REINFORCED CONCRETE PILE FOUNDATIONS IN THE WEST BEYNE BRIDGE.

By E. A. C. LISTER, F.C.H.,

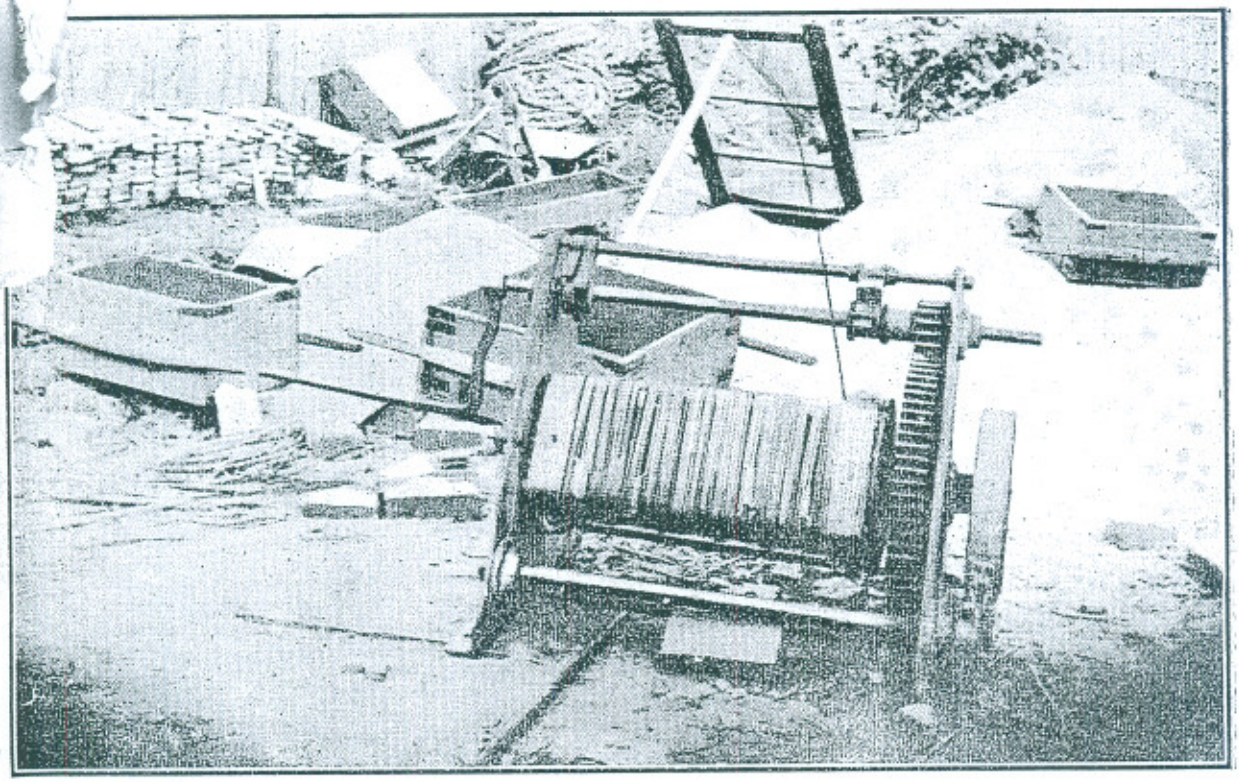
Executive Engineer, N.-W. Railway.

The West Beyne river is one of the numerous small rivers which rise from large jheels at the foot of the Himalayas. It runs south and eventually discharges into the Sutlej. The railway from Lahore to Umballa crosses the river by a bridge of four spans of 100' founded on brick wells. This bridge had to be extended when the line was being doubled. About three miles below the bridge the Kapurthala State built a dam across the river with the result that at the railway bridge site there is always some 8' or 9' of water standing.

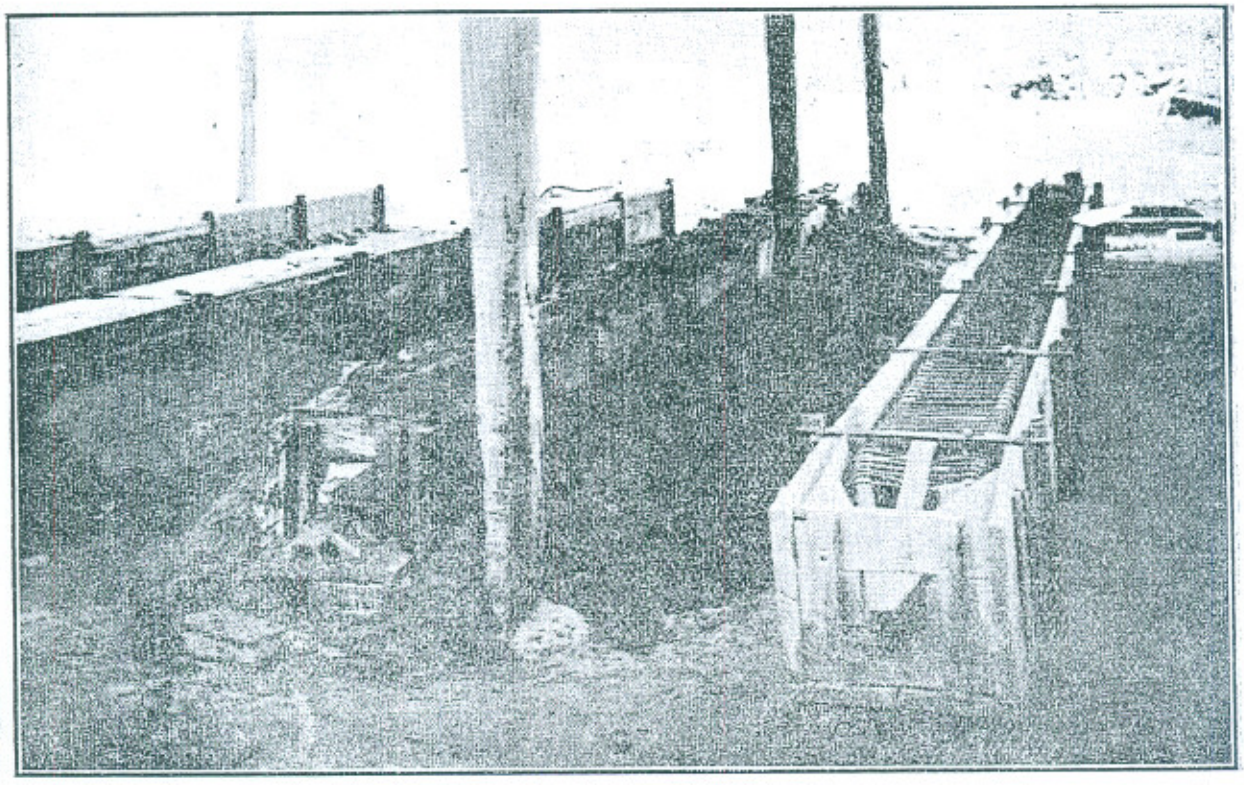
In most cases in this country, where a big bridge has to be doubled it is usual to build a new bridge for the second track about 80' to 100' up-stream. When extending a bridge for doubling the line, particular care has to be taken not to interfere in any way with the foundations of the existing bridge. The existing bridge in this case was built about 1867. The foundation consisted of two circular wells for each pier and abutment. No completion drawings could be found, but it was assumed that the wells were sunk probably not more than 25' below river bed level. The piers and abutments were heavily protected by pitching stone extending to an unknown depth. To sink wells alongside the existing bridge as foundations for the new bridge was inadvisable owing to the risk of blowing and so damaging the old bridge, and also owing to the presence of the pitching stone which would have made well-sinking very difficult. The West Beyne river is one of a number of streams which, with the Beas river itself, flow down the Beas valley. The valley is about seven miles wide and in high floods the whole valley is liable to inundations. About 22 per cent. of the valley railway is nett waterway. The line was badly damaged in 1878 and again in 1893 and 1894. Of all the bridges in the valley only one has never been washed away. The railway depends for its stability on a

heavy wide bank pierced by numerous flood openings. There are five viaducts aggregating seven hundred and fifty spans of seven foot arches, and six bridges totalling ninety 15-foot spans amongst others. To build the bridge for the West Beyne on a new alignment up-stream involved having two comparatively weak banks in place of one heavy one. Also the Grand Trunk Road crosses the West Beyne about three hundred feet up-stream from the railway, and the ground between the road and the railway is much cut up by borrow pits. A new alignment has in addition disadvantages in the extra cost of earthwork and inconvenience for inspection. It was evidently desirable to double the line by widening the existing bridge rather than by building a separate one for the second track. A design of foundations was required which would not be impeded by pitching stone, and which would not endanger the existing bridge. It was decided to use ferro-concrete piles, the piles to be connected by a heavy reinforced concrete platform on which the brick piers would be built. A small number of piles were made and tested by driving with a steam pile-driver having a one-ton drop-weight. The piles were a complete failure and crushed to pieces. After this the powers that were did not smile on the scheme. However, no one could suggest anything better, and the author was allowed to try his luck again. From experiments and observations of the crushed piles there was good reason to believe that the quality of the sand was chiefly to blame. The sand was too fine and contained a lot of mica. Also a one-ton drop-weight was undoubtedly too light for a pile weighing $2\frac{1}{2}$ tons. It only shattered the head of the pile and had very little driving power. A patent pile-driver with a drop-weight of two tons was obtained from England, the design of the reinforcement was altered, fresh specifications for the material were made out, and the proportion of cement slightly increased. No more trouble was experienced from failure of the piles, and with the new pile-driver the old pattern piles drove very well. A lot of the latter were used in the wing wall foundations which have a much lighter load to bear, and about twenty of the old piles were used as beams and columns for a foot-overbridge across the Beas station goods yard.

Design of foundations.—The thickness of the piers had to be the same as in the old bridge, *i.e.*, 10' 0". The spans were 102' clear and 109' centres of bearings. The load on the foundations



Hand Winch converted for winding square spiral for pile reinforcement.



Skeleton of pile in mould ready for concreting.

of a pier was as follows :—

Train with two engines	220	tons
Girders	100	,,
Ballast	50	,,
Permanent Way	31	,,
Brickwork	392	,,
Total ...	793	tons

No allowance in the train-load was made for impact, as the train has to run over two spans before the load is fully applied and so the load can never be suddenly applied. Also there is a large buffer of masonry, etc., between the load and the foundations, and lastly the moving load is a comparatively small fraction of the total load. This load was distributed over piles driven at five-foot centres or 18 piles to a pier. This gives a load of 44 tons to each pile. To carry this the pile had to be driven till the last blow of the monkey falling four feet gave a penetration to the pile of one inch. The piles after driving were cut off to a uniform level, leaving the four $1\frac{1}{2}$" reinforcement rods projecting about one foot above the concrete. Rolled steel beams were laid longitudinally and transversely from pile to pile. Cross rods were laid in both directions across the squares formed by the R. S. beams. The whole surface was concreted up, making a very heavy ferro-concrete slab twelve inches thick. On this slab the brickwork for the pier was built. The Specification for the piles was as follows :—

Aggregate. Boulders from Pathankote broken to pass through a $\frac{1}{2}$" screen as the upper limit and a $\frac{1}{8}$" screen as the lower limit.

Sand. Quartz bajree was brought from Delhi and passed through a pulverizer. This was double screened to pass through 12 meshes per inch and to be retained on 30 meshes per inch. Most of the piles were made from this sand, but a Baxter's stone-breaker was put up at Pathankote and the dust from this screened as above gave an excellent clean sharp sand. Great importance was attached to the quality and gauging of the sand and the result fully justified the trouble and expense.

Cement. Gillingham's " Red Hand " brand cement was chiefly used but a certain amount of " Pyramid " brand was also used. Both are excellent cements. Careful tests were taken of all the cement used both by the assistant engineer on the work and by an independent expert.

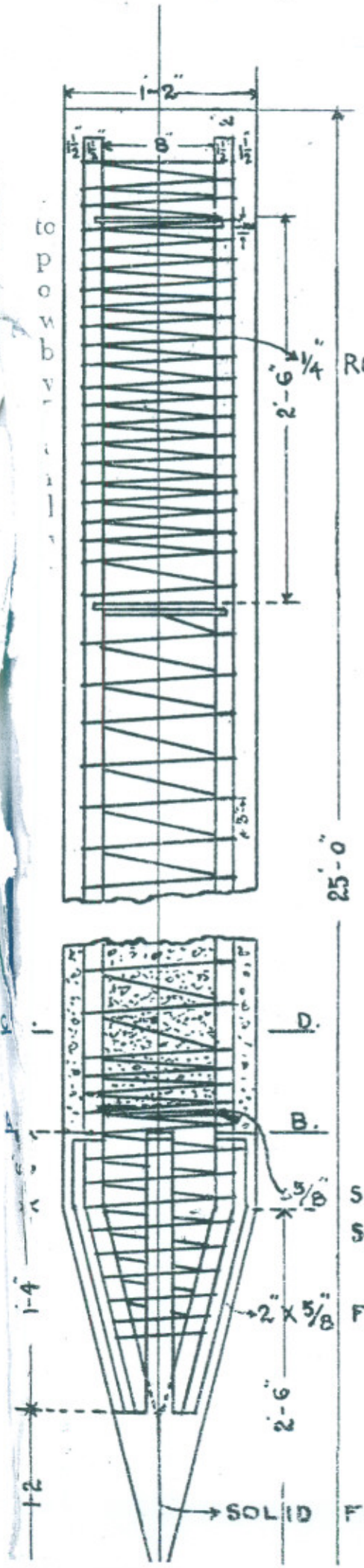
Reinforcement. The main reinforcement consisted of four $1\frac{1}{2}$" round steel rods 27' long. To save wastage and joints these rods were obtained from England cut to correct length. The rods were arranged to form a square of $9\frac{1}{2}$" centre to centre of rods. The outside dimensions of the pile was 14" × 14", so that there was $1\frac{1}{4}$" of concrete outside each rod. Round the rods $\frac{5}{16}$" half-round iron was hooped at 3" pitch. The rods were kept in place by $\frac{3}{8}$" square cast iron struts placed $2\frac{1}{2}$' apart. These struts were left in the concrete. At either end of the pile, where the shock due to driving the pile is greatest, the pitch of the hooping was reduced to $1\frac{1}{2}$". The pile terminated in a heavy forged shoe weighing about 80lb. supplied by Messrs, Burn & Co.

The Moulds were made of planks, and so arranged that the sides could be taken off without disturbing the pile. The sides were removed seven days after the pile was made. The pile was gently rolled over 14 days after manufacture and the bottom planks removed. No pile was allowed to leave the works till it had set for 28 days. All the piles were cast horizontally. To cast them vertically is far more troublesome and expensive. According to experiments made by different experts the increase in strength due to vertical casting is only from 2% to 5%.

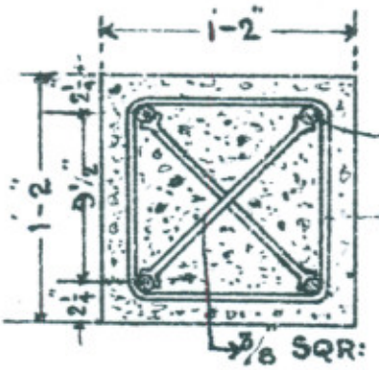
The mixing was all done by hand in small batches of three c.ft. of aggregate each. The proportions of the concrete were 1 of cement, $1\frac{1}{2}$ of sand, 3 of broken stone. The different materials were measured in suitable boxes. Water was added from water-cans provided with rose heads. The exact amount of water varied considerably with the time of year. The less water used the better, as excessive water tends to let the cement escape in cracks in the mixing floor and moulds. The moulds were painted over with a mixture of white lime and soft soap to prevent the concrete adhering to the moulds. All the work was done in the sub-divisional workshops at Beas. This involved carrying the piles about 300 feet to a small temporary platform, loading into trucks with the help of a three-ton fixed crane, taking out seven miles by train and unloading there with a derrick. The disadvantage of reinforced concrete work is the careful supervision it requires. To simplify supervision it was considered advisable to make all the piles at headquarters, and every pile was made in the presence of the assistant engineer or a European supervisor. The piles were run out from the unloading derrick to the pile-driver, and there lifted vertically by a steam winch

N.W.R.
WEST BEYNE BRIDGE
DETAIL
OF
FERRO CONCRETE PILE

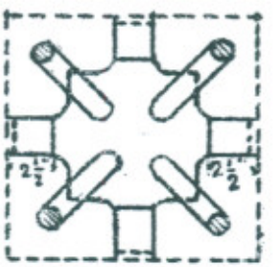
Scale 3/4" = 1 Ft



SECTION ON C.D.



SECTION ON A.B.
CONCRETE REMOVED



provided for the purpose on the pile-driver platform and lashed to the trestle. The cap of the pile-driver was let down on the pile which was then ready to drive. The drop-weight consisted of a heavy steam cylinder weighing two tons. When in work the whole weight of the drop-weight is carried on the pile and not by the trestle, and is lifted by pressure on the pile head. After various delays pile driving was begun on 12th October 1910. The pile-driver was however constantly out of order. Nearly all the failures were due to the use of cast iron, which should never have been used on a machine of this sort, subject as it is to heavy vibratory shocks. In the first 80 working days the machine was out of order for 40 days. In the last 105 days the machine was out of order for six days only. Practically all the cast iron had to be replaced by gun metal castings.

As previously mentioned the bridge consists of four spans of 102ft. Out of the two abutments and three piers, one abutment and two piers always had 5' to 10' of water round them. The last span had high ground under it. A bund was made to enclose the abutment, and two piers and a channel cut through the last span to pass the cold weather stream. The bund formed three sides of a square, 250' each side. When the foundations for the abutment and pier in high ground were finished the bunds were closed and the stream diverted. A flood in January breached the bunds badly, and when rebuilt a new bund was built up and down stream so as to divide the enclosure into two compartments. The enclosed space was emptied and kept dry by two 10-inch centrifugal pumps. Work was progressing satisfactorily when the heaviest cold weather flood known for many years came down in March 1911. The diversion channel originally 20' wide by 4' deep scoured out to 120' wide by 12' deep. The large portable engine used for driving the pumps was marooned on a small island of stone and sand bags, with a stream 12' deep on either side. One compartment of the enclosure was cut and this just enabled the pile-driver to be saved. The flood lasted about three days and did a lot of damage, carrying away tons of material, timbers, rails, etc., and seriously delayed the work. The pile-driving was done by a gang of Bombay khalassies. After they had got accustomed to the work they were given the driving on piece-work. Pockets of quicksand were occasionally met with. On one occasion after a pile had been driven some 10' to 12', a single blow sent the pile down 8'. The promptitude of the khalassies in releasing all the lashings saved the pile-driver from being dragged right over. For some unexplained reason,

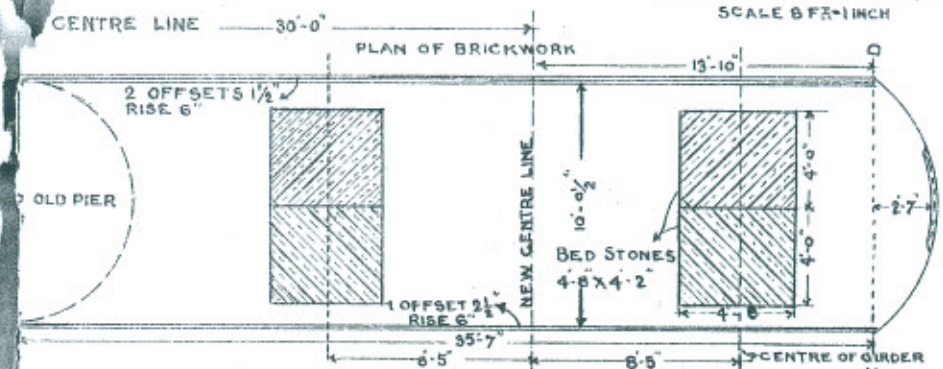
whenever a pile struck a loose pocket of this sort, the pile drove eventually very hard. In this particular work a lot of the details in designing had to be a matter of guesswork. The piles had to be made weeks before they were driven ; in fact most of them were made before a single one was driven. The length of the piles was fixed because it was a suitable sort of depth for the foundations to go. No one had any idea as to how deep a pile could be driven or what it would bear when driven any particular depth. In the east abutment, pile No. 16 drove $\frac{7}{8}$" with the ten test blows, after driving 22', whereas pile No. 17 only 5' away drove 2" under the test blows, after driving the full length of the pile, *viz.*, 28'. Wherever a pile failed to stand up under the test blows, a relieving pile was driven close alongside it and the load distributed between the two. Excluding wing walls, 20 out of 83 piles required relieving piles to be driven, making a total of 103 piles. There were in addition 16 piles under the wing walls.

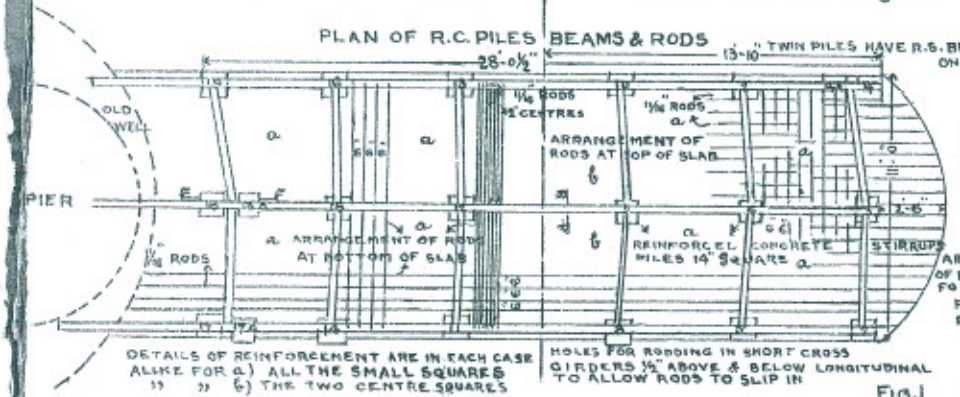
The reasons for adopting ferro-concrete pile foundations have been gone into in great detail. Except under special circumstances, they are not recommended, as the difficulty of getting the right plant, the careful supervision required, and the uncertainty about the depth to be driven, all mean that it is very difficult to say how long the job will take to finish. The author's thanks are due to Capt. E. P. Anderson, R. E., for the photographs which accompany this paper. He was the Assistant Engineer in charge of the work, and was responsible for the design of most of the details of the work and all the practical supervision of it.

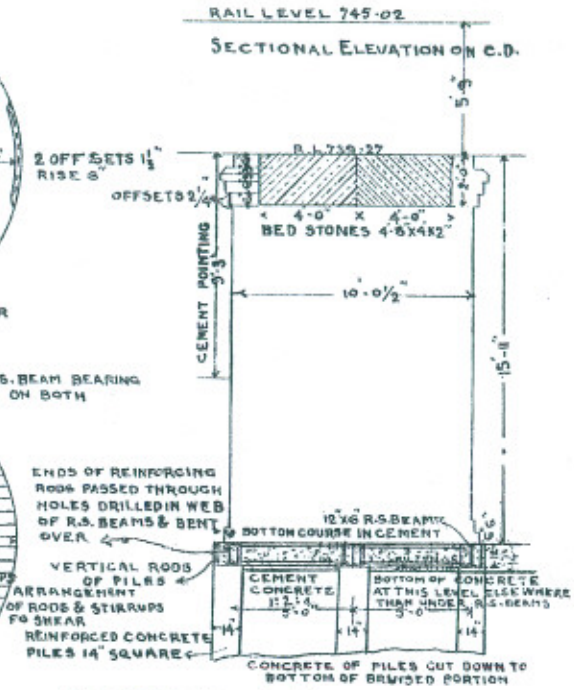
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N.W.R
WEST BEYNE BRIDGE
DETAILS OF PIER Nº 1
SCALE 8 FT = 1 INCH







FIGS 1.2.3.&4 SCALE 4 FT = 1 INCH

DETAILS OF PILES

Nº	REDUCED LEVEL OF SHOE	DRIVEN BY 2 TON MONKEY BLOWS Nº	DROP FT	PENETRATION INCHES	REMARKS
2	700.56	10	4	1"	
3	700.52	10	4	5/8"	ALL PILES ARE ACCORDING TO THE
4	697.01	10	3	1¼"	IMPROVED DESIGN IN X.E.N. LHRS
4A	705.82	10	4	5/12"	DRAWING Nº 10 D.J. DATED 23.2.10 1910
5	698.42	10	3	4/5"	
6	702.42	10	4	3/4"	PILES MARKED A WERE ADDED
7	701.45	10	4	5/8"	OWING TO EXCESSIVE SET OF THEIR
8	700.42	5	4	3/16"	NEIGHBOURS UNDER TEST BLOWS
9	701.90	10	4	11/12"	
10	699.22	10	4	1 1/12"	CONCRETE IN PILES 1:1½:3
11	698.47	5	4	½"	CONCRETE IN SLABS 1:2:4
12	703.05	8	4	1/4"	AGGREGATE ½" CRUSHED STONE
13	701.62	10	4	4/6"	FROM PATHANKOT
14	701.29	5	4	3/4"	SAND CRUSHED DELHI SAND STONE
15	703.71	10	4	3/32"	1/8 TO 1/30 IN NEW PILES & SLABS
16	701.56	10	4	13/16"	HAMIRA SAND IN OLD PILES
17	696.69	5	3	1¼"	CEMENT GILLINGHAM BRAND
17A	702.74	10	3	1 1/2"	
18	698.96	10	4	1 3/8"	
18A	703.77	10	4	1 1/4"	
19	701.68	10	4	3/4"	

Fig.1
DETAIL AT F.F.

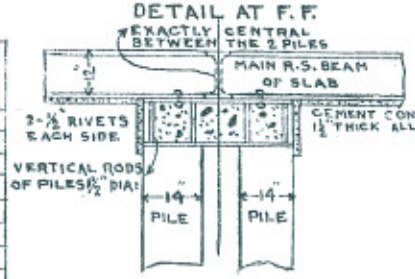


Fig. 2
JOINT OF R.S. BEAMS

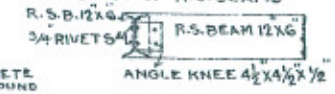


Fig. 3
STIRRUP



STIRRUPS FIXED ON EVERY THIRD ROD

Fig.4
SECTION ON A.B.



RIVETS STAGGERED 3½" PITCH
⅞" DIA.

ALL PIERS & ABUTMENTS
IN ALL CASES GIRDERS ARE FIXED BY L IRON KNEES SEE FIG. 2
BEAMS OVER TWIN PILES RIVETTED BY 4 Nº ½" RIVETS TO MAIN BEAMS

Discussion.

In the absence of the author the Chairman called on Captain E. P. Anderson, R.E., to introduce Mr. Lister's paper.

CAPTAIN ANDERSON said that the paper contained an account of the first use that had been made of reinforced concrete piles in the foundations of a railway bridge on the North-Western Railway, and he believed it to be the first in the whole of India. The reasons for doubling the bridge on the existing alignment had been fully treated by the author, but there was just one additional reason that he might mention. The West Beyne bridge is situated between two long arched viaducts, which were put in hand almost before the bridge. To make a new bridge on a fresh alignment and come back on to these viaducts would have necessitated unduly sharp reverse curves in the approaches, which would be a serious drawback in a level section of the line where high speeds are otherwise attainable. Referring to the question of the amount of water used in cement concrete, which had been raised in the discussion on the previous paper, Captain Anderson mentioned that he used 75lbs of water per cubic foot of cement in making the piles. The difficulty of leakage from the moulds was got over by having a man ready with a lump of wet clay, which was applied to any place where a leak was seen. The bearing power of the piles was calculated by Ritter's formula as recommended in Marsh and Dunn's book on "Reinforced Concrete." The effect of the light monkey in attempting to drive such heavy piles as these, weighting about 2½ tons, might be compared with that of attempting to drive a heavy wooden picket into the ground with a light hand hammer instead of a heavy mallet. The head of the pile was simply splintered up as that of the wooden picket would be. The various causes of delay in completing the bridge were enumerated, amounting to some 25 months out of a total time of 35½ months. All of these were due to causes entirely beyond the control of any one in India, and the actual time taken—10½ months—after deducting them, did not seem unreasonable for a work of this size. When the men had become accustomed to the work, three piles were driven daily, and there seemed no reason why this rate should not be improved on in future. Among the causes of delay mentioned was the supply of cement of bad quality from England; but from what had been said in the discussions on other papers it seemed that the North-Western Railway was not the

only department which had recently experienced this. Cement of infinitely better quality was purchased in the open market in India quite as cheaply. It need hardly be added that only the very best quality of slow-setting cement should be used in such work. Samples of sand and aggregate were shown. Information recently received went to show that the shape and size of the corrugations on the teeth of the jaws of a stone-crusher affected the way the stone broke, *i.e.*, into "slips" or cubes. To show the record height of the floods of March 1911, Captain Anderson mentioned that, after the January floods, the earth dams in the river bed were rebuilt $2\frac{1}{2}$ ft. higher than before. The rolled steel joists over the heads of the piles were a portion of the design which might be modified in light of subsequent experience. They were calculated to be sufficient to take the whole load, which could just as well be done by a deep reinforced concrete beam. But it must be remembered that this was a first attempt and no risks could be taken. In concluding his remarks Captain Anderson laid special emphasis on the ease of carrying out such work, provided the proper plant and materials and trained staff were available. The piles cost about Rs. 6 per lineal foot driven complete, and each complete slab about Rs. 1,500.

MR. SCOTT pointed out that during the discussion the question of the quantity of water to be specified for, and used in, reinforced concrete work had been raised by several speakers, but for this no hard and fast rule could be laid down, because the quantity of water required largely depended upon the quality of the aggregate used, and also in India very largely upon the temperature of the air at the time that the work was being carried out. In the case of the reinforced concrete syphons constructed by the speaker upon the Upper Chenab Canal, it was specified that 22 lbs. of water per 60 lbs. of Portland cement should be used, but it was found that, when carrying out the work in the month of April, with the temperature of the air at 90° Fahrenheit, that this quantity of water was insufficient. The concrete was hand-mixed on brick platforms, and then passed through a mixing machine and carried in mortar pans to the work, but it was found that, even though the mixing was done under awnings in the shade, the concrete began to set initially in the mortar pans, therefore the quantity of water had to be increased from 30 to 35 lbs. per 60 lbs. of cement used. The amount of ramming is also one that should be left to the judgment of the Engineer in charge of the work. The appearance

of the rammed concrete will generally tell him whether too much or too little water is being used, and how far the ramming should be continued. Mr. Scott added that, from his experience on the Upper Chenab Canal, he was of opinion that no hard and fast rule could be laid down as to the quantity of water to be used in reinforced concrete; it depended very much upon the density of the aggregate used, and also very largely in this country upon the temperature of the air at the time the work was being carried out.

MR. BELL considered that the addition of 75 lbs. of water for every 100 lbs. of cement used was excessive. He would like to know whether the aggregate was washed immediately before being used, as, if not, this might explain the necessity for adding so much water. The author had stated he did not consider much ramming necessary, and the speaker would like to know whether Captain Anderson had ever measured the percentage of contraction induced in a concrete mixture by ramming, in order to arrive at some idea of the compactness of the concrete. As the piles had been cast horizontally the concrete was nowhere more than 18 inches in depth—and for this very little ramming would have been necessary, but it did not follow that, in dealing with a large mass of concrete, running to a considerable depth, that ramming would not be advisable. A particular case did not constitute a principle, and the speaker contended that concrete in ferro concrete work should always be thoroughly rammed.

MR. ROBERTSON agreed with Captain Anderson's remarks about the Baxter crushers. There were two in use at Mangla and the same tendency to turn out ballast with a large quantity of "slabs" in it had been noticed. Ballast broken by hand from similar boulders gave good cubical stuff without the "slabs," and therefore, as Captain Anderson said, the machines were to blame for the slabbing, and not the cleavage of the stone. It is true the machines break the stone along its lines of cleavage, but the shape of the space between the jaws is such that the flat pieces lie against one or other jaw, and slip out as the jaws open.

CAPTAIN ANDERSON replied to the discussion. As regards the remarks of Mr. Scott, he agreed that the determination of the amount of water was largely a matter for the judgment and experience of the engineer. But when, as in the case of piles, large numbers of reinforced concrete articles were being

made one after the other under precisely similar conditions, it wa a great advantage to determine once for all the correct proportic of water, and stick to it, as, by doing so, the attention of t supervising officer could be spared for looking after other impc tant points. In making both piles and slabs prolonged ha ramming was avoided. The wet mixture was worked in round the reinforcement with small rammers, and finished off by a little ramming with a big rammer in a very few minutes. In reply to Mr. Bell, Captain Anderson said that the aggregate was only slightly damped before mixing and laying. The amount of ramming required depended on the proportion of water used. In the case of a wet mixture relatively little ramming was necessary. No measurements of the contraction referred to by Mr. Bell were made, but the speaker imagined that the amount would be very slight.

MR. LISTER wrote that considerable interest appeared to be taken in the amount of water required for making concrete. The quantity varied, however, not only with the temperature, but also with the design of the reinforcement. Where the reinforcement consisted of small bars close together, it was difficult to thoroughly ram the concrete and the only way to get all the interstices properly filled with the concrete was to make the mixture fairly fluid. In the big Liver Buildings in Liverpool (which the author saw under construction) the engineer in charge admitted that in awkward corners, and big intersections of rods, the concrete was intentionally made wetter in order to get it well home.