

CONCRETE WORK IN NEW LOCO. SHOPS.

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The concrete work in the New Loco. Shops is of two descriptions :—ferro-concrete, and concrete used in lieu of stone in architectural work.

In this paper it is not proposed to go into details of strength and stresses in the case of the ferro-concrete, but merely to give a description of the work and how it was carried out.

The ferro-concrete work consisted of 32 square pillars to carry the east and west walls of the erecting shop. The heights and thicknesses of these walls are as follows :—

3' thick up to 17'-9" ; 2'-7½" thick up to 30'-3" ; 2'-3" thick up to 42' ; 1'-10½" thick up to 52' ; and 1'-6" thick up to top of gable and which is 66'-3" high. These walls are carried on ferro-concrete pillars 3'-6" square and spaced at 18ft. centres.

Plate A shows an end elevation of the wall referred to.

The reinforcements in each pillar consist of sixty-four ¾" diameter rods set staggered in two rows along the inside and outside faces of the pillar, *i.e.*, along the face of the pillar which faces into the shop, and the opposite face. The distance of the first row of rods from the face of the pillars is 2⅞", and the second row is 3" behind the first. All the rods are spaced 3⅝" apart. The reason why the rods are placed along the faces of the pillars is because the stresses they are intended to counteract are those due to wind pressure on the wall. These rods are bound together at every 18" of their height by sheets of expanded metal let down over the rods and also a wire $\frac{5}{16}$" diameter : was wound in a spiral round the rods for the whole of their length. The height of each pillar above ground level is 12'-5" and the total length of the reinforcing rods is 18'-6", giving the rods a length 7'-0" in the foundations. The rods at their bottom ends enter into holes in a ¾" plate 4' × 4' and have a nut on the bottom end the reason for which will be given later. On Plate B is a sectional elevation of one of the pillars showing reinforcement, etc. The expanded metal netting and wire winding are also shown.

The wall of the erecting shop referred to is a continuation of the end wall of the machine and fitting shop and butts at its far end into the Tender Shop wall running at right angles to itself.

These two walls, *i.e.*, Machine and Fitting Shop and Tender Shop were first built and carried up to the level of the springings of the arches connecting the reinforced pillars. Work on the pillars was then begun and the following procedure adopted.

The plan on Plate A shows a portion of the outlay for the twenty east wall pillars.

Two feet of concrete was first put in the foundations. The base plate was then put in position, raised and supported at its four corners on four bricks.

A wooden template was made which consisted of a number of sleepers cut in halves and battened together, in the centre of which an exact profile of the column was marked by a deep groove cut in the sleepers. In this template sixty-four $\frac{3}{4}$" holes were drilled in the exact positions where the reinforcing rods should come. The templates were laid across from edge to edge of the foundation excavations at ground level and adjusted to their exact positions. The templates were then fixed by pegs driven in at the corners. Thus, when each template was fixed and each $\frac{3}{4}$" plate before mentioned had been laid in its correct position, there were two exact parallel surfaces one below the other about 6' apart on which were marked profiles of the column in its correct position. In the template above were holes through which the reinforcing rods passed and vertically below each hole in the template was the corresponding hole in the $\frac{3}{4}$" plate where the reinforcing rods terminated.

The rods were then let in through the holes in the template and passed through the holes in the $\frac{3}{4}$" plate and a nut fixed on at the bottom end, in this way all the rods were fixed in their exact positions and the accuracy of the work was frequently checked by means of masonry pillars which were truly and accurately placed in suitable positions at the commencement of the work, and in which centres had been set out with a theodolite.

Plate B shows clearly how the wooden template described was fixed and used, etc.

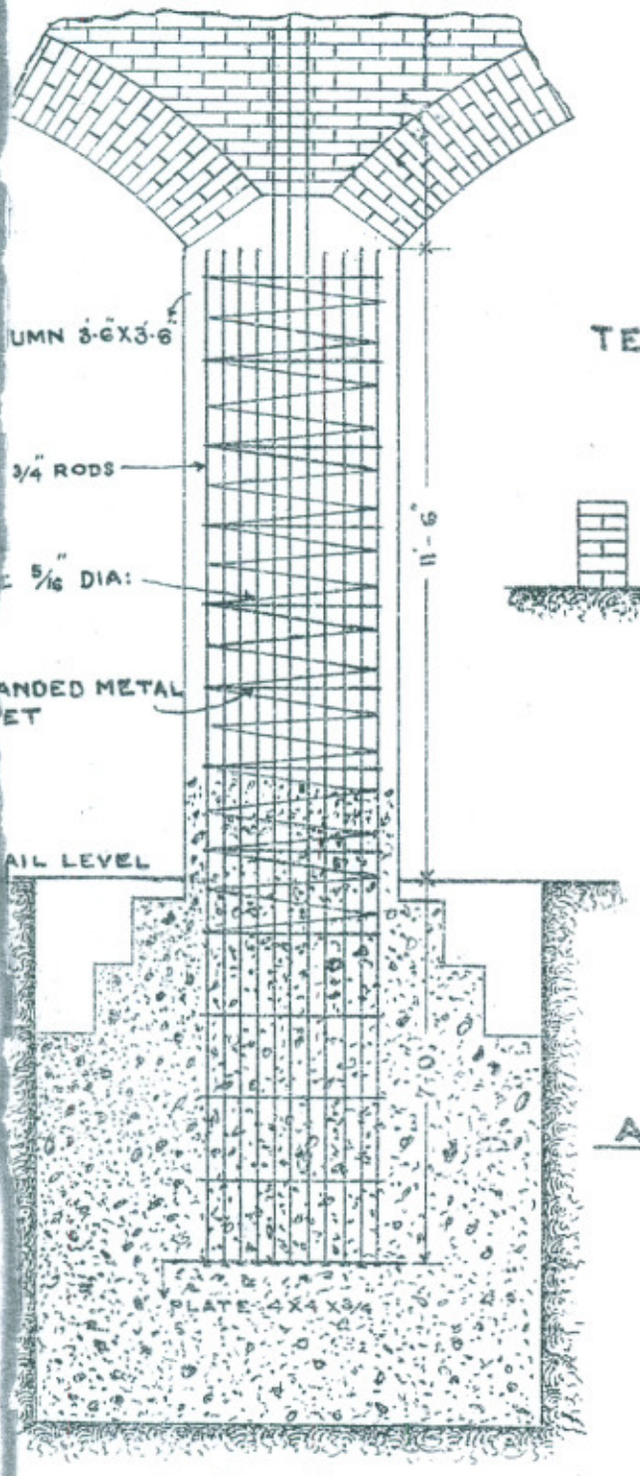
Two more feet of concrete was then put in which fixed the reinforcing rods once for all, and at the same time the position of the column. The procedure was then quite simple up to ground level, at which point the wooden template had to be removed. This was done by unscrewing the battens and sliding the sleepers forming the template over the rods ; in this way each template could be used several times. Before reaching the

PLATE B.

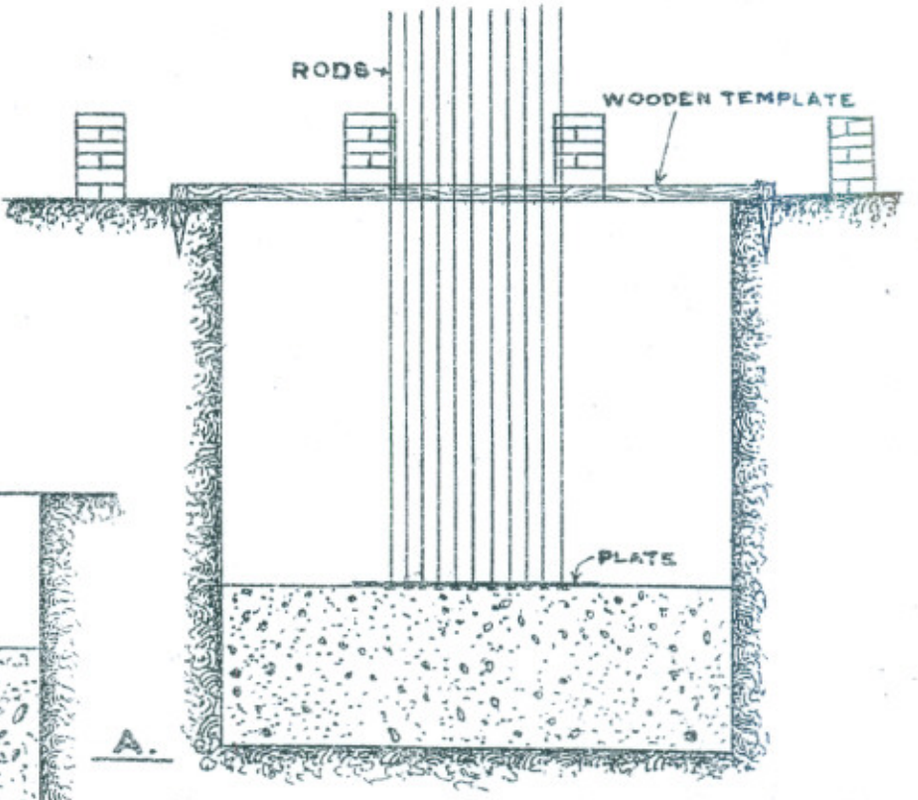
NEW LOCO SHOPS LAHORE

Scale 1/5" = 1'-0"

SECTIONAL ELEVATION OF COLUMN SHOWING REINFORCEMENTS

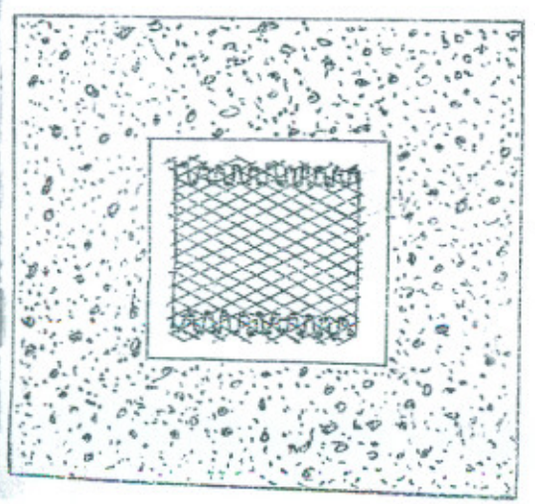


SECTIONAL ELEVATION SHOWING TEMPLATE & METHOD OF SETTING RODS

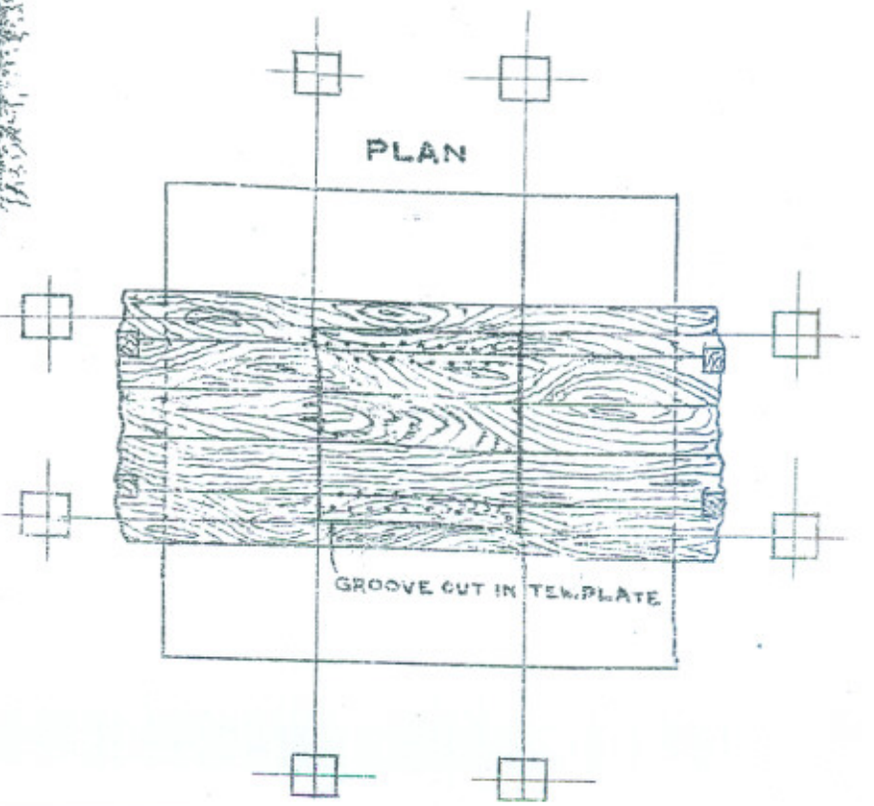


A.

PLAN AT A.A.



PLAN



ground level there were two offsets to reduce the size of the foundation, but in this there was no difficulty as the rods were fixed by the concrete below and held in their correct position by the template at ground level. A removable framework was laid round the reinforcements and filled ; then the frame was removed and on top of the filling, as soon as it had set sufficiently, a smaller frame was put and filled, etc.

The columns themselves, which extended from floor level to a height of 12'-5", from which point the arches sprang, were 3'-6" by 3'-6" and, it being necessary to build each column from floor level to the top in one day so as to ensure a compact monolithic mass, the whole system of construction had to be planned with this end in view.

In the actual building of a column, the great point was to make certain that all the concrete was properly rammed, and to insure absolute contact with all the reinforcements ; with these points in view it was decided to fill in 9" layers. This would have been impossible if the mould had consisted of one box the size of the column which had to be filled from the top, as first the expanded metal binding the reinforcements together would stop the concrete being thrown down from the top, and secondly would also prevent men from going down to ram ; hence to do away with these difficulties a box was designed as follows:—

It consisted of a strong base frame of 4" by 4" timbers, at the four corners of this frame four uprights were fixed consisting of 4" by 4" timbers equal in length to the height of the column. At the top end of these upright timbers holding them at the required distance apart another frame was fixed consisting of 3" by 2" timbers. In two places also in their length the upright timbers were strutted by 3" × 2" timbers.

Two grooves each $1\frac{1}{16}$" wide and $\frac{3}{4}$" deep were cut on the inner angle of each upright. The walls of the box consisted of wooden slides each 9" deep by 1' thick which were grooved and tongued along the edges which came in contact with one another. By this means the column could be built in 9" layers and thorough ramming insured, and at the same time no delay caused to the work, as after 9" had been filled four slides were let down the grooves from the top, and filling and ramming continued, and so on. Before starting a column all the reinforcements in the way of expanded metal were let on to the rods at the top and, as each was required, it was pulled down into its proper position and fixed.

Plate C shows an elevation and plan of the box described.

As I have mentioned before, a column from ground level to the top was built in a day and to insure this being possible and to avoid all delays everything was prepared beforehand as follows:—

When the foundation concrete had been brought up to ground level a small frame 3'-6" by 3'-6" section column and 4" deep was put round the reinforcements the morning before the column was to be started. This frame was then filled with concrete and the frame removed the same afternoon. Thus at floor level there was a small column 4" high in the exact position and forming the base on which an actual column had to be built.

The base frame of the mould box was then fixed round this footing of concrete, and the mould box, which was so constructed as to be put together in an hour or so, was erected and everything got ready to make a start the first thing the following morning. There was no doubt about the box being in the correct position and square, the only point to be watched was that it was plumb. To ensure this and to do away with any chance of its moving out of plumb during filling, at the four corners of the top frame four eye-bolts were fixed ; from these eye-bolts stout wires were run which had eye-bolts at their other ends also, these eye-bolts being screwed for a length of about a foot were run through holes in R. S. beams which had previously been bedded into the ground at a convenient distance from the column. By running nuts on to the eye-bolts they acted as adjusting screws and by means of them the frame could be pulled in any direction into plumb and fixed there. To act as a check, two plumb bobs were continually kept suspended down the outside of the box so that any movement could be detected.

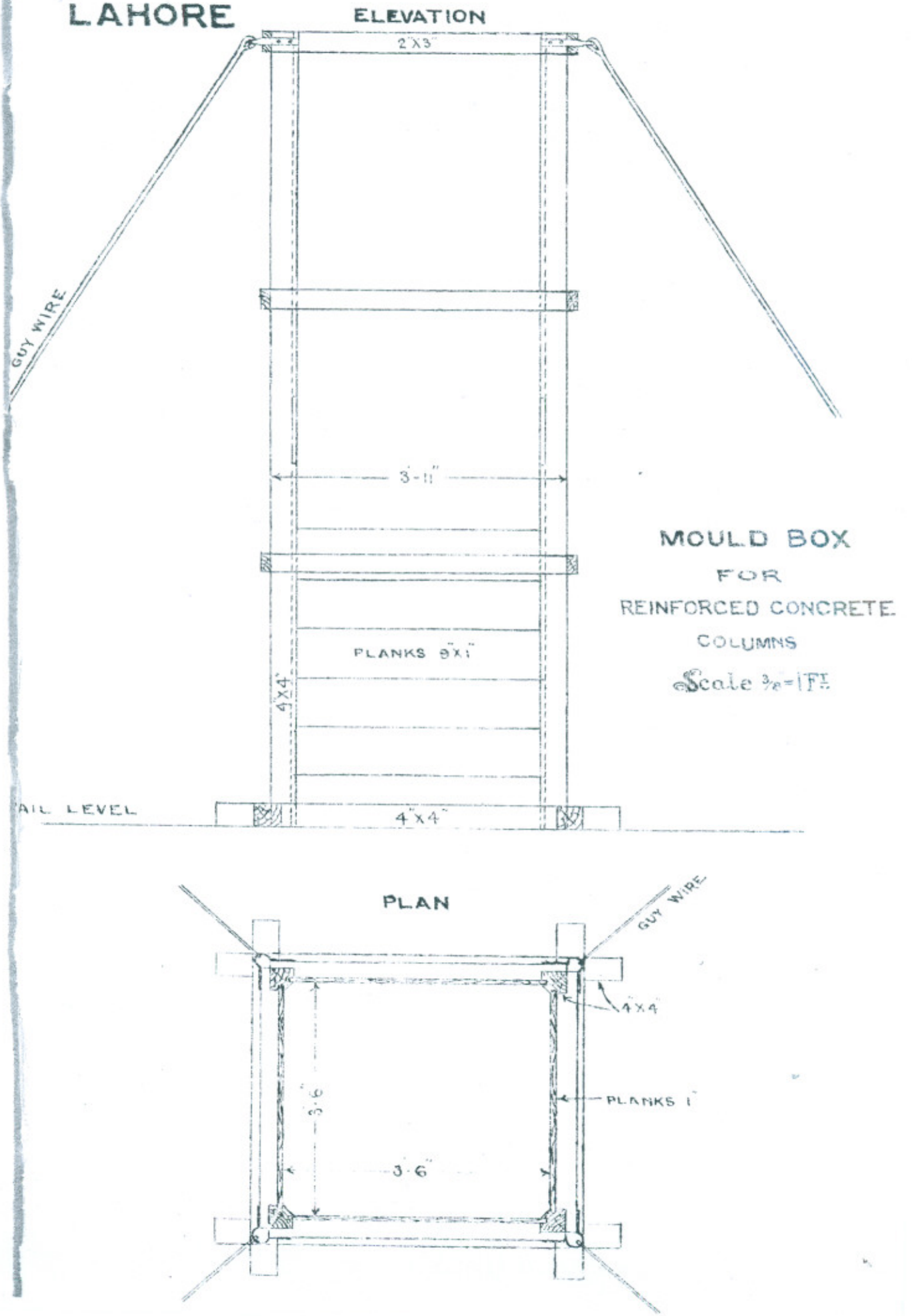
These preliminary adjustments, which, although they sometimes appeared excessive and took a considerable amount of time and trouble to arrange, left one practically free to look after the mixing and ramming of the concrete and the setting of the expanded metal during the actual filling of the boxes, and also afforded a great deal of security and confidence.

So much for the actual building of the columns. As regards the composition and mixing, etc., the following might prove of some use to anyone who should happen to have charge of a similar work.

The foundation concrete up to 1'-0" below ground level consisted of six parts of Pathankote shingle, two parts of sand and

PLATE.C

NEW LOCO SHOPS
LAHORE



MOULD BOX
FOR
REINFORCED CONCRETE
COLUMNS
Scale 3/8=1Ft.

one part of Portland cement. This was hand mixed in heaps consisting of 3c.ft. to 1c.ft. to ½c.ft., as it was found that if coolies were allowed to deal with larger quantities than this at a time, the mixing was not so thorough ; also the small quantities were mixed much quicker and so were laid fresher. The sand was first mixed dry with the cement, then added to the shingle and turned over once dry. After the water was added it was turned over three times. The mixing was done in a low shed the floor of which was covered with sheet iron 20 B. W. G. One set of men mixed the sand with the cement and then handed it over to another set who turned it over dry with the shingle and so on, each time the heap was turned over it changed hands, that is it started at the top of a line at the head of which were the measuring boxes, and it was gradually passed down the line to the end when two men filled it into pans to be carried to the work. The advantage of this system was that it did away with coolies running about getting into each other's way and also kept the men much fresher, with the result that a pile was passed along the line very quickly, which was a great point, first because it pushed the work along quickly, and secondly and more important the concrete reached the work fresh, and, as this work was carried on during the months of May and June, a great danger lay in the concrete starting to set during mixing, due to the heat. A mixing machine was used for a time but had to be abandoned as it was found that the concrete was setting before it reached the work. All mixing was done with English spades and water was applied through a rose. The trouble experienced in getting the coolies to use an English spade properly was amply repaid by the results later. With regard to the quantity of water used in mixing, it was found that 45lb. of water to every c. ft. of cement used was hardly sufficient, the mixture thus obtained being somewhat dry ; 50 lbs. gave a more satisfactory result, though the tendency was to use even a little more.

The ramming was effected round the reinforcements by means of wooden mallets sufficiently small to go between the reinforcing rods. The larger body of the centre of the column was rammed with an ordinary cast iron hand rammer. About five men were employed continually on the ramming, two of them being masons.

The best results in ramming were obtained when the mixture was fairly dry, it was found that the drier the mixture was, the more perfectly it could be rammed ; and although

sometimes when ramming was first started the mixture seemed too dry, yet after continued ramming it invariably got into that plastic stage when if a quantity was picked up and turned over on a trowel it formed into a ball and could be thrown off leaving the trowel practically clean.

To prevent the concrete sticking to the mould boxes the sides of the latter were rubbed with a mixture of soft soap and white lime, two of white lime to one of soft soap. This, however, did not prevent the wood from warping ; so instead of the above, thick black rape oil was smeared all over the inside of the box and this gave a more satisfactory result.

Each column was allowed to set seven days before the false work was removed and during this time the wires holding the box in plumb were left in position. Twenty-four hours after a box had been filled it was covered over with sacking and grass and a jet from a 1" pipe was kept continually playing over it, which ensured perfect saturation. After the false work had been removed the jet was still kept playing over the column for 14 days longer. Through a mistake on one occasion a box was removed after three days but without any unsatisfactory results.

Each mould box was used at least three times, and several of them four times, and they were in fairly good condition at the end of the work.

The composition of the columns above ground level was three parts of Pathankote stone, broken to pass through a $\frac{3}{4}$" mesh, one part of sand and one part of Portland cement. This composition was arrived at after due trial, cubes 4" × 4" × 4" of the following compositions were made and tested.

	Shingle.	Composition.		Compression in tons at which they failed.
		Sand.	Cement.	
(*a*)	2	1	1	22·875
(*b*)	4	1	1	22·
(*c*)	4	1	1	23·4
(*d*)	3	1½	1	16·875
(*f*)	4¾	1	1	12·1

The samples were made, allowed to dry for 24 hours, and then immersed in water for seven days, after which they were allowed to stand for 21 days and then tested. The different results obtained from the two similar compositions B and C can be accounted for, as in B Rawalpindi stone was used, and in C Pathankote stone, which is stronger and more suited to the work.

The reason why in the work itself a composition of 3 : 1 : 1 was fixed on when 4 : 1 : 1 had shown the best results, was that in the specimens above the aggregate was somewhat smaller than that actually used, and the object aimed at was to obtain as nearly as possible the same percentage of voids in the actual work as there was in the experimental samples B and C.

It might seem strange that a composition of 4 : 1 : 1 should give better results than 3 : 1½ : 1, the mixture usually adopted in column construction, but doubtless this can be explained by the fact that the Pathankote stone is inclined to break in flats rather than cubes ; hence the percentage of voids would naturally be less, and thus a richer mortar filling the voids would give a better result than an excess of a weaker mortar over the voids to be filled ; for after all the strength of concrete largely depends on the aggregate. The cement before use was always tested to ensure that no deteriorated or bad cement was being used.

Regarding cost, taking the total concrete work done—that is, foundations and columns, it worked out to an average rate of Rs.105 per 100 c.ft., that is, including false work, cost and erection of reinforcements, etc.

The labour rates given were Rs.13-4-0 per 100 c.ft. for foundation work and Rs.20 per 100 c.ft. for all work above ground level. The broken up stone used in the columns cost Rs. 18-8-0 per 100 c. ft. at the site of the work.

As far as it is possible to judge up to the present, these columns have proved successful ; there are no signs of failure in any of them, although, since they were built, there have been several severe wind storms.

They are decidedly more economical and better fitted for the work they are doing than anything else which could have been substituted in their stead.

CONCRETE WORK IN LOCO. SUPERINTENDENT'S OFFICE.

The second description of concrete work as already mentioned was used in lieu of stonework in the mouldings and

relief work of the new Loco. Superintendent's Office. It will be seen from photographs of the office, that although the building covers a large area of ground as it is a single storey building, the effect would have been somewhat monotonous to the eye if it had been built throughout in brick. Also the lights and shades of the design would not have been sufficiently emphasized.

This has been obviated and the desired contrasts obtained by the use of shingle and cement concrete to pick out the architectural features, such as the twin columns to each arch, the heavily moulded archivolts and the architrave and cornices. The frieze has been carried out in brickwork, the red of which contrasts well with the light grey of the concrete. In the blank wall above the line of arches and below the architrave course, circular openings have been pierced, which in addition to being ornamental afford light and air to the fanlights in the main building. These circular openings are filled with a tracery of geometrical pattern in concrete.

A porch projects thirty feet from the main line of the building at its centre, the moulded work of which is carried out in the same manner. The arches have panelled keystones of concrete over them and a balustrade of concrete balusters runs round the top. In the porch, as in the end wings of the building, the line of semi-circular arches supported on twin columns gives place to segmenta arches. These arches spring from rectangular piers buttressed back at the line of springing. The bases of the buttresses, the set backs or weathered courses and the arches with their keystones are all of concrete.

Behind the porch at the intersection of the main corridors a square tower rises to a height of over 50 feet. The string courses round the tower, the four feet circles for the clock faces, and the gables rising from the sides of the pyramidal slate roof, each supported on two scrolls capped by a broken cornice, are all formed in concrete.

The gables on the wings as already mentioned are carried on segmental arches, springing from rectangular buttress piers. Over the three centre arches the gable rises, and the buttresses of these arches rising through the entablature are finished off in the pediment crowning the gable.

The other two arches, one on either side, are finished off by a horizontal moulding to correspond with the pediment, and their buttresses end in pyramidal finials above the moulding.

New Loco Shops, Lahore.

Between the porch and the end gables, the flat line of the cornice is broken by a small pediment, rising by pilasters from the keystones of the two central arches. These pilasters terminate in the line of the cornice.

In the main corridor there are a number of fanlights to ventilate and light the passage. The stringing course of this corridor wall, in which the pilasters on each side of the fanlights terminate in small pediments, serving to break the skyline of the building, are also composed of concrete.

The effect of the concrete work has been to bring the design more into prominence, and the colour of the concrete moulded work, against the red of the remainder of the building as a background, has the effect of throwing out the detail work considerably. Also, if the details of the mouldings are examined, it will be easily seen that it would have been quite impossible to have done them with anything like accuracy or neatness in brickwork.

Thus the question practically resolved itself into finding something which would elaborate the design as much as stonework would, and which would at he same time cost much less and could be constructed fairly rapidly; for in getting out the estimates this point had not been considered and only moulded brickwork had been allowed for. Concrete was suggested as an experiment and a somewhat original idea—and, although no work of a similar character had previously been done by the Railway, the suggestion was adopted and as results have shown, has worked well.

The points in favour of concrete against stonework are, cost and rapidity of construction, and against brickwork, accuracy and effect; also it will be seen from the table given later that the difference in cost between the concrete and the rate allowed for moulded brickwork is not great.

The following is a table showing the cost per 100 c.ft. labour and material inclusive of the wooden moulds, for all the different types of work done; also the same table shows the cost of the wooden moulds per 100 c.ft. of concrete work done, which enables one to see what proportion of the total over-all rate was spent on the moulds.

CALCULATED RATES FOR SHINGLE AND CEMENT MOULDED WORK.

No.	Description.	Total quantity of shingle and cement moulded work of each description.	Cost of shingle and cement moulded work per 100 c.ft. (1) including cost of shingle and cement, (2) cost of woodwork, (3) labour.	Cost of woodwork moulds per 100 c.ft. of shingle and cement.	Remarks.
			Rs. a. p.	Rs. a. p.	
1	Flat stones under columns at verandah floor level	165 c.ft.	81 4 0	4 12 3	
2	Flat stones under bases of columns	139 ,,	103 2 0	11 5 6	
3	Bases of columns	52 ,,	159 6 0	54 4 3	
4	Columns	346 ,,	117 3 0	38 5 0	
5	Capitals of columns	55 ,,	159 6 0	64 0 0	
6	Arches	1,235 ,,	100 0 0	20 9 6	
7	Circular openings in haunches of arches	510 ,,	95 5 0	14 3 9	
8	Fillings for openings ...	105 No. (80 c.ft.)	578 2 0	37 8 0	
9	Cornice stones	5 034 c.ft.	85 15 0	9 5 9	
10	Balustrade	80 No. (30 c.ft.)	132 13 0	8 6 9	

Now the estimated rate for moulded brickwork in Lahore is Rs.60 per 100 c.ft., but it is never possible to get anything like well moulded evenly burnt bricks if the moulding is at all intricate ; the rate for stonework is Rs. 522 per 100 c.ft. Looking at these rates and the results, it is evident that the concrete work is best at the price. The objection might be raised that it is imitation work, but that is hardly true, as it is not intended that it should be mistaken for stonework, it is quite a style by itself.

In making all the mouldings two points were chiefly aimed at, cheapness and finish. Now, in order to get a good finish on

the face of the stones, a very fine shingle had to be used in a fairly rich mixture ; also the face of the stones was required to stand a good deal of wear, tear, and weathering, so it was necessary that the composition forming it should be tough. If all the stone had consisted of the same composition as the facing, the cost of the work would nave been exceedingly high, so after experiments, the following plan was adopted. The main body of each stone consisted of a composition of six parts of Pathankote shingle, small enough to pass through a $\frac{3}{4}$" screen, two parts of sand and one part of cement, a strong and cheap mixture. The facing of each stone consisted of a composition of two parts of very fine shingle, passed through a screen of six meshes to the inch, and one part of cement ; with this second mixture all the stones were coated on their exposed faces for a thickness of $\frac{1}{4}$ of an inch. This coating was not put on as a plaster but formed an actual part of the stone as will be shown later.

All the work was done in wooden mould boxes, which were designed very much after the style of mould boxes for cast iron-work with this exception, that there was always one open side to every box, from which the box was filled. It was always arranged that the side of the box which carried the moulded face should be at the bottom. This served two purposes—first, as already explained, all the faces of the stones were of a richer and finer composition than the body of the stone. By having the moulded face at the bottom of the box it was possible to fill to a depth of about $\frac{1}{4}$ of an inch with the required composition, and then ram gently with small wooden rammers to ensure that the angles and curves of the moulding were completely filled. As soon as this was done, the second mixture composing the body of the stone was filled in behind the face composition and rammed. Thus the two became homogeneous as, of course, it did not take more than a few minutes to fill and ram the first lot of concrete, which was therefore quite fresh and would bind with the second lot, when that was filled in. The second advantage of having the moulded face at the bottom of the box was, the filling behind the face concrete by its weight and the ramming it got all tended to make the first layer take up the exact shape of the moulding, and also when shrinkage occurred, as it did when the concrete started to set, the tendency was not for the concrete to leave the moulded face of the box. The above practically applies to all the stones which only had mouldings on one face, such as cornice stones, etc.

In the case of columns, the procedure was somewhat

different. The column moulds were in three lengths each 2' 5" long, and consisted of hollow cylinders the required diameter, having the necessary curves ; thus each column consisted of three separate stones. In order to use only the facing concrete on the perimeter of the column a circular galvanised sheet iron cylinder was made ½ inch less in diameter than the column mould, and when filling the mould this cylinder was put inside and the space of ¼ inch between the cylinder and the mould was filled, with the facing mixture. Inside the cylinder the coarser mixture was filled, then the cylinder was withdrawn and the concrete rammed. This filling was done in 6 inch layers and it was found that this gave the required results.

In the actual mixing of the concrete for this work, proportion of water used, etc., what has already been said with regard to the ferro-concrete work applies to the above also.

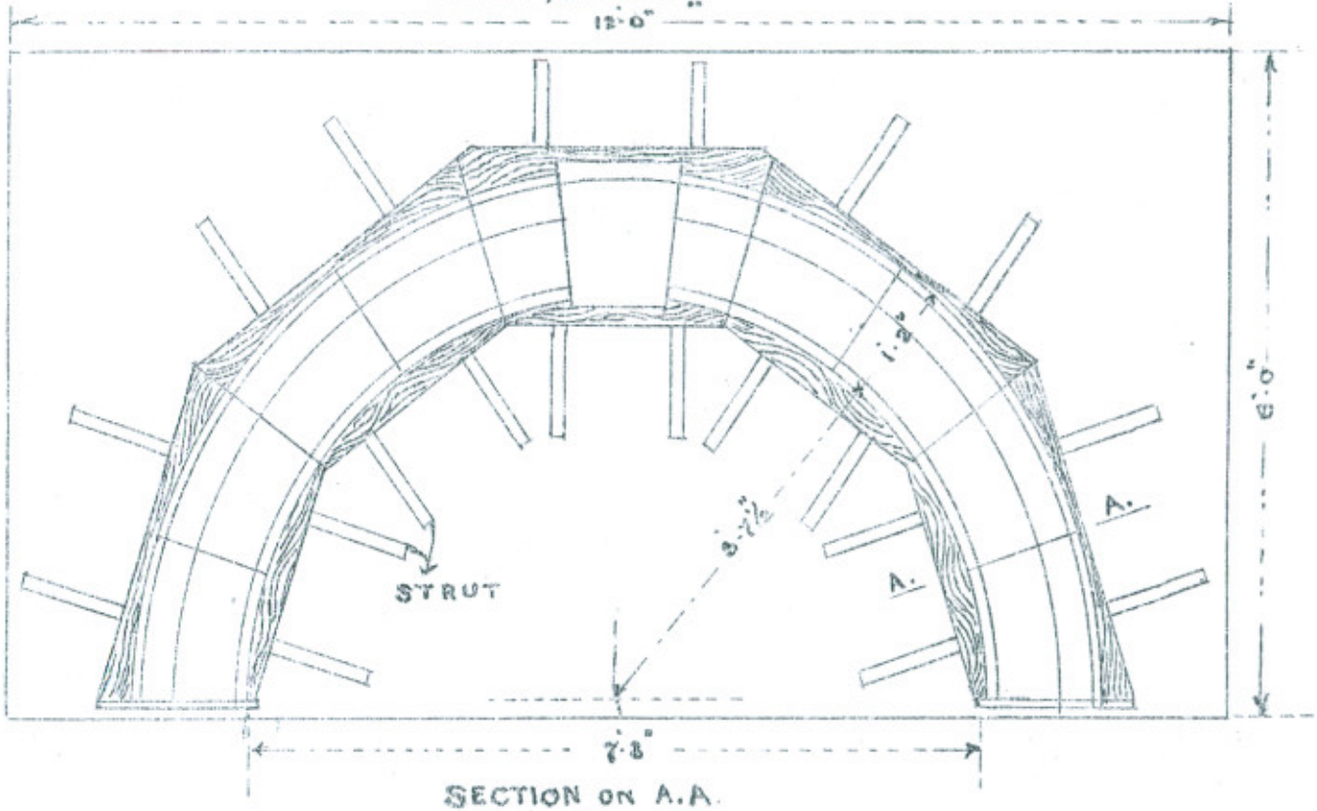
It might be suggested that there would be a tendency for the two mixtures of concrete used not to combine, as sometimes happens in the case of floors, when the wearing surface is of a different composition to the main body of the floor, yet that tendency was not evident. Several of the stones which turned out failures were broken up to see if this was the case, but beyond the fact that it was quite apparent two different mixtures had been employed, there seemed to be no tendency for them to separate.

All the mould boxes were made of well-seasoned deodar wood and were so constructed that they could be taken to pieces to get the stones out, for in many of the stones there were re-entrant angles. In certain mouldings such as arches where at the bottom of the moulding there is a bead moulding, this portion of the mould was made of kikar wood, as deodar was too soft and would not give the fine lines required ; similarly in all cases where sharply defined lines were required, that part of the mould was made of kikar wood. In the case of the semi-circular arches one complete mould the size of the full arch was made with five divisions in it ; these divisions merely consisted of thin sheet iron plates sliding in grooves cut in the vertical sides of the mould. The whole mould was built on a plane surface consisting of 2 inch thick wood planks battened together as a foundation which ensured the arch being perfect, as it was first carefully drawn out on this background and then the pieces composing the mould fitted to the drawing. When the stones were taken out of the mould they were labelled in such a way as to ensure the same

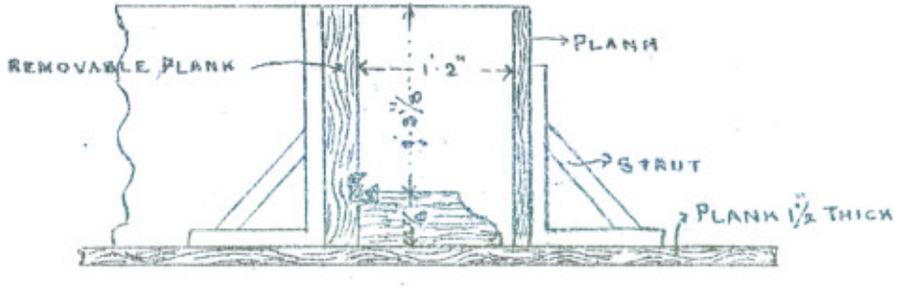
NEW LOCO SHOPS
LAHORE

PLATE. D

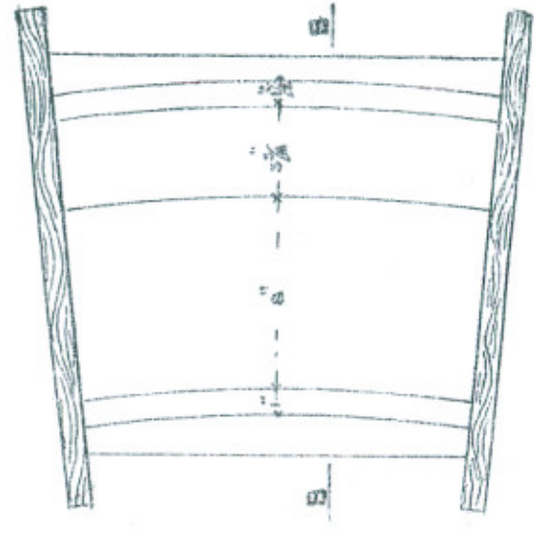
MOULD BOX
FOR FRONT SEMICIRCULAR ARCHES
SCALE 3/8" IN = 1 FT



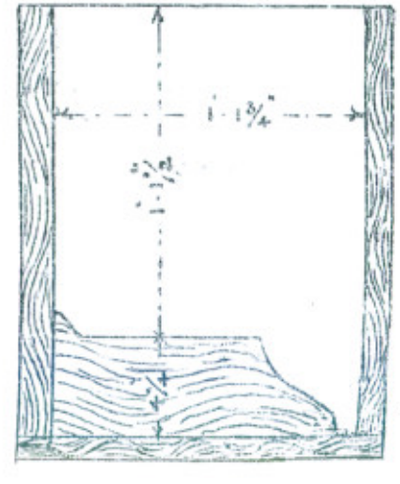
SECTION ON A.A.
SCALE ½" IN = 1 FT



MOULD BOX
FOR WING ARCHES
SCALE 1" IN = 1 FT



SECTION ON B.B.



stones coming next to one another in the actual work. In the case of the other arches there were only one or two moulds made in which one stone only of the arch could be made at a time ; but the advantage in this second method was that the stones thus made were interchangeable and so the same care in labelling was not required ; also, if a stone turned out a failure, it did not affect the remainder of the arch in the same way as in the first case. The cost of the mould itself worked out cheaper, the elaborate arrangements to hold the component parts of the semi-circular arch together not being required in the case of the single mould.

Plate D gives a plan and section of the semi-circular arch mould and also a plan and section of the mould used for the segmental wing arches.

All the mould boxes were rubbed with oil before being filled and after a box had been in use some time, it was found that it had absorbed sufficient oil to do away with the necessity of oiling. The oiling also had the effect of preserving the wood and preventing warping.

The percentage of failures in making the stones was exceedingly small, working out at about one per cent.

This has probably been the first time any attempt has been made to use concrete in architectural work to any large extent, up in this part of India at least, and there certainly seem possibilities in the idea. The results are undoubtedly good and the experience gained from this first attempt would probably make it possible at another time to produce a better and cheaper class of work. The appearance of the work does not fall far short of stone ; in fact the details of the mouldings are better than could be got in stone, and the more elaborate the mouldings the better it lends itself to the work.

DISCUSSION.

On the motion of the chairman, a vote of thanks to the N. W. Railway authorities and Mr. Inglis, Carriage and Wagon Superintendent, for the arrangements made to shew the Congress their workshops, was passed, and also one thanking Mr. Bennett for his donation of Rs. 100 towards the Congress funds. Mr. Bell was then asked to introduce his paper.

MR. BELL on rising emphasised the fact that the paper was not written with the intention of going into details of strength and stresses in the case of the ferro concrete, but merely to give a description of the work and how it had been carried out. He had not been concerned with the designing of the columns, but had merely been instructed to devise a method for constructing them. He was responsible for the composition of the concrete used in the construction and had personally superintended the work. Certain modifications had been made in the original design, but these were more with a view to facilitating construction than in any way modifying the principles on which the design had been based, and, although the author had not the designer's calculations, he was ready, to the best of his ability, to answer any questions which might be raised regarding the design itself. The paper omitted to explain the necessity for adopting reinforced concrete columns 3'-6" × 3'-6" to carry a wall, which it might be urged could have been carried on brick piers, by increasing the area of the pillars and spacing the arches farther apart. The positions of the arches were, however, regulated by the erecting pits of which there had to be a certain number in the erecting shops. The pits running parallel to one another, extend the whole length of the shop, and the closer they were together the fewer 40-ton cranes were required to serve the pits. Each pit had a line leading from it out of the shops, and the result of having the pits so close together was that there was only a very limited amount of room between the lines for the piers.

Regarding the second portion of the paper, the author pointed out that most of the members of the Congress had probably noticed the concrete facework used in the new Loco. Superintendent's Office when driving down to the Carriage and Wagon Shops that morning, and he would be interested to hear their criticisms.

MR. MONTGOMERY pointed out that on the Simla Hydro-Electric Work, where Captain Battye had used more complicated form of reinforced concrete construction than had perhaps been attempted elsewhere in Northern India, it had been found advisable to use wet concrete as is done in England, and refrain from ramming it to any great extent. The concrete was worked in with iron bars round the reinforcement.

MR. DORMAN said, if it would not be going outside the limits of the paper, he would like to ask the author for some particulars of the soil under the piers of the Loco. Shops. From the figures given in the paper, it appeared that the pressure intensity on the foundations was about 2¼ tons per square foot. The Military Works Hand-book of Specifications lays down that, in the loamy soil of Upper India, the pressure should not exceed 0·8 ton per square foot, and in Punjab P. W. D. Paper No. 55 a pressure of 1¼ tons has been prescribed for original ground. In the Railways, despite the liability to vibration from passing trains, a much greater intensity is apparently permitted than in the Buildings and Roads.

The actual intensity of pressure on the piers at ground level works out to less than 10 tons per square foot. The four inch cubes of the same material crushed after twenty-one days setting at 23·4 tons, equal to 210 tons per square foot. Mr. Dunn mentions in his "Lectures on Reinforced Concrete" that, when six-inch test cubes gave 2,880 lbs. per square inch, the same concrete tested in a pillar fourteen inches square and twelve feet high gave 2,500 lbs. so that it may be safely assumed that, the Loco. Shop piers will stand as much as the test cubes, especially as the concrete in the latter cannot have attained anything like its maximum strength in twenty-one days. The factor of safety in the pillar on this assumption would be over 20 without taking any account of the reinforcement, so, as far as the dead load was concerned, the column might have been built of plain Portland cement concrete on somewhat similar lines to the excellent concrete work in the Loco. Superintendent's Office which has been described in the second portion of the paper, or even of stone laid in cement mortar.

The author has, however, stated that the reinforcing rods were introduced to counteract stress induced by wind pressure on

the high wall. If the pillars and wall act as a single unit it would seem that the reinforcement in the pillars had been calculated to resist a pressure of about 30 lbs. per superficial foot of wall surface. The great care taken to complete each pier in a day, however, would seem to have introduced a plane of weakness at the junction with the brick work on top of the pillar. With 30 lbs. wind pressure the resultant would fall twelve inches outside the edge of the wall at the joint where seventy per cent. of the roads end, and where the concrete had been finished off and kept covered with damped sacking and grass for a month. The strength of a chain is the strength of its weakest link, and there was no use in reinforcing the pillars to take 30 lbs. wind pressure on the wall, when the wall itself would have been blown down off the top of the piers long before all the reinforcement would have come into action. The roof and buttress piers to carry the gantries inside the building would help to steady the high wall in a gale, but, if the wall was to have been of equal strength to the piers to resist lateral pressure, the piers should have been calculated as cantilevers and taken some distance up the wall, thus dividing the wall into panels which might also have been reinforced horizontally.

Finally, assuming all above ground to hold together in a gale, the pressure on the foundation would no longer be uniformly distributed. The plane of the resultant pressure would cut the base within twelve inches of the leeward edge of the concrete, and would induce a maximum pressure on the toe of nearly 7 tons which no Lahore soil will stand. This again shews that the reinforcement, if at all necessary, was out of all proportion to the actual requirements. Had the foundations been designed in reinforced concrete to resist shear and overturning, they would have been cheaper than the solid foundations used.

MR. NICHOLSON said that any one seeing the new Railway Offices that morning, could not but appreciate the relief afforded to the eye, by the effect of the artificial stone or concrete, compared with a building of brick. On the Upper Jhelum Canal in the construction of Suketar II level crossing, which was mostly built of brick, string courses, cornices, etc., of stone had been introducod, and the small extra cost (covered by savings elsewhere) was well repaid by the artistic effect produced. This procedure had subsequently been adopted in the constuction of the level crossing at Baloki. The

rate of the stonework given in the paper appeared high. The cost of stone roughly to dimension would be not more than Re. 1 a cubic foot in Lahore, and smooth dressing of the face or point dressing 14 or 6 annas, respectively.

Mr. Nicholson had recently had an opportunity of seeing the new Ganges Bridge at Sara Ghat in course of construction, where the whole of the masonry work was being done in concrete. The wells were made of large moulded blocks of concrete 1: 3: 6, and the piers of smaller blocks from the finer material obtained from the Baxter's stone-crushers. These smaller blocks were about 2' × 3' × 1', and were made of a 1 : 2 : 4 mixture, in cast iron moulds laid in a surfaced floor. The concrete was put into the moulds sufficiently wet to enable it to be worked with small spades about 3" × 3". No special material was used for the faces (which are vertical ones) but careful working of the small spades on the faces brought up a good smooth surface. The moulds were so arranged with cotter pin joints that they could be opened and removed without in any way disturbing the blocks. In this way three blocks could be made per mould per day. The inside of the cast iron moulds, which were machined all over, were only white-washed to prevent the concrete adhering to the moulds. Another point of interest was, that the cement used was obtained from the India Office in iron drums instead of wooden barrels. The cost was only 9 annas extra per drum, and, when empty, the drums could be put to some use, whereas no one seemed to have discovered a real use for empty cement barrels. It was self-apparent, that the iron drums kept the cement from the effects of the atmosphere, and there was no loss in transit owing to barrels breaking.

It was evident that the question of the wetness of concrete was a point open to much discussion. It would appear that the object to be obtained was to overcome the cohesion of the unset mortar so as to cause it to settle into all corners of the mould and leave no voids. There were two distinct methods of procedure, ramming or exerting force on a dry mixture which had considerable internal cohesion ; and poking or working a wet mixture which had but little cohesion. The two methods were entirely distinct, and to try to ram a wet mixture was useless, as it caused the aggregate to segregate which was the one thing to be avoided. It appeared to be a much surer method to work a wet mixture into the mould, as it was more

certain and cheaper. It was of course assumed that the mixture was not wet enough for segregation to take place.

MR. BELL, in reply to Mr. Montgomery's suggestion that it was preferable to use a comparatively wet mixture in reinforced concrete, said that this was, to a great extent, a matter of opinion. No two authorities seemed to agree upon this point. Mr. Bell preferred a dry concrete well rammed ; that is to say, a concrete in which there was sufficient water to hydrate all the cement present, and this was insured by the addition of 45 to 50 per cent. by weight of water to the quantity of cement. In a wet concrete, (one which became jelly like under ramming), there was a tendency for voids to form through an excess of water, which materially weakened the concrete. Also, as it was impossible to ram such a concrete thoroughly, one could never be confident that the reinforcements were properly in contact with the concrete, which was one of the essential points in reinforced concrete work. A very good practical way of judging whether there was sufficient water in the mortar used in a concrete, was to take some mortar in the hand and roll it into a ball. This ball when dropped on to a hard surface from a height of about 18 inches, should retain its form without breaking.

In answer to Mr. Dorman's question, the soil on which the foundations of the piers were laid, consisted of a hard solid clay with a certain quantity of sand and kunkar intermixed. This clay appeared to be of considerable depth, the excavation in places having been taken down over twelve feet. The foundation pressure, which Mr. Dorman worked out at about $2\frac{1}{4}$ tons per sq. ft., was not, the speaker considered, excessive for the quality of the clay met with. To work to a rule laid down for foundation pressure over such a large area as Upper India, where necessarily the weakest soil must be considered as the average, would tend to limit the initiative of the Engineer, and prevent him taking advantage of favourable circumstances. The actual result in the present case justified the pressures worked to.

Mr. Dorman gives two reasons for not building the pillars in the New Loco. Shops, of reinforced concrete.

(1.) The intensity of pressure due to dead load was not great enough.

(2.) There was a plane of weakness where the arches and brickwork sprang from the pillars. Mr. Dorman also suggested

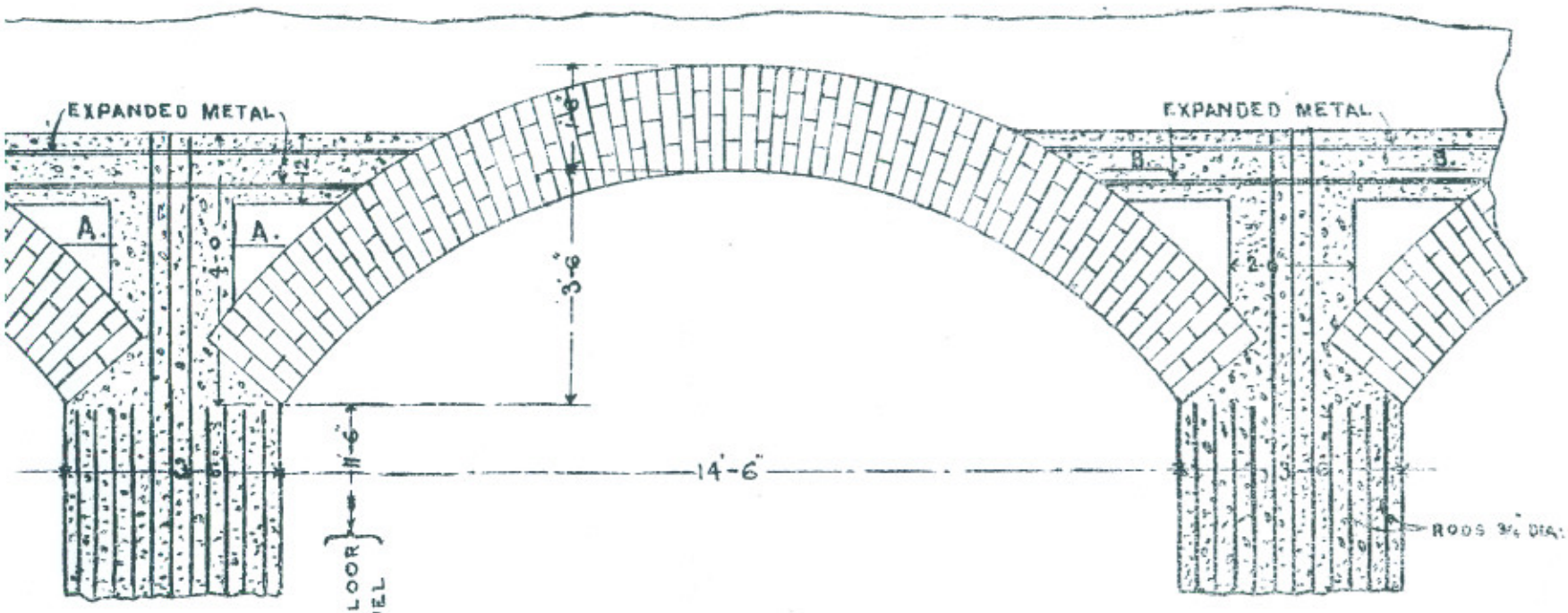
that, even supposing the reinforced concrete pillars necessary, it would seem that the intensity of pressure on the toe of the foundation, due to wind pressure, would have been excessive, from which it followed that the foundations had not been properly designed, and it would have been better and cheaper if they had also been designed in ferro-concrete. In support of his first argument Mr. Dorman quoted certain tests made by Mr. Dunn, which gave compressive stresses of 2,500 lbs per square inch on a test column, as against about 160 lbs per square inch stress on the columns in the New Loco. Shops. The great point about these two figures was that, in the case of the first they were laboratory tests, made under the most favourable circumstances and by an expert at that description of work, and the second was a working load. In practice it was usual to allow from 360 to 500 lbs per square inch as a working load for pure compressions, so that the figure worked to in the New Loco. Shops did not seem too small, considering climatic and other disadvantages under which the work was carried out, as already described in the paper, as against the experienced labour and up-to-date appliances employed by firms in England.

With regard to the second point a reference to plate B would show that the reinforcing rods at the centre of the columns projected 4 feet up into the wall above. The drawing did not make it clear however how the reinforced concrete was constructed above the springings, as the drawing was really part sectional and part outside elevation. Mr. Bell had therefore proposed another drawing. (Plate E) clearly illustrating this point. As soon as the arches had been built, a box was formed of brickwork round the rods, fourteen in number, which had been continued upwards. The internal dimensions of this box were 2' × 2'-9", as shown. Where the rods terminated, it was formed into a T, the arms of which butted up against the haunches of the arches and were reinforced with sheets of expanded metal. It was true that this upper piece of reinforced concrete was constructed one month after the main columns, but every effort was made by chipping and grouting the old surface with neat cement and fine chippings to make the joint as efficient as possible. This did away with the line of weakness at the springing of the arches, where the total stresses, due to wind pressure on the wall, fell on a reduced sectional area. Above, where the rods and concrete ended,

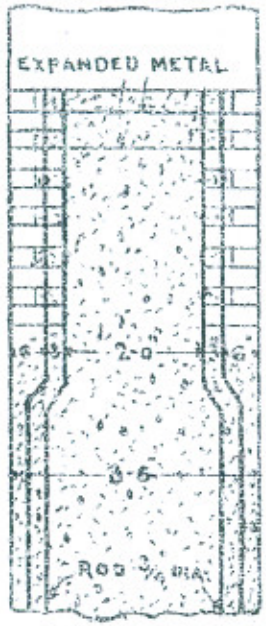
ABOVE SPRINGING OF ARCHES

NEW LOCO SHOPS
LAHORE

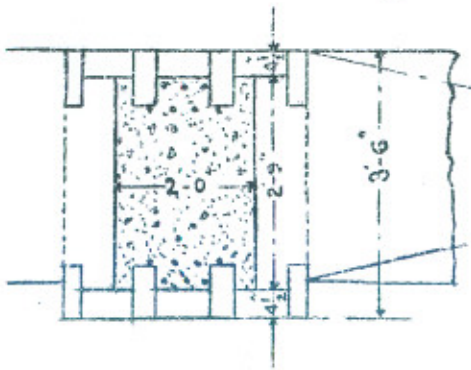
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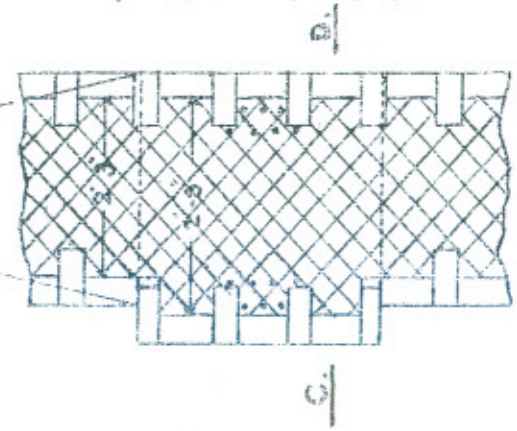
SECTION ON C



PLAN AT A.A.



PLAN AT B.B.



the wall was continuous and therefore had only to be designed to answer the requirements of an ordinary wall under ordinary conditions, and it was not necessary that the columns should be projected further into the wall or otherwise tied to it in any way.

In connection with the third point, Mr. Bell agreed with Mr. Dorman that, if the reinforced columns and their foundations stood on a plane surface without any lateral support, there would be a pressure at the extreme edge of the leward toe of about 7 tons per sq. ft. due to a wind pressure of 30 lbs. per sq. ft. on the walls. But just as the base of the foundations was capable of taking a pressure of $2\frac{1}{4}$ to $2\frac{1}{2}$ tons per sq. ft., so were the walls ; and this was a most important point. It must be remembered that the foundations went down to a depth of ten feet below ground level and as they consisted of the same solid clay as that which formed the base, they were capable of taking an equally large pressure. Thus any tendency to increase the pressure on the foundations, which could only happen if the column tended to overturn, would create a lateral pressure on the walls of the foundations and set up a couple which would take as much pressure as the base of the foundations themselves. It was for this reason that the rods were projected down into the foundations. A line of discrimination must be drawn between the conditions of a brick wall standing on a concrete foundation in which there is no cohesion between wall and foundation, and a reinforced column which is tied to its foundations by a great number of rods. The whole aim in building these columns had been to get a homogenous mass equally capable of taking tension as well as compression. A simple illustration was the difference between the tendency of nail standing on its head on a table to overturn as against that tendency when the nail is driven for a distance of about quarter of its length into the wood of the table. If the figures for the tensile and compressive stress at the ground line of the columns were worked out, it would be found that at the extreme outside edge of the columns, the maximum tensile stress was about 48 tons per sq. ft. and this surely justified the adoption of reinforced concrete. Also throughout the length of the column there were heavy tensile stresses due to wind pressure varying from 29 tons per sq. ft. at springing line to 4 8 tens per sq. ft. at ground line. This was mentioned as it went to prove that neither concrete alone nor stonework, as suggested by Mr. Dorman could have been substituted in place of the reinforced concrete. Also the cost of stonework in Lahore, as

stated elsewhere in the paper, was considerably higher than reinforced concrete.

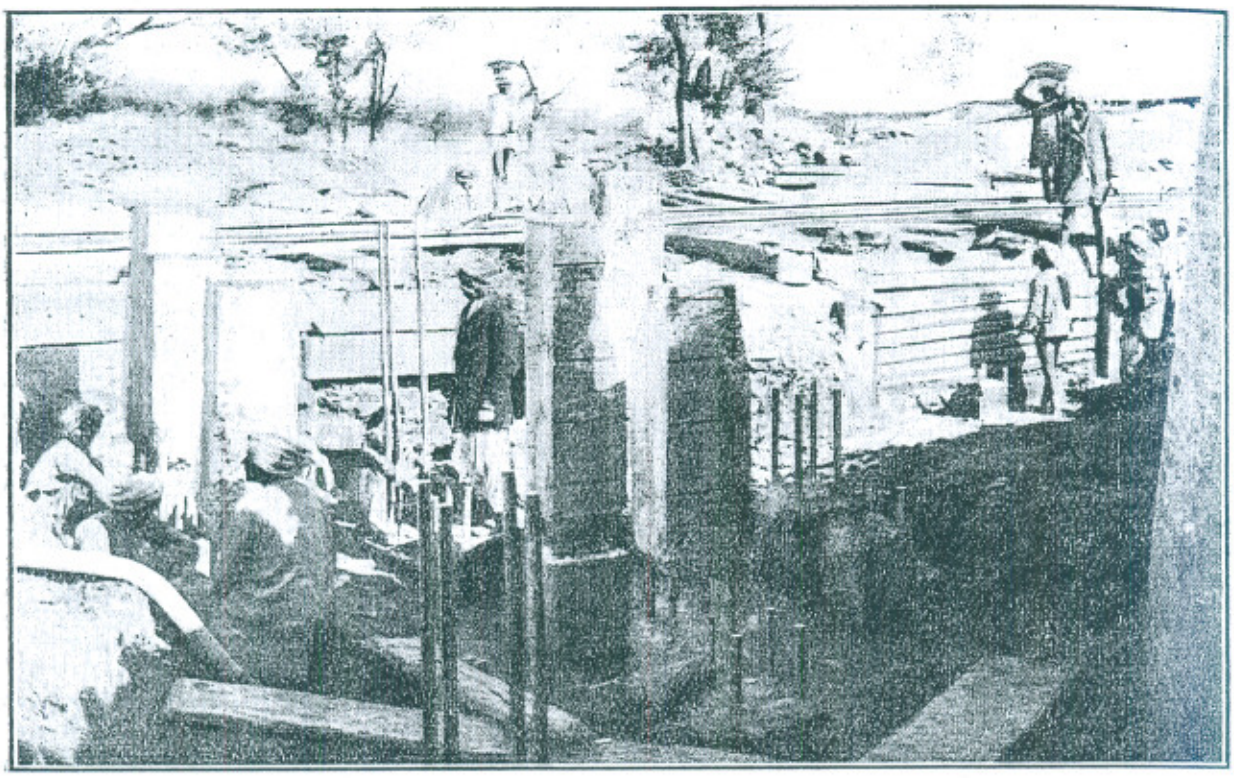
Mr. Dorman has also suggested that it would have been cheaper if the foundation had been designed of reinforced concrete. The overall figure for the work was Rs. 105, but for the concrete in the foundations it was Rs. 80 per 100 c.ft., as against Rs. 220 c.ft., for the reinforced concrete. This would mean that a reinforced concrete foundation would have to be nearly one-third of the dimensions of those used to be economical. It might be possible to design a foundation which would answer these conditions and, at the same time, fulfil the practical requirements of construction and the speaker would be very interested to see such a design.

Thus it was clear that neither concrete alone nor stonework would have been able to stand the tensile stresses which exist in these columns and against stonework there is the further objection of cost. This also excludes any question of a steel-work structure and, under the circumstances, it appears that reinforced concrete was admirably suited to the requirements.

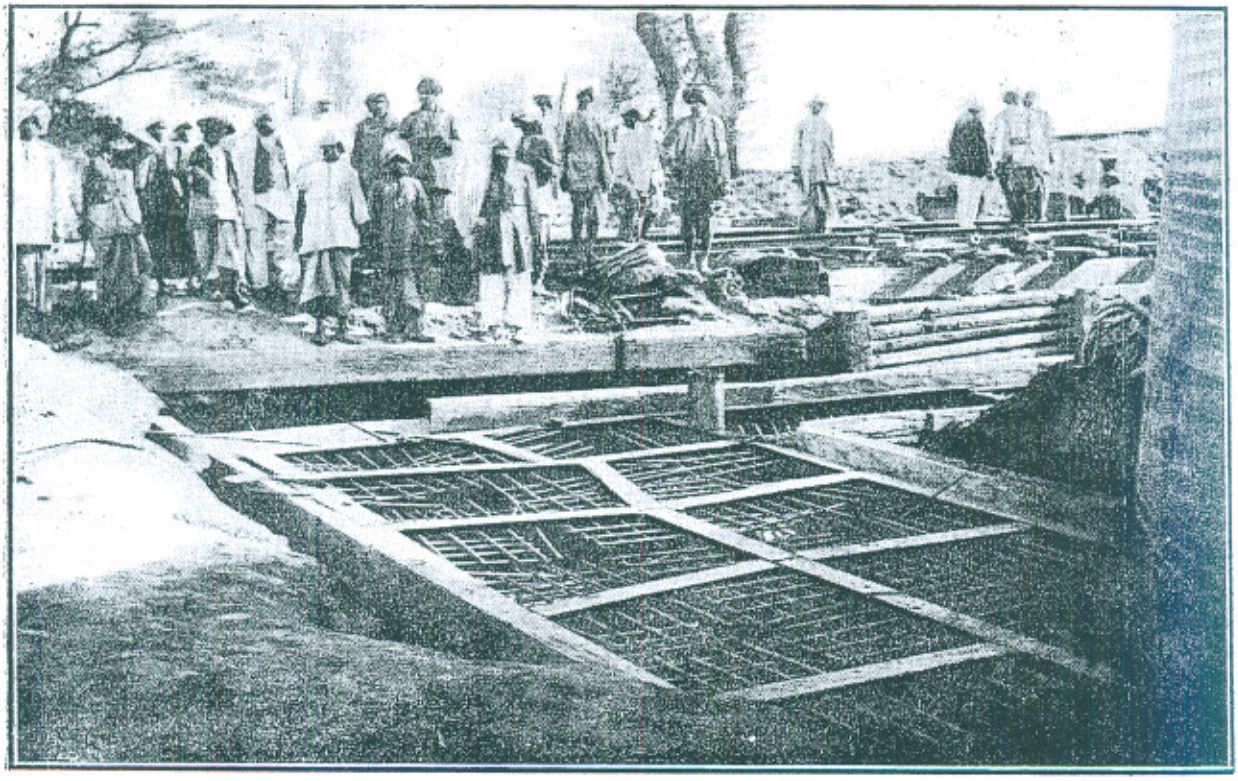
The CHAIRMAN said he thought Mr. Bell had answered most of the questions. Personally he had not been able to follow all the calculations and there appeared to be some discrepancy between Mr. Dorman's figures and Mr. Bell's which could be investigated by those taking an interest in the subject.

As regards the permissible pressure on foundations, Colonel Maclagan mentioned that some ten years ago, when Under-Secretary, he had been put on by the Chief Engineer to write a note on this subject. He had worked out the pressures for several of the principal buildings in Lahore, and, though he could not remember the exact figures (they varied considerably) some of them were really high—the Chairman thought over three tons— and the buildings stood all right.

The use of concrete for stone mouldings, the Chairman thought, might be more general and probably would be when a good cheap cement could be locally obtained. In conclusion, the chairman asked the meeting to pass a vote of thanks to Mr. Bell for his very interesting paper.



Cutting pile heads to level after driving.



Reinforcement of slab ready for concreting.