor had been poured. The diagram represents the average for all spans. On pages 53 and 54 will be found individual data for each truss of each span. A diagram has been made for each of the trusses since one was a heavy truss and the other a light truss.

It will be noted that only on one case for individual spans did the final position of any panel point fall below a straight line between the ends of the truss.

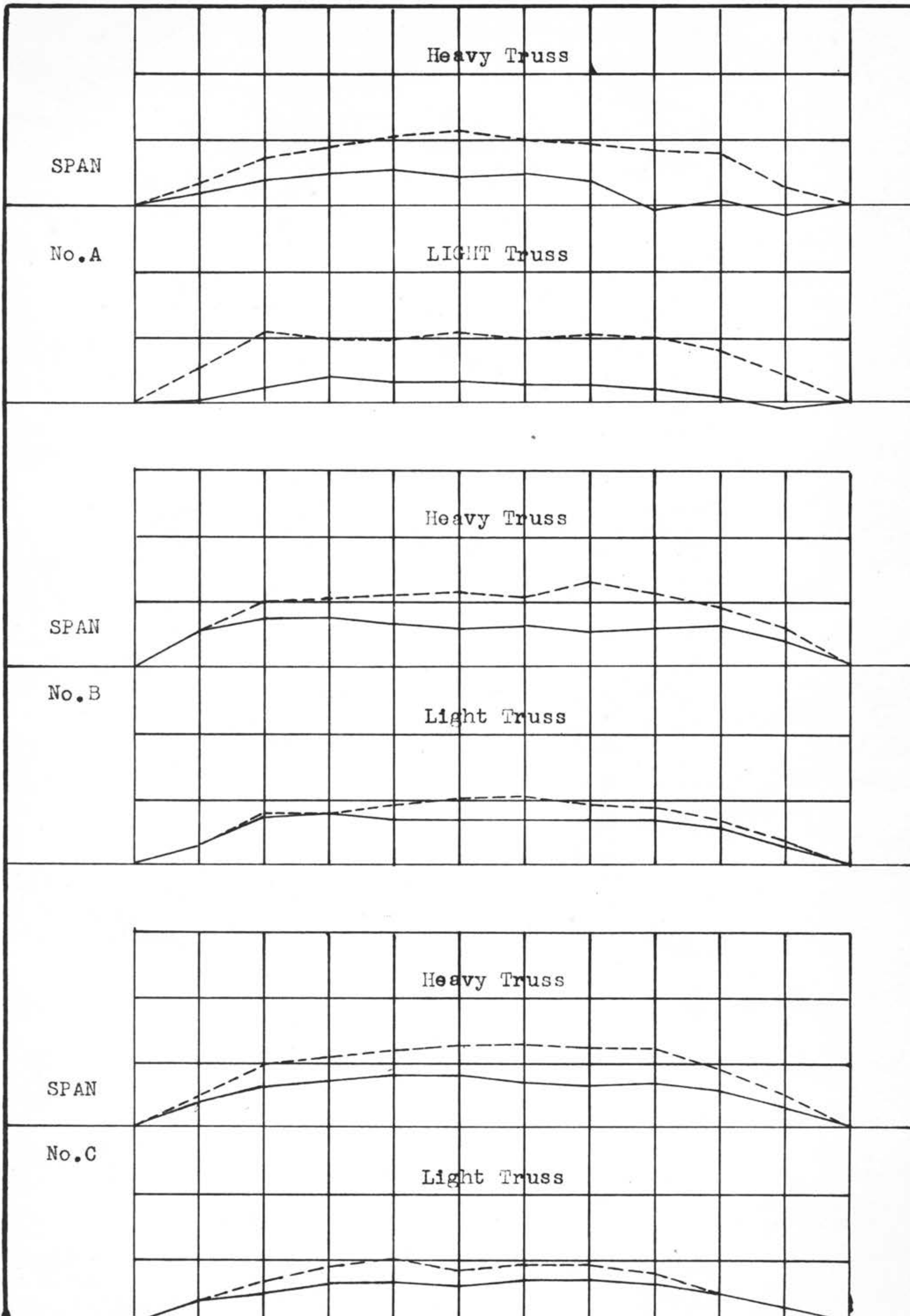


SCALE

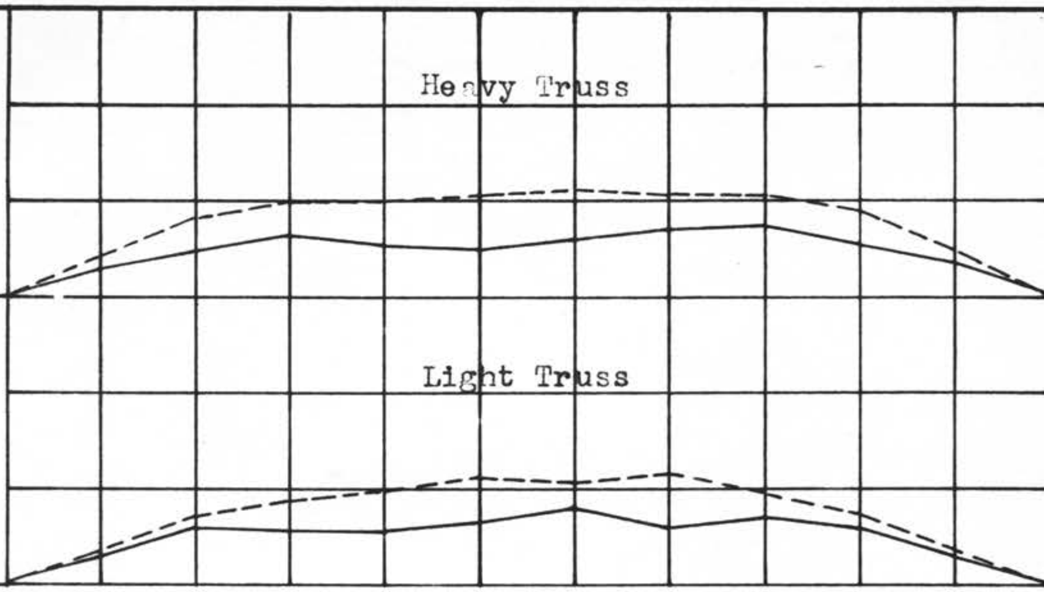
Vertical 1"= 5"
Horizontal 1"= 2 panels



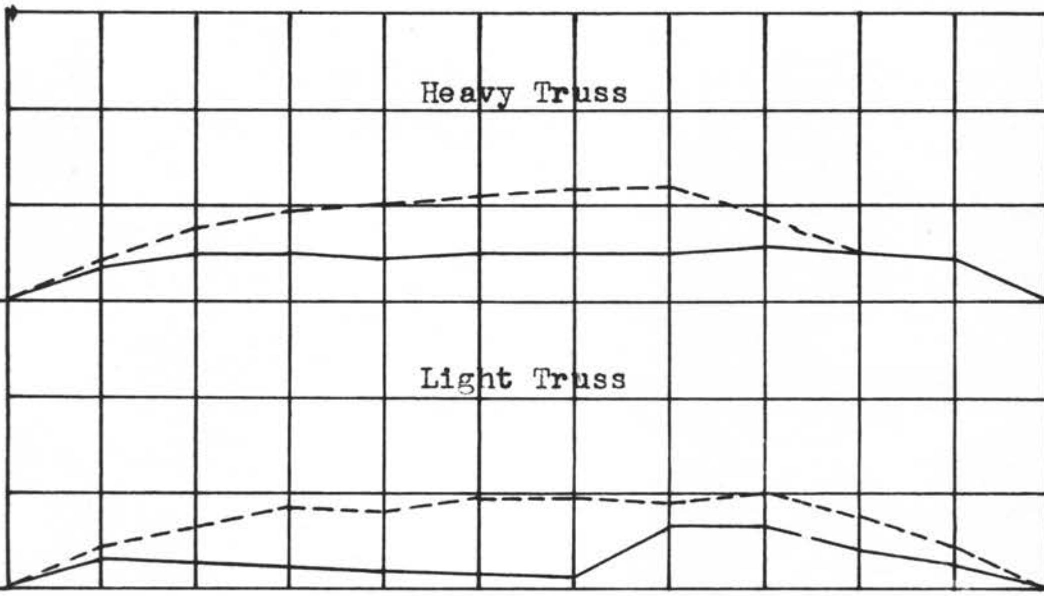
This diagram shows the average camber for the six spans. The upper curve is the initial camber, the middle curve is the camber after the span had been swung, the lower curve is the final camber.


Heavy Truss
SPAN
No.A
LIGHT Truss
Heavy Truss
SPAN
No.B
Light Truss
Heavy Truss
SPAN
No.C
Light Truss

SPAN No.D



SPAN No.E



SPAN No.F