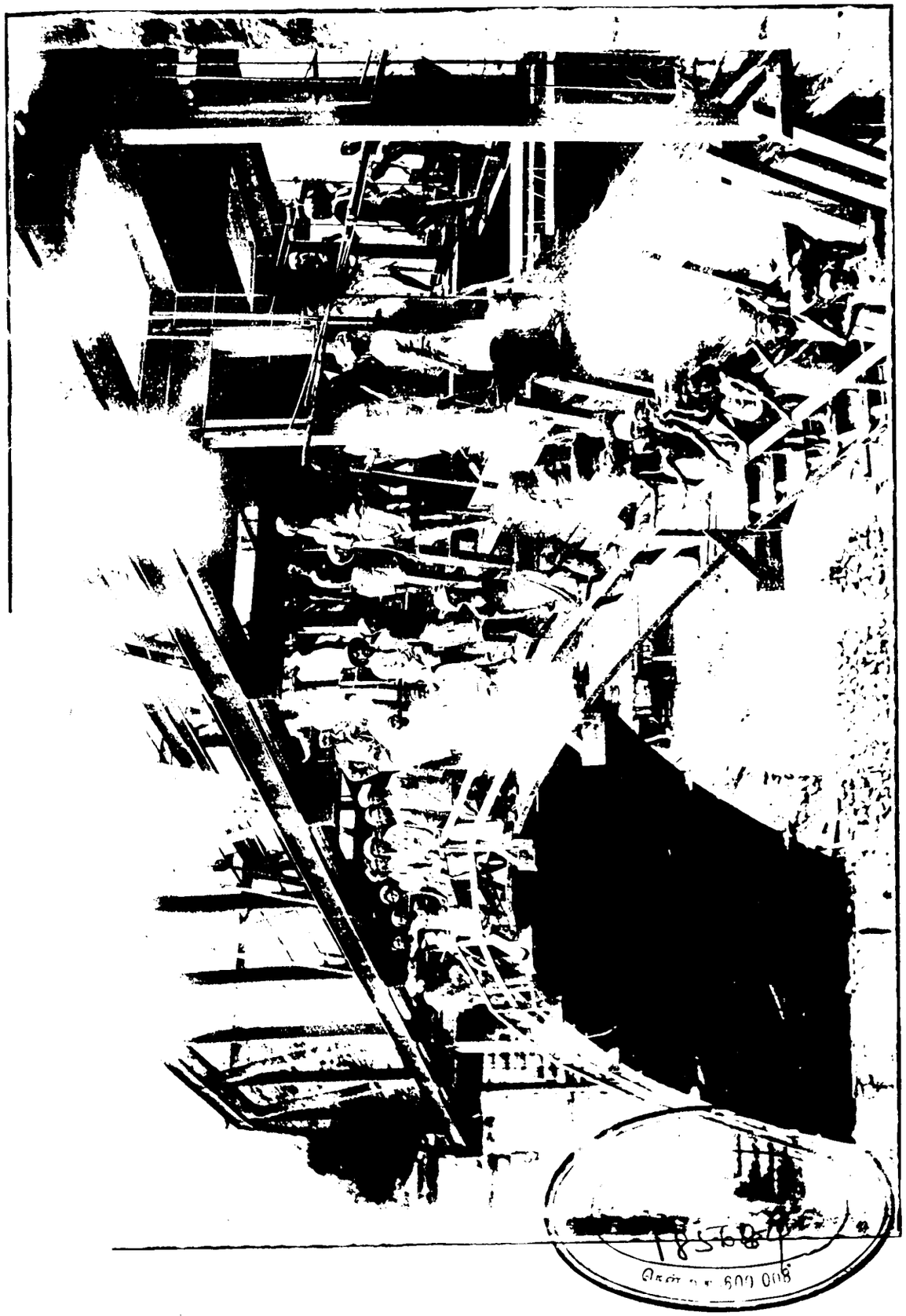
Parappar Bridge in Travancore.



support the full weight of one arch rib. The device was then hit upon of providing on staging suspended from the old girders two light reinforced concrete temporary arch ribs exactly to the curve of the permanent ribs and turn the permanent arch ribs over these temporary ribs, the temporary ribs being arranged to be cut out and removed after the completion of the whole work: The temporary ribs were designed to be 3′ 6″ broad by 10″ thick from end to end, reinforced with 12 rods of $\frac{5}{8}$″ dia. near the intrados, and an equal number of rods near the extrados, the whole tied together with stirrups of 1″×$\frac{1}{8}$″ flat iron. The permanent ribs were to be 2′ 0″ wide throughout and their depth was to be 6′ 0″ at the springings and 3′ 3″ at the crown. The reinforcement was to consist of 7 rods $1\frac{1}{8}$″ dia. along the intrados and the same along the extrados and stirrups of 1″×$\frac{1}{4}$″ flat iron going round all the rods. On the arch ribs were to be raised reinforced concrete columns 18″ × 12″ at 10′ centres. These were to be spanned by longitudinal and cross beams on which was to come the deck slab 8″ thick, designed as a square slab reinforced with $\frac{5}{8}$″ rods in both directions spaced 4″ centre to centre in the middle, the spacing gradually increasing to 9″ near the beams. A clear roadway of 14′ was to be got by canti-levering out the slabs. The blocking course and parapets were also to be of reinforced concrete, the latter presenting a fine appearance.

Details of design.

6. The staging for the temporary ribs was to consist of 4 lines of heavy angle ribs 6″ × 6″ × 0″. 45 bent exactly to the required curve, 2 for each concrete rib placed at the distance of 3′ 9″ clear between the legs of the angles which were to be placed with their table downwards. The distance from centre to centre of one pair of angles on one side of the bridge to the other pair of angles on the other side was to be 10′ which was also to be the central distance apart of the temporary as well as the permanent concrete ribs. Each angle rib was to consist of 5 segments joined with fish plates and bolts. Each of these ribs was to be supported by one pair of suspension rods 1″ dia. from each cross girder of the old bridge, the rods to pass not through the flanges of the girders but just by the side of them through small plates about 12″ × 2″ × $\frac{1}{2}$″ placed across the top flange of the girders, one plate for each pair of suspenders, which were all to be threaded for 6″ at each end and provided with nuts and washers to admit of the curve of the arch being accurately adjusted. There were 9 intermediate cross beams in the old bridge at 12′ 6″ centres. There were therefore 72 suspenders on the whole at 18 for each angle rib. Across these angle ribs and resting on their tables were to be placed the laggings on which the temporary arch was to be turned. The angle ribs were to be stiffened with horizontal and diagonal braces of angle iron. In addition to these main angle ribs there were to be 6 light angle carriers and one T carrier all bent exactly to the curve of the main rib for carrying the planking of the gangways. These carriers were to rest on cross beams of timber bolted to the underside of the main ribs by the suspension rods. After the temporary concrete rib is turned on the staging thus provided for it,

Details of the staging.

and after the concrete has had time to set, timber posts 6" square were to be erected on the temporary rib one between each pair of suspenders and tightly wedged up against the underside of the cross girder of the old bridge. These posts were for taking any upward thrust that might be induced in the supported points of the temporary rib by the weight of the permanent rib while the latter was being made, the downward pull, if any, on the arch being taken by the suspenders. As these stresses will vary in intensity and kind as the permanent arch rib is laid portion by portion, these posts were provided at every supported point of the temporary rib. The permanent ribs were then to be turned on the temporary ribs after providing suitable boxing. The permanent ribs were to be tied together near the springing by a horizontal diaphragm of reinforced concrete 19" thick extending up to the first pair of columns. Beyond this there were cross diaphragms connecting the ribs below every pair of columns. Four pairs of columns which will be partly below the maximum flood level were also connected with thin walls of concrete to strengthen them against shocks. After the permanent ribs were turned and given about three months to set, the columns, deck beams and slab were to be laid. The forms for the columns, beams and slab were of the usual kind and call for no detailed description. The whole credit for evolving this ingenious system of construction and settling every detail connected with the design is due solely to the Chief Engineer Mr. Bastow who to the great regret of all connected with the execution of the work had to be away in Australia for most of the time the work was in progress.

Arrangements for the work.

7. The locality where the bridge was to be built is very feverish especially in the summer months from February to May. All the labour needed for the work had to be imported from Shencottah on the east or from Kottarakara and Quilon on the west. It was our experience that in such places work is not done satisfactorily or rapidly by contract. This work besides had so many novel features about it that could not be safely entrusted to a contractor. It was decided to have the whole work done departmentally. It was considered essential that a subordinate should be posted specially for this work, and accordingly Apprentice Engineer Mr. Philip was posted to Thenmalai towards the close of November 1912 to hold charge of this bridge work and of the work "constructing buildings at Thenmalai for the Forest Department" for which an estimate for about Rs. 30,000 had been sanctioned and work commenced. He was on the work till the permanent ribs were turned in February 1914 when he was transferred to Nagercoil having been promoted to the Assistant Engineer's grade; and his place was taken up by Mr. K. Narayana Pillay, M. A. B. Sc., Supervisor.

Coolies' lines and work sheds were arranged to be put up. The left bank of the river was steep and there was no space there to put up sheds. Only one small shed was put up on that side later on for mixing all the concrete needed for the left half of the bridge. There was ample space on the right bank, and here were put up all the other sheds. One large shed was built close to the river for mixing concrete. Higher up and close to the road was put up another large shed for stacking cement and iron materials and one end of it was partitioned off into a room for keeping tools and small stores. Further up 3 lines were put up for the coolies to live in. On the other side of the road and close to the river was put up a work shed for the carpenters and blacksmiths to work in, and above it were the maistry's quarters. Higher up on the hill was put up a hospital shed, and some distance away even a contagious disease shed. As stated before, the place is very unhealthy and it was thought best to have a medical officer on the work to see to the sanitation and health of the camp and administer medicine. Temporary sheds in a place like Parappar where jungle wood is abundant and *Etta* reeds and *Bothai* grass are plentiful do not cost much. All the sheds were put up before March 1913 and the Medical Officer, an Apothecary on Rs. 100 reported for duty that month.

Materials for the work.

8. The materials most needed for the work except of course cement and iron were readily available close at hand. The large amount of timber needed for the falsework was supplied by the Forest Department on indents furnished them. There is an extensive area of splendid virgin forest in the Shendurni valley where that Department have been for some time previously working a saw mill by steam power at a distance of about 10 miles by road from the site of the work and they were therefore in a position to supply without delay all the timber needed in scantlings. Any little sawing that might still be necessary could be done by manual labor at the bridge site. Good blue granite rock for concrete metal was available all along the road quite close to the bridge site, although some of the piece-workers for its supply chose to bring it from a distance of about 2 miles where they found stone of quite good quality but a little less tough and slightly easier to break. Excellent sand was available in the river bed at the bridge site, clean, coarse and sharp. Lime and surki needed for masonry was got from Quilon by train. All the cement used was Gillingham's Hand Brand sent to Thenmalai by train from Quilon out of the general supplies for the Department. Most of the reinforcement rods were received from the General Stores at Trivandrum *via* Quilon while the long rods $1\frac{1}{8}$" dia. needed for the reinforcement of the permanent ribs were got direct from Messrs. Walker & Co., Colombo. The order for the mild steel centring with detail plans and full specifications was placed by the Chief Engineer with a firm in England and it was all received complete with clear erection marks early in August and needed only fitting up at site.

Preliminary works.

9. Actual work in connection with the new bridge was started early in November 1912, on receipt of plans of the skewbacks. These were to be of reinforced concrete with the reinforcement for the temporary and permanent ribs sticking out of them sufficient-

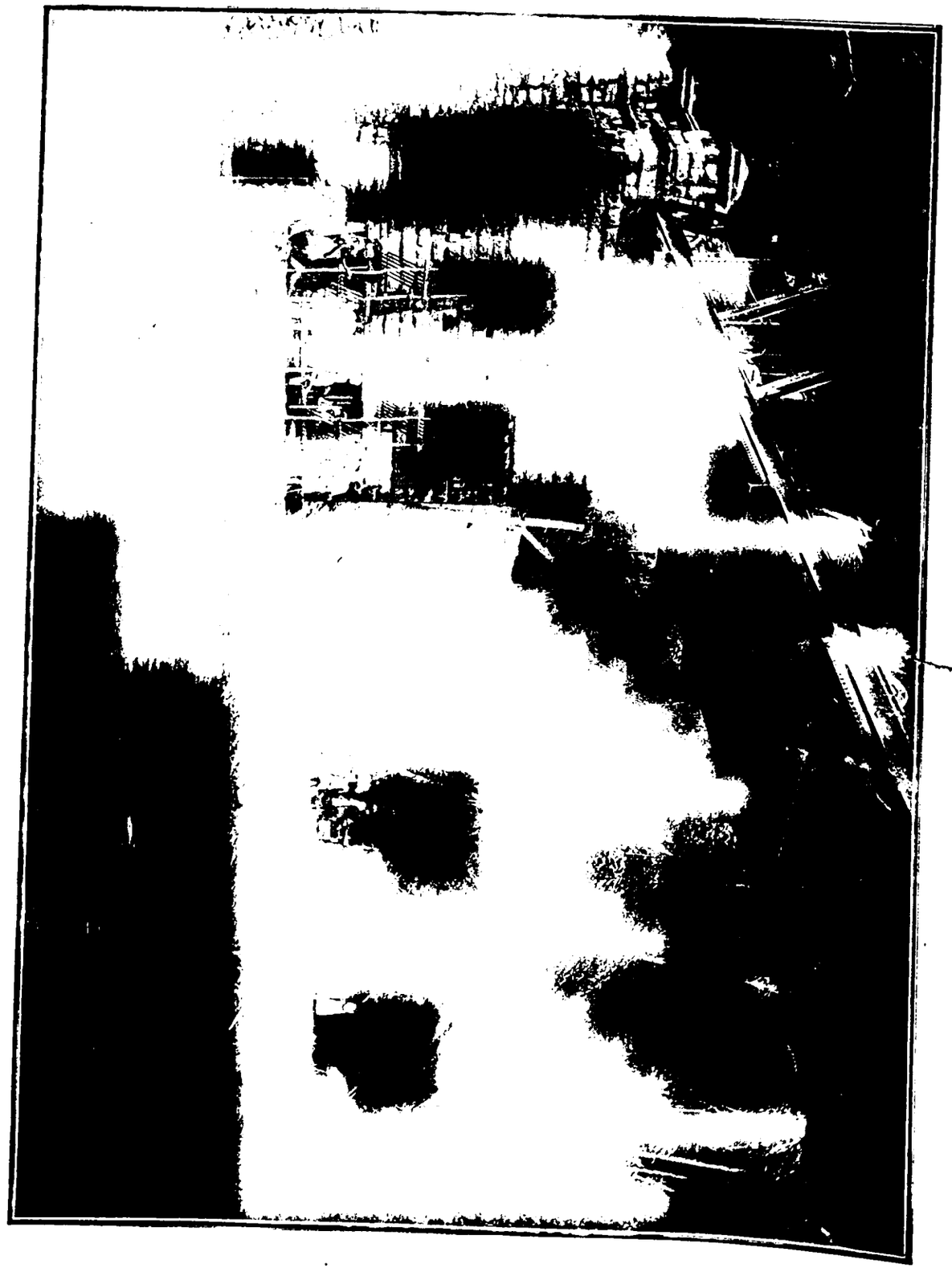
ly for overlap. They were to be let 3′ into the masonry of the abutment and made 4′ broad by 10′ high at the back to distribute the thrust of the arch over a large area of the old masonry. It was the work of cutting out these large recesses in the coursed rubble masonry of the abutments that was started early in November. The masonry above would not stand if left unsupported for the full width of 4′. What was therefore done was to cut out first narrow grooves about one foot broad at either end of the 4′ width, insert uprights of double headed rail at the ends of these slots and wedge up and support the masonry above and then cut out the centre portion of the recess. The cutting out had to be done by stone masons and was a laborious process. To facilitate the laying of the skewbacks and the erection of the staging and other works to be done from near the abutments, temporary platforms of rubble masonry were built alongside of them for their full length. The width of the platforms was about 10′ and they were raised to the level of the springing of the arch. These appear prominently in some of the photographs and proved to be of great use in all the stages of the work.

Strengthening the Abutments.

10. It was considered desirable to add to the stability of the abutments, especially the right one, by a backing of concrete carried up to the level of the springing of the arch ribs. Before arranging for this, the old ramps leading down to the river were improved and a junghar for taking carts across the river was provided about a hundred yards below the bridge site and the bridge was closed for traffic. The back of the abutments was excavated down to where the footings of the wings met, leaving one block of masonry below. The necessary plant for the grouting of the abutments as described below having been got ready in the meanwhile, the joints of the old masonry were very effectively cleaned out by a jet of water under pressure let down from a cask placed on the top of the abutment and the necessary surki concrete backing was laid in both the abutments about the middle of April.

Grouting the Abutments.

11. As stated already, the masonry of the old abutment especially of the right one was not quite satisfactory, several small and some large voids having been disclosed while cutting out for the skewbacks. It was therefore decided to grout the masonry with cement grout under pressure. The best place in the abutments wherein to deliver the grout was of course the inner face of the skewback recesses. These recesses were built up with temporary masonry leaving a little space of about half an inch between it and the permanent masonry at the back. Three pipes 2″ dia. with screw end were inserted in each recess while building the masonry, one at the bottom level one about half way up the recess and one at top. About 1″ at the top of the recess was left open for the escape of the air which the grout would dislodge from the voids in the masonry. Four large water barrels for grout were put up side by side on the bridge platform close



to the abutment. Holes made in the side of the casks near the bottom were connected with bamboo pipes for enabling the grout to flow from one cask to another, and to the hole in the last cask was attached a canvas hose whose lower end connected with one of the pipes built into the abutment. Grouting work of this kind had been done previously by Mr. John Kuryan, Executive Engineer, in the Pallode bridge on the Trivandrum Shencottah road and his experiences had been communicated to the officers of the Department. Neat cement grout although it would flow very freely was objectionable, first on the score of cost and secondly because it would shrink much while setting in the joints of the masonry and would leave voids. It was therefore decided to use grout of cement and sand in the proportion of 1 to 1. The sand, if it was not to separate from the cement, had to be very fine. Fine sifted sand and cement were mixed in the proportion of 1 to 1 and half as much water as the quantity of cement in the mixture was added. The casks were filled with grout so prepared, the hose connected to the bottommost pipe of the recess in the right abutment and the entry from the cask to the hose opened. The grout ran down the hose for a short time but within 5 minutes about 6" depth of sand with a small percentage of cement in it settled at the bottom of the cask. A proportion of 2 of cement to 1 of sand was tried to see if the sand would not so easily separate but as this mixture did not show much better results, 1 to 1 proportion was adhered to, the grout was made a little more liquid by the addition of 20 per cent. more water and was then thrown as it was prepared into the cask connected to the hose and kept well stirred the whole time and a steady supply kept up. By this arrangement the grout was flowing down all right. The voids in the abutment masonry were evidently getting filled up as could be seen from the steady rise in the level at which grout was exuding from the joints of the coursed rubble masonry. After rising in the abutments to 1" above the level of the pipe, the grout refused to flow and collected at the lower end of the hose without entering the pipe. The hose was then unscrewed, the pipe in the abutment plugged and the hose attached to the middle pipe above it. When this was done the grout again began to flow freely until it rose in the abutments a little above the level of the pipe. After this the hose was fitted to the top pipe to complete the grouting. Grouting was next done through the pipes in the other recess commencing from the bottom one. Naturally less grout was consumed here than through the first set of pipes. The left abutment was similarly grouted after the right was finished. Altogether 51¾ barrels of cement were used for grouting the right abutment and 10 barrels for the left. The grouting was done on the 18th and 19th of April. A day or two later the temporary masonry in the recess was dismantled and removed, when it was found that the grout had worked quite well into all the openings in the masonry.

12. The skewbacks had next to be moulded. The proportions for the concrete, the size of the metal and the grade of sand to be used had been under

correspondence with the Chief Engineer and it was decided to use for the massive skewback blocks 1¼" metal with a small proportion of 1½" metal for the inside, while for all the rest of the reinforced concrete work metal that had actually passed through a ¾" sifter was ordered to be used. As regards the grade of sand and the proportion of cement, it was decided to have test blocks made and tested in the laboratory of the College of Engineering, Madras. But as this would have entailed some delay, the skewbacks were arranged to be laid with cement and sand in the proportion of 40 lbs. of the former to 1 cft. of the latter, the mortar obtained therefrom to be mixed with 2 cft. of metal. Before the skewback was laid the joints in the masonry of the recesses were thoroughly well raked out and cleaned. The reinforcement of the skewbacks was all erected in position and well tied. Each skewback could not be completed in one day, as it involved the laying of a comparatively large quantity of concrete in a cramped and limited space. Those on the right abutment were done in three days and those on the left in 2 days in the month of July.

Moulding Skewbacks.

13. The mild steel centring was received from England in August, but prior to erecting it, the old bridge had to be raised up a little over 2 feet to get the cross beams clear above the proposed level of the concrete deck of the new bridge. This raising was done with screw jacks without a hitch in the first half of September. The metalling over the bridge and more than half of the buckle plating had been previously removed. Platforms suspended by ropes and chains were hung alongside of the abutment. A little dismantling was done of the masonry below the end cross girder of the bridge which was coming just over the abutment and the jacks were inserted between it and the cross girder. Two jacks were placed on each abutment as close to the main girder as possible to minimise the strain on the cross girder. The top boom of the girder was tied with stout ropes to trees above and below the bridge to safe-guard against the bridge inclining to one side or the other while being raised. The jacks at one end of the bridge only were worked at a time. After one end was raised up about 6," the other end was raised and the bridge brought to the level. Baulks of timber were tightly wedged up against the cross girders, the jacks eased and placed about 6" higher up and further raising continued. After the bridge was raised to the full height, good cutstone masonry was built up over the abutments to the cross girder level.

Jacking up the old bridge.

14. Immediately the bridges were raised to the proper level, the erection of the steel centering was started. Prior to doing this a level platform was made on the right bank on which the steel arch, the suspenders and the position of the cross girders of the old bridge were set out full size. One set of suspenders received were found to be too short and others were got ready in their place,

Erection of the steel centering.

the screw at the ends of others had to be continued a little more and some bolt holes also had to be drilled in some of the angle plates. After getting all this done, the erection of the steel centering was not a difficult matter. The cross beams coming below the steel rib were slung below the bridge at the proper places, the segments of the main angle ribs lowered to rest on them and the suspension rods passed through the bolt holes in the angle ribs and cross beams and bolted up. After the curve was corrected by adjusting the suspension rods, the gangway ribs were all fitted up and stiffened with the stiffening angles. The planking for the temporary ribs as well as the gangway planking had been got ready in the meanwhile and these were laid, steps provided in the gangways in the steep portion near the abutments and handrailing fitted up on the outer side of the gangways. Everything was ready early in October for doing the temporary ribs.

15. Specimen mortar blocks had been in the meanwhile tested at Madras and the results of the tests communicated. For all reinforced concrete work in the State, we have been generally adopting the proportion of 1 : 2 : 4 or 1 : 2½ : 5 by volume for cement, sand, and metal. The cement was generally measured loose and its measurement admitted of great differences in the amount of the cement according to the kind of supervision exercised over the measuring. It was decided to weigh the cement for each mix. 40 lbs. per cft. of sand and 35 lbs. per cft. were proposed to be tried. 4 grades of sand were selected for trial as those likely to give the best results.

Mortar tests.

A. Sand passed through a sieve of 3½ meshes to the inch.

B. Do. Do. Do. but retained on one of 30 meshes to the inch.

C. Sand passed through 3½ meshes to the inch but retained on one of 16 meshes to the inch.

D. Sand passed through 8 meshes to the inch and retained on a sieve of 30 meshes to the inch.

4 blocks for each kind of mortar or 32 blocks in all 5"x 5"x 5" were made on the 29th of August, kept wet for a day and then in water until they were taken out, packed and despatched to Madras on the 5th September. The blocks were tested for compression in the testing machine of the College of Engineering on the 11th September and the average results obtained from each kind of mortar are shown below. The 4 specimens of each kind gave varying results, but one or two that gave wholly unreliable results due perhaps to damage in packing or in transit have been excluded in striking the average.

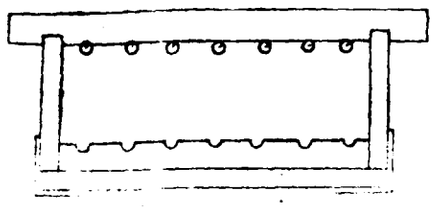
Mortar with sand A & 40 lbs. of cement per cft. of sand. Crushing strength lbs. per Sq. inch. 3361

A	35 lbs.	2796
B	40 lbs.	2586
B	35 lbs.	2295
C	40 lbs.	2879
C	35 lbs.	2558
D	40 lbs.	2890
D	35 lbs.	2419

As may have been expected, with each grade of sand 40 lbs. cement per cft. gave higher strength than when 35 lbs. only were used, and the specimen of sand A in which the coarsest particles only were sifted without removing any of the fine particles gave decidedly better results than any other kind of sand. It was therefore decided to use for all work sand A with 40 lbs. cement per cft. In the month of November concrete blocks 9"x 9"x 9" in the proportion of 40 lbs. of cement to 1 cft. of sand A and 2 cft. of $\frac{3}{4}$" broken stone were sent to Madras and tested. Some of the blocks were crushed in the direction of their laying while others were crushed normal to the direction of laying. This was done to see if a greater crushing strength was got in the latter case than in the former. The results obtained were however inconclusive.

Laying the temporary ribs.

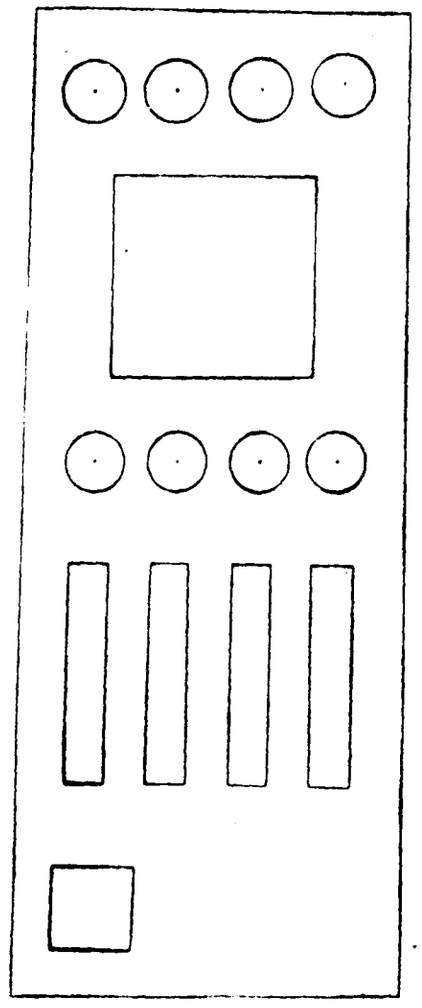
16. The boxing for the temporary ribs was quite simple. The bottom planks were supported on the table of the angle rib, and side planks in one height worked to the curve of the arch were placed butting against the leg of the angle rib. Longitudinally the planks were merely butted against each other. Their bottoms were kept against the sides of the angle by battens across, on which slots had been cut for the bottom line of reinforcement rods to rest on. Battens were also placed across at the top to serve as strut and tie and to these were tied at long interwals the top reinforcement rods. These battens come at 5' or 6' intervals, generally at the joints of the longitudinal planking. The reinforcement rods were well washed and cleaned in the river and a thin coating of neat cement applied to them. After all the reinforcement rods were erected in position and just before the laying of concrete, all the cement sticking to the rod was washed out. This process was adopted generally in the case of all the reinforcement rods to prevent the rods rusting in the intervals that must necessarily elapse between their being washed and cleaned and their being embedded in concrete. The flat iron stirrups to go round the rods were made previously by overlapping the ends of the plate and rivetting the junction. Prior to the erection of the reinforcement in the box its sides and bottom were well smeared with oil.



The temporary ribs were laid in two days, about one fourth of the span from each springing was done on the first day, and the middle half the next day.

Method of mixing concrete.

17. So many different ways of mixing concrete are in vogue that a few words regarding the method adopted on this work (and generally in all the works the writer had to do) will not be out of place. The cement barrels are brought from the store and placed at the further end of the mixing shed from the work.



Next comes the platform weighing machine or a pair of scales for weighing the cement. Next is a space of about 6' of platform and after that we have a number of trenches in a line about 7' x 1' 3" x 1' for mixing mortar, the number of trenches depending on the amount of concrete to be laid in a day. Beyond the trenches is a space of about 10' for mixing concrete which is delivered to the work from the other end of the platform. A cement barrel is opened and the contents thrown on the platform. The cement needed for 1 cft. of sand is weighed in 2 or 3 chatties. In the meanwhile a bottomless box 1' x 1' x 1' is placed in the space between the weighing machine and the trough and filled with the prepared sand stored a little distance away. The box is taken out leaving the measured sand on the platform, the weighed cement thrown on it, and the two intimately mixed dry and thrown into the near end of the trough.

Water is poured thereon through the rose of a watering can, 2 persons with mamatties stand across the trench facing the weighing machine, mix the mortar carefully and leave it at the other end of the trench. An open box 2' x 1' x 1' is placed on the platform on the other side of the trench and filled with metal which is washed in baskets in a barrel of water, as it is brought. The whole of the one mix of mortar is thrown on the measured quantity of metal and the whole is intimately mixed with spades as it is dragged along the platform and delivered to the conveying coolies at the other end. Thus the concrete is mixed not by mixing metal, sand and cement all together and then adding water, but the cement mortar is prepared first. The

account of the harvest when, in Travancore as in the east coast, even the allurement of good wages cannot take away labourers from the field. Afterwards, a good number of carpenters were on the work and the forms for the columns, beams, and slab were all up early in May. The concrete of the columns was laid a few days prior to the laying of the deck. The deck itself was laid about the middle of May working from both ends towards the middle, a day's work being closed over a cross beam. The concrete was done with all the reinforcement of the beam as well as of the slab previously placed in position. Rods were left sticking out of the slab to connect with the reinforcement of the blocking course and the pedestals of the parapet.

Completion of the work.

22. The writer of this paper had to leave the work immediately the deck was laid and is therefore not in a position to give an account from personal knowledge of the work that was thereafter done to complete the bridge. He has unfortunately not also been able to communicate with his friends who were in charge of the remainder of the work for detailed information nor was he able to visit the work recently as he had intended to do. He has therefore to content himself with barely mentioning that the steel centering was taken out and the old girder bridge was dismantled and removed some time after the platform of the new bridge had set, that the reinforced concrete parapets of the new bridge were finished, the roadway metalled and the bridge opened for traffic and that the temporary ribs have been after some delay cut out and removed quite recently, bringing to a successful completion a substantial well-built arched-bridge with the largest span on this side of India turned on centerings of an original design which have proved to be quite satisfactory.

—FINIS.

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