PAPER No. 213.

THE SYPHON UNDER THE RAKH BRANCH FOR THE MARH-CHINIOT DRAIN.

By S. L. Malhotra, I. S. E., Executive Engineer.

Introduction.

In a lucid and painstaking paper before this Congress last year, R. B. Bawa Natha Singh proved that the most effective means of combating the evil of waterlogging and lowering the water table in an area are the provision of a network of suitably designed surface drains, and to remove rapidly the rain water in the upper reaches of the area. Working on this principle, a five-year scheme for constructing surface drains in the Chaj and Rechna Doabs has been adopted by Government.

The Marh-Chiniot drain is the main drain of the Lower Chenab West Circle under this five-year plan of Drainage construction. This drain is designed to serve an area of 150 square miles between the Mian Ali and Rakh Branches, by means of the Marh Salar Drain out-falling into it at Marh by means of a syphon under the Rakh Branch and the area in the fork between the Rakh and Jhang Branches totalling 450 square miles. The original scheme contemplated two drainage systems *viz.*, (1) The Marh-Hinduana-Kubrika drain with an outfall at Kubrika and (ii) the Marh-Narwala-Mungi drain with an outfall into Maduana. These are shown dotted on the plan (plate I). Finally, however, after a minute and detailed investigation of the problem, it was decided to adopt the sanctioned line of the Marh-Chiniot Drain shown on plate I which consists of the main drainage along Khan-Sarwala Drain with an outfall below Chiniot after crossing the Jhang Branch at 1,96,800. This is expected to deal with the existing drainage and cope with the further advance of the subsoil water table, there being no necessity for future extension towards Lyallpur. The substitution of the present Marh-Chiniot drain for the two originally proposed systems avoids lengthy drainage lines through Lyallpur to join Maduana. Further, the syphon under the Jhang Branch R. D. 1,18,680 for the Marh-Hinduana-Kubrika system was not safe and the outfall into Kubrika was inefficient and defective.

The sanctioned Marh-Chiniot Drainage system consists of a main drain and a network of branch drainages. The main drain starts from Marh at the outfall of Marh-Salar drain of the Lower Chenab East Circle at the syphon under the Rakh Branch and crosses the Jhang Branch at R. D. 1,96,800 by means of another syphon. This note deals with the construction of the Rakh Branch syphon by the Author.

Rakh Branch Syphon.

This work was completed in July 1937 at a cost of Rs. 1,00,000 (one lac). The cost of the work does not appear to justify its selection as a Congress Paper, but the design and construction are expected to provide interesting and useful information for engineers employed on construction of modern hydraulic structures. No apology therefore appears to be needed for presenting this Paper to the Congress for discussion. As the perusal of the note will show, the work was carried out under about 13 feet of head of subsoil water and elaborate pumping arrangements had to be made to keep the working area free from water.

Site.

The syphon is situated at R. D. 81,500 of Rakh Branch, the site of the old Marh escape, the abandoned channel of which is to form the outfall reach of the Marh Salar drain. This site is one mile upstream of the Marh canal rest house, and two miles from Marh Balochan railway station from which all the plant, machinery and material had to be carried by a *kacha* road.

Diversion of the Rakh Branch.

As the Rakh Branch irrigates the dry area in Lyallpur District, closures are a rare occurrence on this channel, the only one worth the name occurring at the end of December every year, for about two weeks. The syphon work which involved heavy earthwork in slush, pile driving and complicated stone masonry in flared walls, was expected to take about six months, and a diversion for the branch was therefore considered a necessity. The diversion, which had to carry 1000 cusecs, the full supply discharge of the branch, was about 3000 feet long, and was kept about 500 feet away from the branch opposite the site of the work to keep it at a safe distance against seepage into the foundations. The work on this diversion was of a very difficult nature, as borrow pits more than one foot deep could not be dug, the subsoil water level being within one foot of the natural surface. The earth from the old spoil bank of the escape channel had to be carried up to a lead of even about 1000 feet to complete the diversion banks which were in very heavy filling, their heights mostly being about 10 feet above N. S. The existing bed of the branch was 4 feet above N. S. at the downstream junction of the diversion with the Branch. The diversion channel comprising over 16 lacs cubic feet of earthwork which was mostly donkey work, had to be completed and tested to full supply level within a period of about five weeks. The work was started on 4th December 1936 and the channel was completed and tested by 9th January 1937, when after the usual winter closure, the Rakh Branch was diverted into it. The channel being in heavy filling, special watching arrangements by day and night had to be made. It was to the great credit of Mr. Panna Lal Malhotra, the S.D.O., that the hurriedly-rushed-through banks of the diversion stood the test well, and the diversion ran successfully during the period of the construction of the syphon.

Design of the Syphon.

The design of this work was originally worked out by Mr. Wells on the lines laid down by Mr. Khosla in consultation with Mr. Montagu. The writer had to revise all the calculations and redesign the reinforced concrete floors and reinforced stone-cum-brickwork barrel walls. The work as finally sanctioned consists of a barrel 10 feet wide and 7·5 feet high. The Marh-Salar drain, outfalling into this syphon, has a catchment area of 150 square miles. The estimated run off from this area, at the rate of four cusecs per sq. mile comes to 600 cusecs. The syphon has, however, been designed to pass 50 per cent more or 900 cusecs, the increase in cost for the extra waterway being negligible, and the main features of the work remaining the same.

The discharge of the Rakh Branch at this site being 1000 cusecs, its regime section in terms of Lacey's wetted perimeter discharge formula, viz., $P_w = 2{\cdot}67\ Q^{\frac{1}{2}}$ should be $B = 70'$, $D = 5{\cdot}5'$ and $P_w = 85{\cdot}4'$. The existing section of the channel practically coincides with this, and the barrel length has been designed to carry this section of the channel with adequate banks and berms. There is thus no constriction in the Rakh Branch section over the barrel, of which the total length is 171 feet. The floors of the barrel and approaches have been kept at 640·72 the bed level to which the Marh-Chiniot drain is proposed to be finally dug, the present bed levels being 3 feet above this. The floor under the approaches has 15 feet deep steel sheet piles and that under the barrel has 7·5 feet deep sheet piles. These piles form the outlines of the compartments of the floor in approaches and the barrel.

For designing the floor in the barrel and in the upstream approach and downstream exit, pressures under the worst conditions with proposed sheet piles were calculated by Mr. Khosla and found to be 12 feet under the barrel and varying from 9 feet at junction with the barrel to 7·5 feet at ends, in the approaches. Under the barrel the floor has been designed to resist the reaction of the load on it consisting of 6·65 feet depth of water, 3 feet bed silt in branch, barrel walls and top and bottom slabs, this collectively being greater than the pressure dug to 12 feet head of water. The floor in this portion consists of 16″ thick reinforced concrete slab with adequate reinforcements both main and cross. The width of the approaches gradually decreases from 40 feet at the ends to 10 feet at junction with the barrel and the floor in these has been designed with reinforced concrete slabs of the requisite spans between the wing walls.

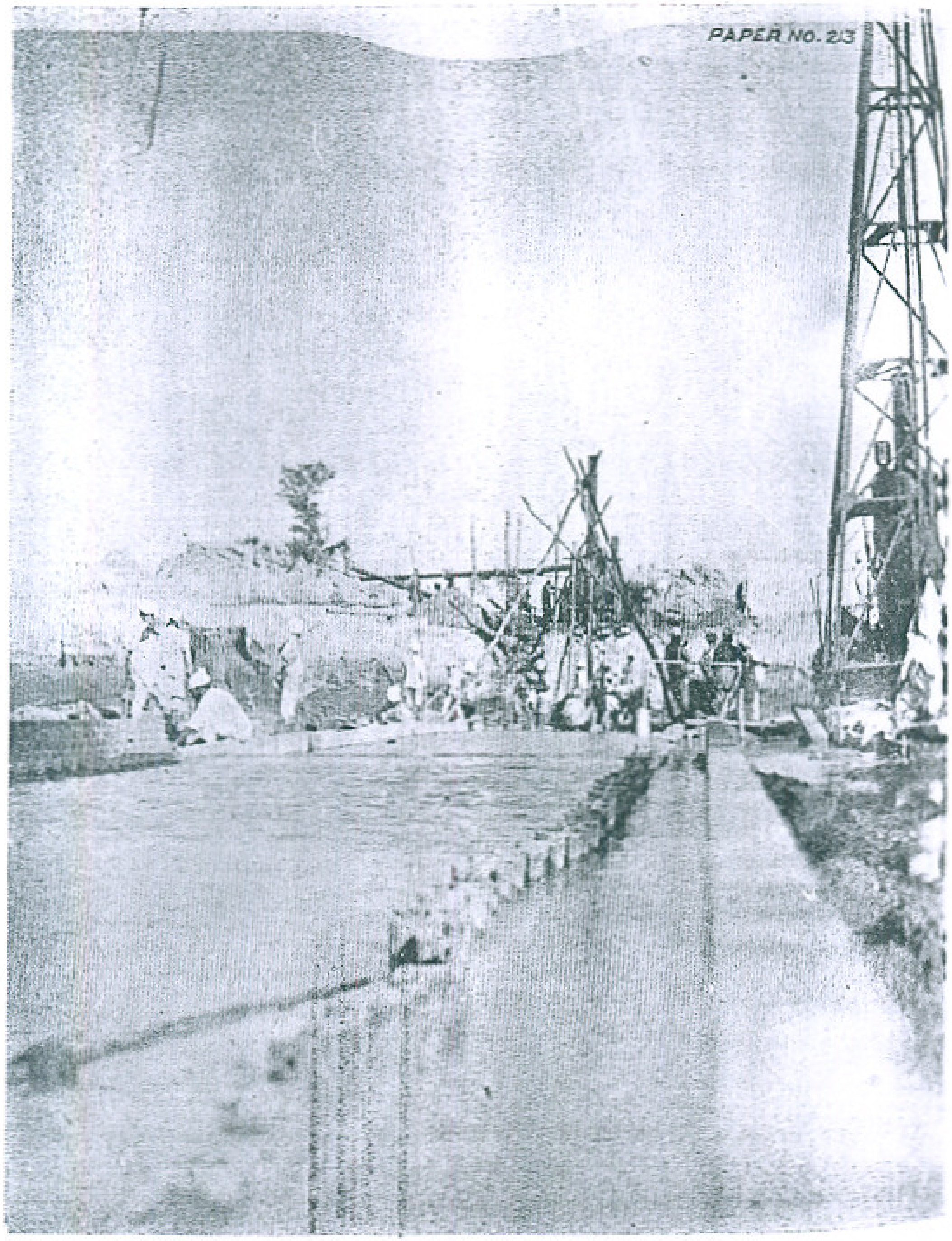
The barrel walls have been designed as reinforced brickwork slabs, supported by the bottom and top slabs of the barrel having a horizontal pressure equal to the sum of the hydrostatic head of 12 feet and the full earth pressure due to the submerged weight of the soil. Adequate vertical and horizontal reinforcement for this loading has been provided. The top slab was designed to carry the loads on it and has different sections in the portions under the banks and the canal. The barrel sides are strong enough to form a reinforced concrete box-culvert and the slabs have been tested as such.

The approaches are flumed and have flared wing walls, which are vertical at the junction of the barrel, and have a slope of 1 to 1 at the ends. There is a 2·48 feet fall in the designed levels, from Marh-Salar into the Marh-Chiniot drain. A drop wall has been provided at the upstream end, with top level at the designed bed level of the Marh-Salar drain. Suitable protections both upstream and downstream of the approaches have been provided. Plates III and IV show the details of work and reinforcements.

Foundations.

The bottom of the raft concrete under the floor slab being 638·6 the foundation pit had to be dug 15 feet below the natural surface, which at the site was 653·3. The spring level at the site at the time the work was carried out was 651·0, and the foundations therefore lay about 13·0 feet below this. Elaborate pumping arrangements had therefore to be made to keep the working area dry during construction. The pumping was a fairly heavy item on this work, Rs. 20,000 approximately having been spent on this. For draining off the working area two sumps one at each end were sunk, to locate the pumps. Plate II shows the arrangements of these sumps. As the downstream protection is at a lower level, the sump on that side was placed 30 feet away from the extreme end of the work while the upstream sump, where the inverted filter and pitching are at a higher level, was placed only 5 feet away from the end of the work. The sumps were sunk about 8 feet below the foundation level, and the pumps were lowered as the level of the pit was lowered.

As the work on the reconstruction of the Marala Weir was also in progress at the time, practically all the useful machinery in the Department had been carried there. We, therefore, had to depend upon whatever was available at Khanki, after meeting the requirements of Marala. There was an old and rejected steam road roller available at Marh, but its engine was found in working condition. This roller and an old Sentinel engine from Khanki were the only steam engines available at the time. These were fixed one at each sump and coupled with 10″ centrifugal pumps. Both these engines, however, could not cope with the increased discharge as the digging progressed, and an extra Petter engine and a 6″ pump were put in at the downstream sump. These three pumps managed to keep the foundation pit fairly dry. As, however, the work progressed there were lots of failures and break-downs in these engines, and finally, a portable steam engine was got from Marala to take the place of the Sentinel of which the furnace was leaking badly. This worked very well.



I. General arrangements, pump and pile driver.

In all, the three pumps lifted about 10 cusecs of water from the foundations. Photograph 1 shows the general arrangement of work and one of the engines working on a sump. There were interruptions in the work due to rains, etc., and pumping had to be carried on for about four months. One drain in the centre, to lead sub-soil water from half of the area to each of the sumps, was dug and worked during the period the excavation was in progress. The earthwork in the upper 7 feet consisted of clay-slush, mixed with a little kankar and was carried out with great difficulty. In the lower strata, sand predominated. In all about 20 lacs cubic feet of slush and saturated sand work had to be dug out from the foundation pit. Leaving about 5 feet on the sides of the margin of the work, the excavation was carried out in steps at a slope of 1 in 5.

Local pumping to keep the surface dry while concreting was in progress was also resorted to, as described later.

Steel Sheet Piling.

After the excavation, pile driving had to be carried out. The pile driver was assembled in the canal bed, and as excavation progressed, it was lowered by stages to the final level.

The sheet piles used on this work were of two kinds. Those recieved from the Lyallpur Division were old Universal piles purchased from Sukkur, which were found surplus after completion of the Jhang Branch syphon. As they were only about one-third of the area required, the remainder were obtained from Panjnad. These consisted of old Ransom "D" piles, extracted from the river bed. The Ransom "D" piles were lighter and cheaper. The pile driving was carried out as described in Congress Paper No. 195. The Universal piles were driven in straight lengths, and the Ransom D in curves under the wing walls of the approaches. The male end always led. Special junction piles had been made where the Universal and Ransom "D" piles joined. At corners where a cross line took off the main, special T piles had to be manufactured.

In straight lengths, the driving was started from both ends and special junction piles with slotted holes of 3″ length were manufactured and driven at the junction. This allowed of the circuit being closed, the junction pile adjusting to the width of the last gap to be closed. The piles even with the greatest care, are liable to get out of plumb and for this purpose, correction piles were prepared.

The pile lines were all continually inter-locked and the compartments were formed by continuous inter-locked lines of piles. The piles used were old and had been extracted after being used once. Great care was therefore exercised in keeping the piles properly inter-locked, and in a few cases, the piles had to be extracted to set right this defect

The pile driver was fed on steam coal and the cost of a shift was practically the same as worked out at Khanki. The contractor was paid only for carriage of piles to site and getting the piles driven at site the rate for Ransom " D" being two-thirds of that for Universal which are one and a half times heavier per square foot. The soil contained kankar nodules which retarded the progress of pile driving and rendered it difficult. The pile driver was worked on a B. G. Track and the device used at Khanki for turning it was employed here also. Photo No. 1 shows the pile driver in position.

In order to tie the floor reinforcement to the piles, holes at requisite intervals to take the bars were bored. For this, the bigger holes to contain the larger diameter bars in the upstream and downstream approaches were bored by means of oxyacetylene plant, borrowed from Khanki. This enabled speedy completion of the work. Smaller holes under the barrel walls were bored by means of ratchet braces. The progress on these was slow.

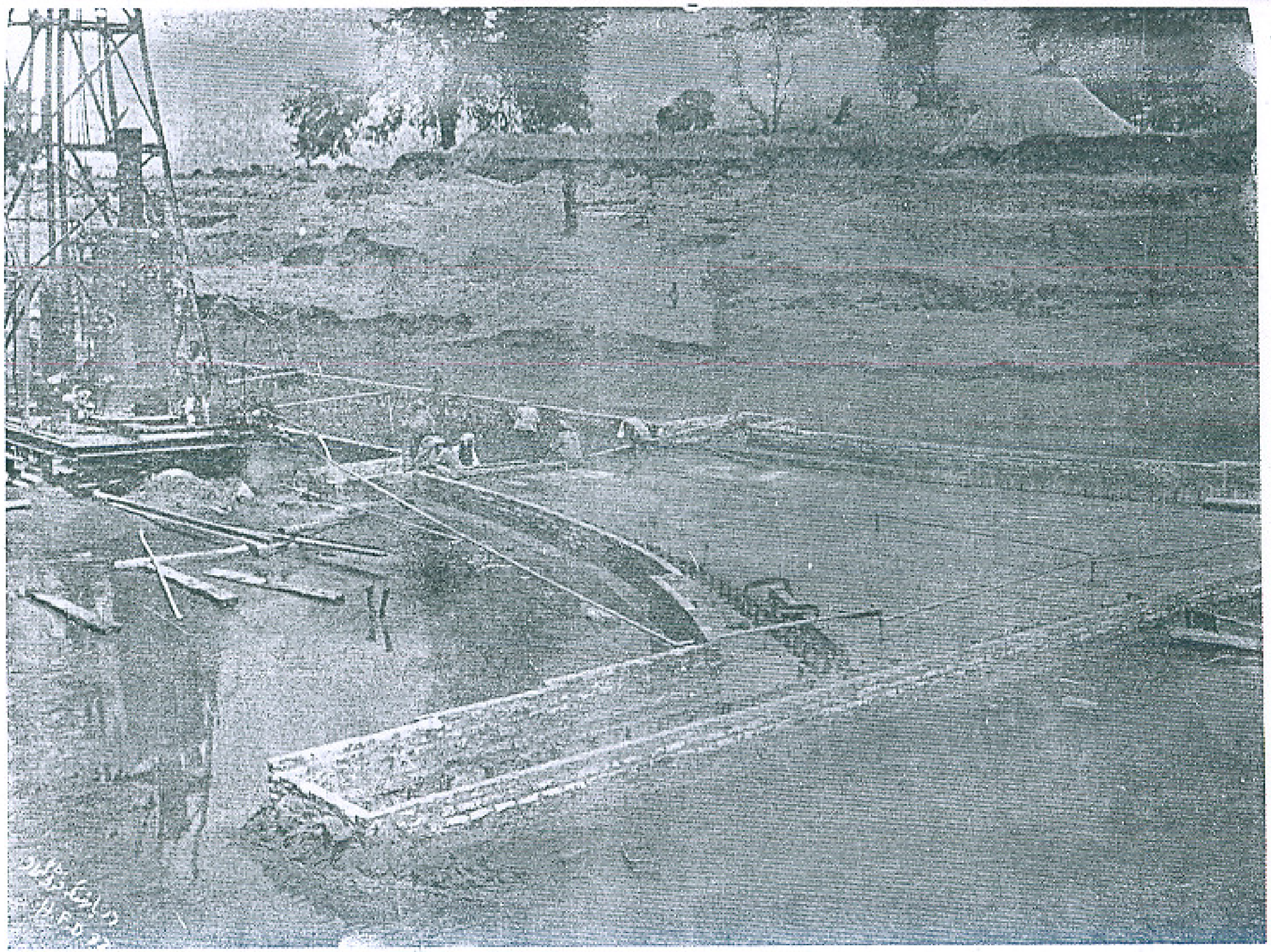
Raft Concrete.

In order to have a hard surface to place the reinforcements on a layer of raft concrete, of 1 : 3 : 6 proportions, was laid at the bottom. In the original design it was only 6" thick, which being too thin to tamp the springs, was increased to 9" thickness. Sangla stone ballast was available in the locality and being cheaper was used for this. It was laid wide enough to give a step of 6" on the sides for constructing the shuttering of the bottom slab. Photo No. 1 shows the raft concrete and shuttering of the bottom slab in progress.

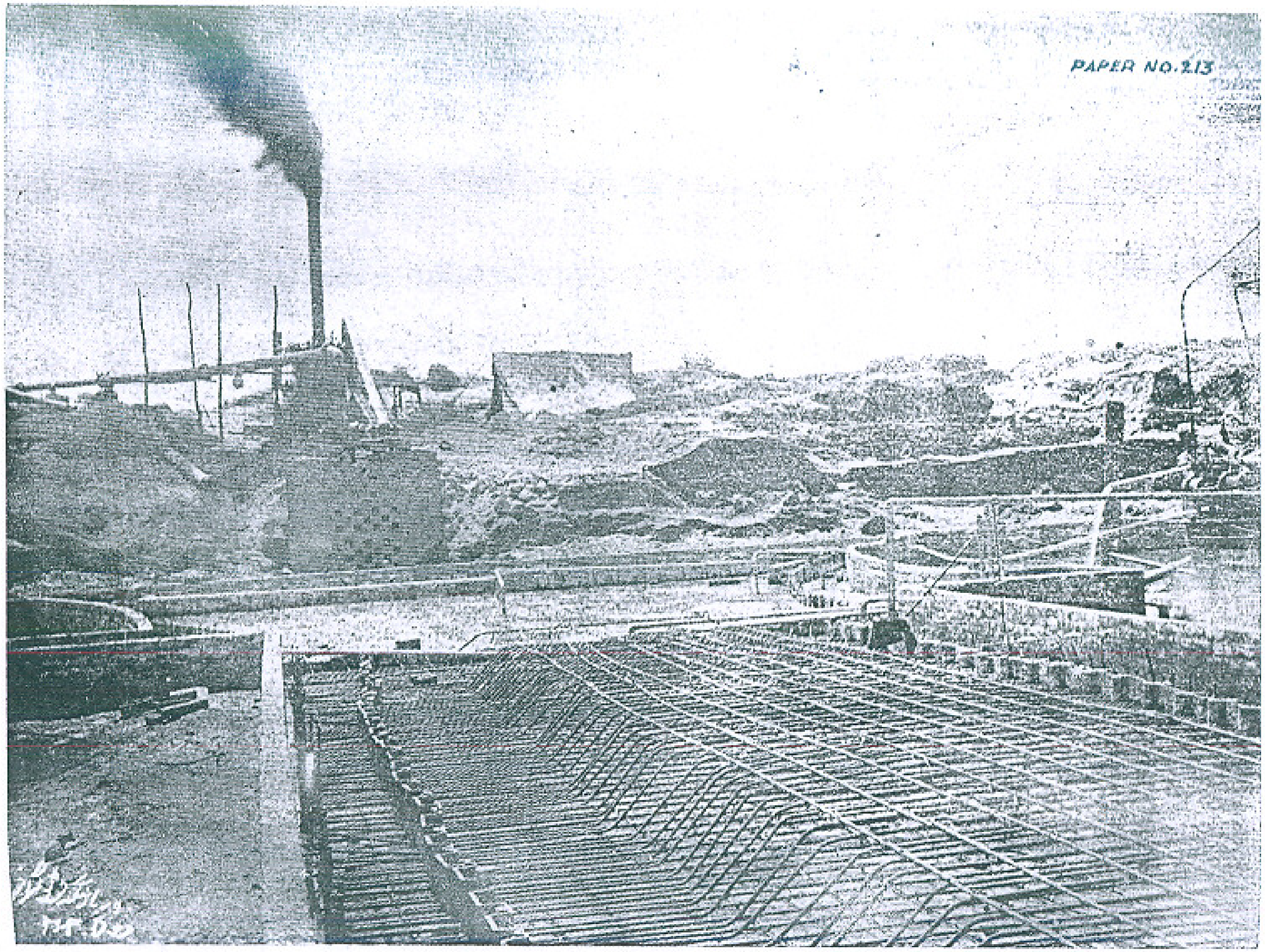
While laying this concrete, the springs underneath this could not be easily tamped, specially in the downstream compartment. Pipes were led out of the work to take up the slight discharge of these springs which were plugged with cement slurry under pressure after completion of the work. In the upstream portion of the work, a tube well was sunk to depress the water level locally. All the pressure pipes on the work, which had been laid at this stage, were connected on top with a suction pipe, which led to the donkey pump of the pile driver. All these served as tube wells and gave a dry surface on top for the raft concrete. The pile driver donkey pump worked till the completion of the floor slab. This arrangement for depressing the water surface locally is shown in photo No. 2, in which is seen the donkey pump working. This photo shows the raft concrete complete, the pile line and shuttering for floor slab. The surface is ready for the reinforced concrete slab at the bottom.

Floor Slab Reinforcement.

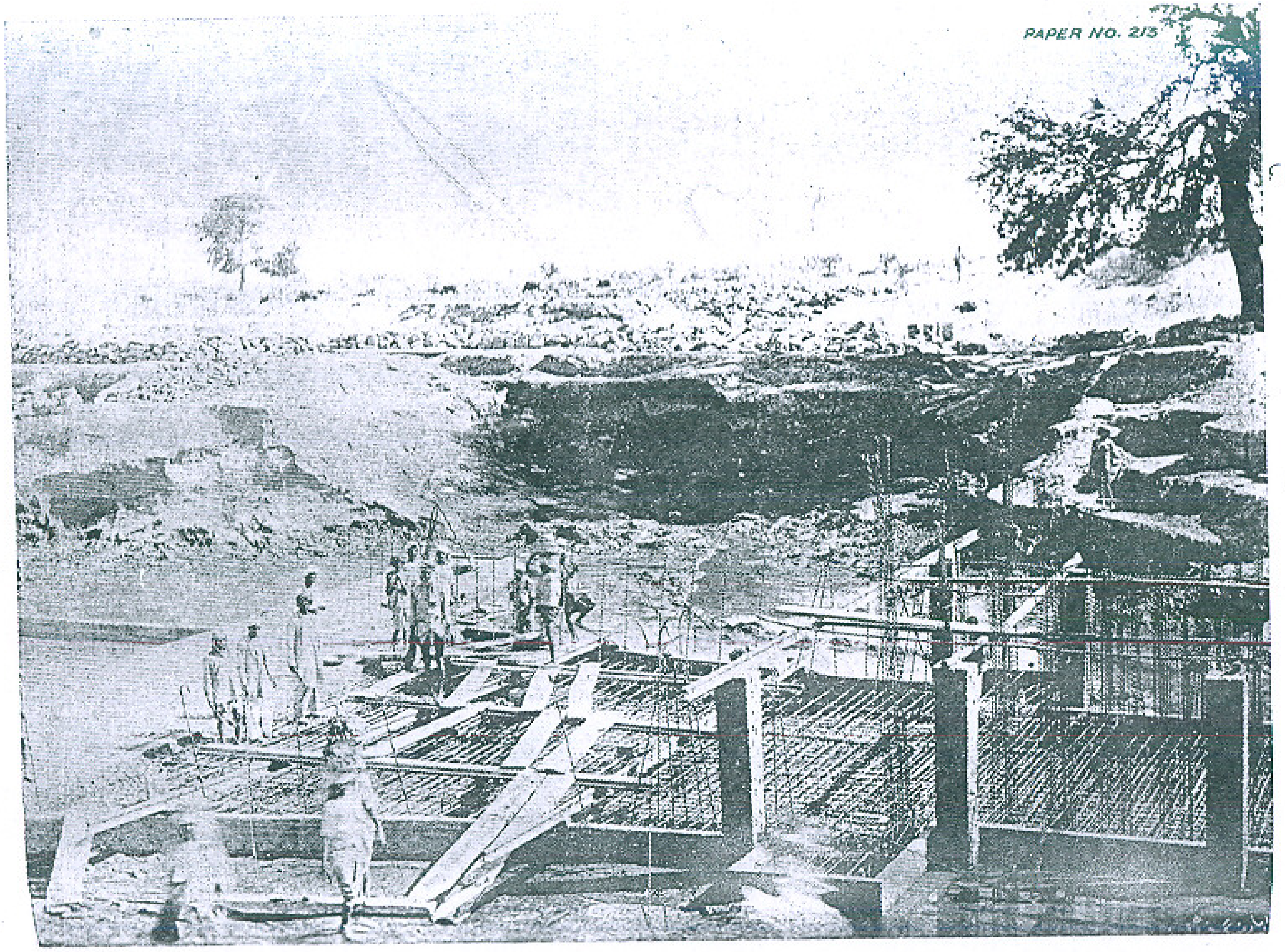
After laying the foundation raft concrete and constructing the brick shuttering on the sides, the reinforcement had to be placed in position.



II Pressure pipe tube wells and raft concrete.



III Barrel reinforcement.



IV. Reinforcement and concreting of floor

As Tata's tested steel was not available, British steel had to be used. The quantity required was worked out and 10 per cent extra was ordered for wastage in cutting, overlaps, etc. The bars ordered were of proper lengths, calculated from plans. The steel obtained was of good quality and there was no mill scale on it.

For bending the reinforcement, a plastered platform was prepared on which the shape of the flumed approaches was marked and the floor reinforcement cut to exact lengths and bent from these.

The main and cross reinforcement bars were passed through the holes in the piles and the whole frame-work of reinforcement was thus tied to the cofferdam of piles. The bottom reinforcement was kept at the proper height by means of precast cement cubes about 2" square section and of requisite heights, which were removed as work progressed. The top reinforcement was kept in position by means of special chairs, on which the longitudinal bars rested. As the cross and main reinforcements had been tied together, the chairs kept in position and at proper height all the frame work. The shape of the chairs is shown in plate IV. Photographs III and IV show the barrel and floor reinforcement in position.

In the barrel portion, the reinforcement of the wall-column was tied to the floor reinforcement and kept in vertical position by special arrangements shown in photograph IV.

Concrete Mixture, Material and Manufacture.

The concrete on this job was manufactured on a scientific basis. Attempts were made to ensure the production of a concrete of guaranteed and uniform strength and have proper "field control" over its making. For this purpose, the mixture was scientifically designed for the required strength as explained below and manufacture was properly controlled and designed proportions were uniformly and closely maintained. Due regard was paid to all the factors determining the strength of the concrete, viz., water cement ratio, consistency or slump, quantity of cement in the mixture, and quality, grading and maximum size of the aggregate.

The method of designing concrete mixtures is based on the water-cement ratio theory, which means that for a given type of aggregate, the strength of concrete manufactured depends on the ratio of the volume of water to that of cement, so long as a workable consistency is obtained or in other words so long as a mixture is plastic and workable, for a constant water-cement ratio, the strength of the concrete is fixed, irrespective of the quantity of the aggregate. The amount of water used in the mixture being the controlling factor for strength, the problem of designing concrete mixtures consists in determining the ratio of water to cement that will give the resulting concrete of desired strength, and the most economical proportion of cement to aggregate to give a workable slump. For this work, it was assumed that it was desired to obtain a concrete to develop a strength of 2600 lb. per square inch after 28 days. The aggregate available were fine sand from foundation pit and washed Pathankot shingle clean and structurally sound. Determination of proportions to mix the ingredients to give the required strength most economically was desired.

Consistency aimed at was such as to allow the concrete to flow round the bars freely after adequate tamping and not to produce slurry or wet mortar on the surface, thus weakening the lower layer of mixed concrete. For this purpose a slump of 2 to 3 inches was allowed. For a strength of 2600 lb. per square inch, a water cement ratio of 0·8, or 5 gallons to a cubic foot of cement, was needed (vide figure 1, "Modern Methods of Concrete Making," by Wynn and Andrews).

There were no arrangements for making the sieve analysis of the aggregate and representative samples of these were sent to the Principal, Government School of Engineering, Rasul, for finding out the fineness moduli of these. The fineness modulus of sand was found to be 1·35 and that of the Pathankot Shingle 6·62. The maximum size of aggregate was 3/4" and fineness modulus for concrete for an aggregate of this size and desired strength is 5·0 and the real mix is 1:5. Therefore, the ratio of sand to the total volume of the aggregate is given by

$$r=\frac{M_c-M}{M_c-M_f}=\frac{6{\cdot}62-5{\cdot}0}{6{\cdot}62-1{\cdot}35}=30{\cdot}8 \text{ or } 31 \text{ per cent.}$$

The sand used was rather fine but as no better was available this had to be accepted.

The shrinkage in a mixture of fine and coarse aggregate was found to be 1/6th. For a real mix containing 5 parts of mixed aggregate the quantity of separate ingredients needed was $\frac{5{\cdot}0 \times 7}{6}=5{\cdot}83$ parts. Therefore the parts of sand needed were $5{\cdot}53\times0{\cdot}31=1{\cdot}8$ and parts of shingle $5{\cdot}83 \times0{\cdot}69=4{\cdot}03$.

"The Nominal Mix" of the concrete for a real mix of 1 : 5 was 1 : 1·8 : 4·03 for dry rodded material.

The bulking in sand was found to be ⅛th or 12 per cent. Therefore for 1·8 cubic feet of dry rodded sand, $1{\cdot}8\times11{\cdot}2=2{\cdot}02$ cubic feet of damp sand available on the work was needed, allowing the bulking experimentally found. The bulking in shingle was negligible and only 2 per cent was allowed. The quantity of shingle needed was $4{\cdot}03\times1{\cdot}02=4{\cdot}11$ cubic feet. The "field mix" therefore, for the quantity of the material available at site was 1 : 2·02 : 4·11. Using 2 bags of cement in a mixer batch, the material required were, cement 220 lb., 4·75 cubic feet of sand, 9·66 shingle.

The quantity of the water required was five gallons to a cubic feet of cement and from this was to be deducted the amount already in sand and aggregate. The water in sand for the observed bulking was assumed to be 2 per cent and in aggregate 1 per cent. The water to be deducted from the sand in each mix $= \frac{4·75 \times 90 \times 0·02}{10} = 0·86$ gallon and from shingle $= \frac{9·66 \times 100 \times ·01}{10} = 0·97$ gallon or total 1·83 gallons. No allowance was to be made for absorption, sand and shingle being damp. The amount of water required as per formula quoted by Mr. S. L. Kumar in his Congress Paper No. 202 is as below :-

$G = AK\ (2VC + Vs + O3Va) = 1·1 \times 1·0\ (2 \times 2·34 + 4·75 + 0·3 \times 4·81 = 13·1$ gallons.

This gives an excessive amount of water, much less being required in actual practice.

Having designed the mixture of concrete sceintifically the actual working was started.

Cement.

All cement used on the work was obtained fresh from Wah. The cement was obtained in paper lined bags, as the season was subject to showers of rain. A suitable godown was made at site for storing the cement.

The cement used on the work was measured by weight, two bags being used in a batch put in the mixer. Cement measured in measuring boxes is generally loose and tends to fluff, and cannot be correctly measured. Its correct measure is therefore best by weight, each bag being 1·17 cubic feet in volume.

The sand from the foundation pit was found to be coarser than the sand in the canal bed and hence this was used. Even this was found to be very fine, as is evident from its fineness modulus and the Principal, Rasul School of Engineering advised the use of 10 per cent extra cement. As, however, the mixture was scientifically designed on the basis of fineness moduli of the aggregates, proper proportion of cement for the available grade of sand automatically was allowed.

The sand was first screened to remove organic impurities, kankar nodules and fine clay pieces. It was then washed in a specially made tank and then dried for use. A simple method for determining the clay contents of the sand was employed at the site of the work. An ordinary rain-measuring graduated glass was taken and half filled with a representative sample of the sand. The glass was then three-quarters filled with clean water and vigorously shaken for about a minute so as to dissolve the dust in the sand and water. The glass was then allowed to stand on a level table for about an hour, thus allowing the clay and silt in the sand to deposit in a layer above the sand. This deposit of clay was found to be less than 1 per cent of the volume of sand, showing thereby its suitability for use in the concrete. Excessive foreign materials consisting of fine dust, loam, clay and vegetable matter in sand are objectionable as they prevent adhesion and reduce the strength of concrete by increasing its porosity. Such impurities can be allowed only up to about 5 per cent which however in this case were found to be absent. As no harmful organic matter was present in the sand no further tests were considered necessary. The sand used was measured by volume after making requisite allowance for bulking as explained below.

Bulking of Sand.

Allowance must be made for bulking or increase in volume of the sand by addition of moisture. Omission of this factor results in under-sanded and over-wet concrete as wet sand contains less of dry rodded material and more water. Sand generally contains 2 to 5 per cent moisture which increases its volume by 15 to 30 per cent or even more. On this work actual bulking was determined by a simple method on the lines mentioned in Congress Paper No. 204. An iron cylinder 2 feet high was filled with a sample of sand and heated from the sides. The shrinkage in the height of sand on drying was determined and gave the bulking. As explained under design for the mixture an allowance for this was made in measuring the material for the " field mix."

Coarse Aggregate.

This consisted of Pathankot shingle, well graded, hard, structurally sound and durable. A sample was tested at Rasul and found to be fit for use in concrete.

As this contained clay and other impurities, though to a small extent, it was considered advisable to wash it. For this purpose a tank was constructed, filled with clean water and basketfuls of the shingle were dipped into it. In order to retain the finer grades of the shingle, the baskets were lined with gunny bags, to disallow sieving through of the finer particles. Each basketful was dipped and drained several times. The water of the tank was changed as soon as it got dirty.

Water.

The water used for washing the aggregates and mixing concrete was that obtained from the tube wells in the foundation pit for keeping the surface in the working area under floor depressed, and it was pumped up into the tanks by means of the donkey pump of the pile driver.

The water was clear and free from oil. It appeared to be also free from alkali and acid and was fit to be used in the concrete work.

Mixing.

Mechanical mixers were employed for mixing the concrete. Two of these one ½ yard and one ¼ yard were got from Khanki. Generally one of these was worked at a time, and as failures were not rare due to the machines being old, one was kept in good order as a stand by, while the other was in use.

A batch consisted of two bags of cement and requisite quantities of sand and shingle which were measured by means of specially prepared measuring boxes. After adding the dry constituents in the mixer feed hopper, the mixer was run for three minutes for each batch to ensure thorough mixing. The mixer delivered the charge on a specially prepared platform from which the concrete was removed by means of baskets to the site of the work.

Water-Cement Ratio.

This is the main factor governing the strength of concrete and the most generally neglected. The quantity of water required for a batch of two bags of cement had been worked out to be 10 gallons. This, however, depends on the temperature and humidity of the atmosphere. A few observations recorded on the work, showing temperature, humidity slump, bulking of sand and quantity of water per bag of cement are tabulated in appendix I. A perusal of these shows that in the mornings when the average temperature was about 84° and humidity 65 p.c., 5 to 5½ gallons were needed and at noon and in the evening when the temperature rose to 98° and humidity decreased to 50 p.c., the quantity of water required rose to 6 gallons. These results practically agree with the observations made on the Deg Diversion by Mr. B. K. Kapur and described in his Congress Paper No. 204.

Consistency and workability of the concrete were carefully regulated by means of slump tests. This was a matter of great importance, as excessive water reduces the strength of concrete even to 40p.c. of its designed value. The aim was to produce concrete of such a degree of plasticity as to work readily in the moulds and round reinforcement bars and to form a compact and dense mass of concrete. A dry mixture results in honeycombed or spongy concrete and it has been advocated by Mr. Khosla that this must be avoided even at the risk of reducing its strength slightly. Due care was taken to enforce strict supervision over the manufacture of concrete and to prepare a workable mixture only.

Test Specimens.

In order to make sure of the strength of the concrete, test cylinders were cast and sent to Rasul for being tested after 28 days. For this purpose moulds were sent for from Rasul and test cylinders prepared according to instructions. Test cylinders were prepared also for the roof slab. Appendix II shows results of these tests, proving thereby that the existing strength of concrete attained exceeded the designed figure by over 50 p.c. Representative samples were taken from different batches of concrete at the delivery platform of the mixers.

Laying Concrete.

The concrete from the mixer was delivered on to a platform of iron sheets and from there carried on to the work by baskets. The mixers were installed within easy reach of the work and tip wagons were not employed. It was considered better to basket the concrete from the mixer to the work in view of the following points in favour of this process :—

(*a*) Carriage of mixed liquid concrete in tip wagons makes slurry and laitance work up to the surface and makes the coarse aggregate settle down, thus making the concrete less homogeneous.

(*b*) Tipping in wagons disturbs the already laid concrete and is liable to displace and distort the accurately and carefully arranged reinforcement.

(*c*) Concrete in baskets is laid in small bits and can be efficiently wriggled and worked.

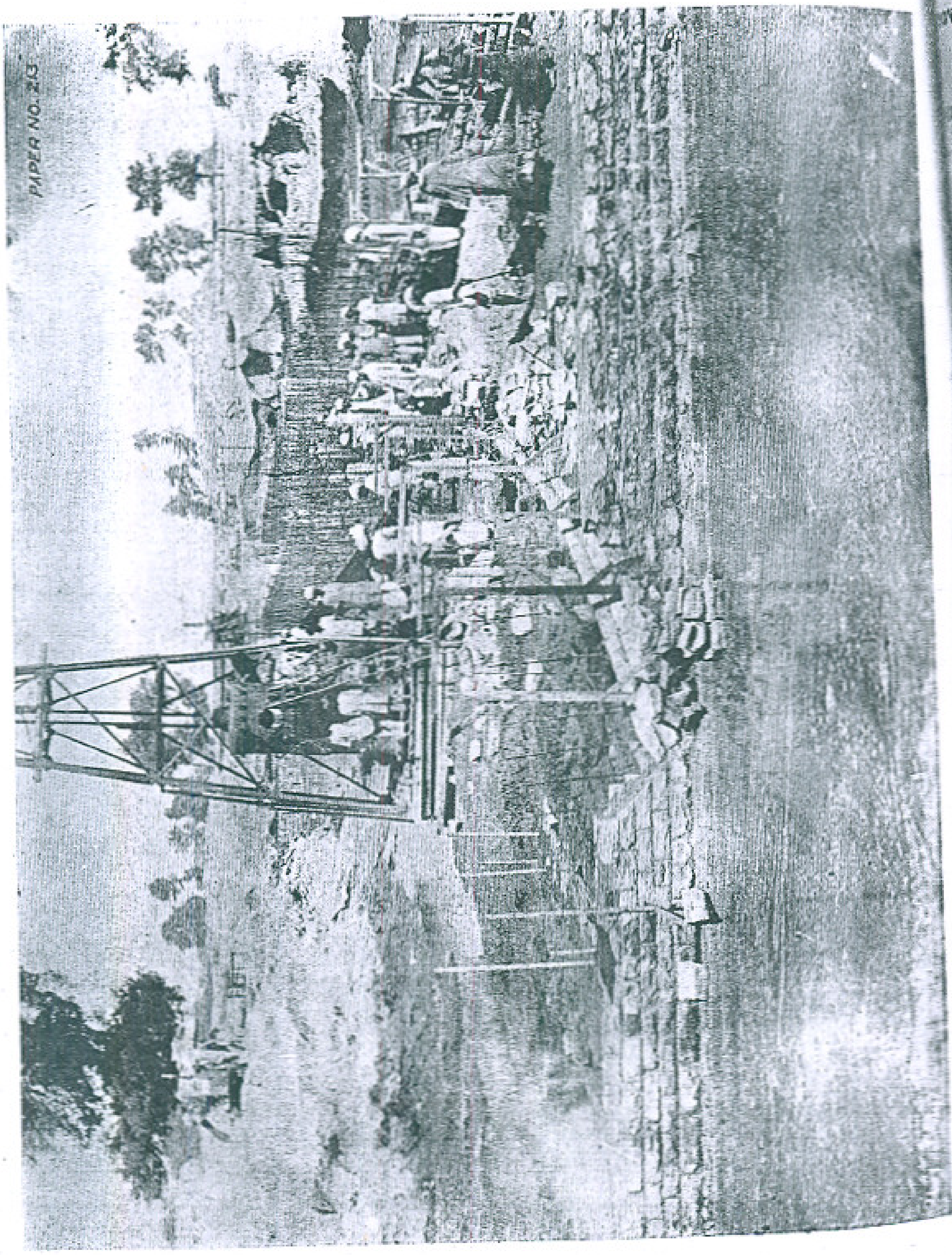
(*d*) Filling in baskets gives another turnover to the concrete thus ensuring its homogeneous texture.

The extra expense involved in basketing the concrete is worth the improvement made in the quality and strength of the work.

Every batch of mixed concrete was carried to the work within 15 minutes of its delivery from the mixer. The baskets were not thrown from a height, but were carefully tipped into the work by being carried within easy reach. Every basket laid was carefully wriggled round the reinforcement. Photograph IV shows concreting in the downstream compartment being done.

The thickness of the floor being less than 2 feet, the concrete was laid *en masse* or in one layer.

The concrete was laid by means of simple gangways consisting of B.G. rails resting on the shuttering walls, covered by wooden boards on which the workmen sat. The whole length of a slab span was completed in a day, the joints being left parallel to the main reinforcement after a



Syph

ay's wor
us day's

(a)

(b)
oved.

(c)
arting

As
o nece
hickne
deform
95.
only

surf
win
pro

W

a day's work. The following precautions were taken to join the previous day's work to new concrete:—

(*a*) A stepped joint was left so as to give a strong overlap.

(*b*) The end was nicked and chiselled and all loose material removed.

(*c*) Neat cement slurry was poured over the joint before starting the next new work.

As the maximum depth of concrete did not exceed 2 feet there was no necessity to place it in layers. The setting heat of concrete for this thickness of slab does not exceed 15°F. and the consequent stress and deformation is negligible as mentioned by Mr. Khosla in his Paper No. 195. Proper care was taken to finish the surface of the floor slab by only sufficient trowelling at the proper time.

As soon as the freshly laid concrete was sufficiently set, the surface was covered with moist sand so as to protect it from sun and wind. The sand layer on the slab was kept scrupulously wet to allow proper setting of concrete.

Wing Walls.

The superstructure was started seven days after laying the floor concrete. The wing walls consisted of hammer-dressed stone masonry. The stone used was obtained from Baghanwala. The section of the wing walls had been calculated to resist the earth pressure and reinforced where necessary. The total weight had been tested to make the floor safe against flotation.

The wings were designed to provide flumed approaches to the syphon and their face slopes increased from vertical at junction with the barrel to 1 to 1 at the ends. For facility of construction, the bottom layer was laid in cement concrete to proper slopes and the stone masonry was built on that. Photograph V shows arrangements for ensuring proper slopes for the faces of walls and work in progress. The mortar used was 1 in 4. The top coarse was point dressed.

Barrel Walls.

The most novel feature of the design was the barrel walls, which consisted of a reinforced brickwork slab of span equal to the height of the barrel, fixed at ends with the top and bottom slabs and lined on face with 1·0 feet thick point dressed stone masonry. The stone facing was provided to safeguard against kallar which in this locality disintegrates brick masonry even in the face of all possible precautions. Reinforcement was calculated to resist the pressure due to water and earth at the back, and consisted of 8, 3/8″ bars per block of 2 feet. This reinforcement was provided at both faces. These vertical bars were embedded in 9″ square 1:2:4 cement concrete columns embedded in the stone-cum-brick masonry in 1:3 mortar. The horizontal reinforcement consisted of stirrups at 1·0 foot vertical intervals, which looped alternatelly round front and back column reinforcement, and horizontal bars at both faces, as shown in plate IV. The stirrups and horizontal bars were tied to the vertical reinforcement bars and formed a rigid frame work.

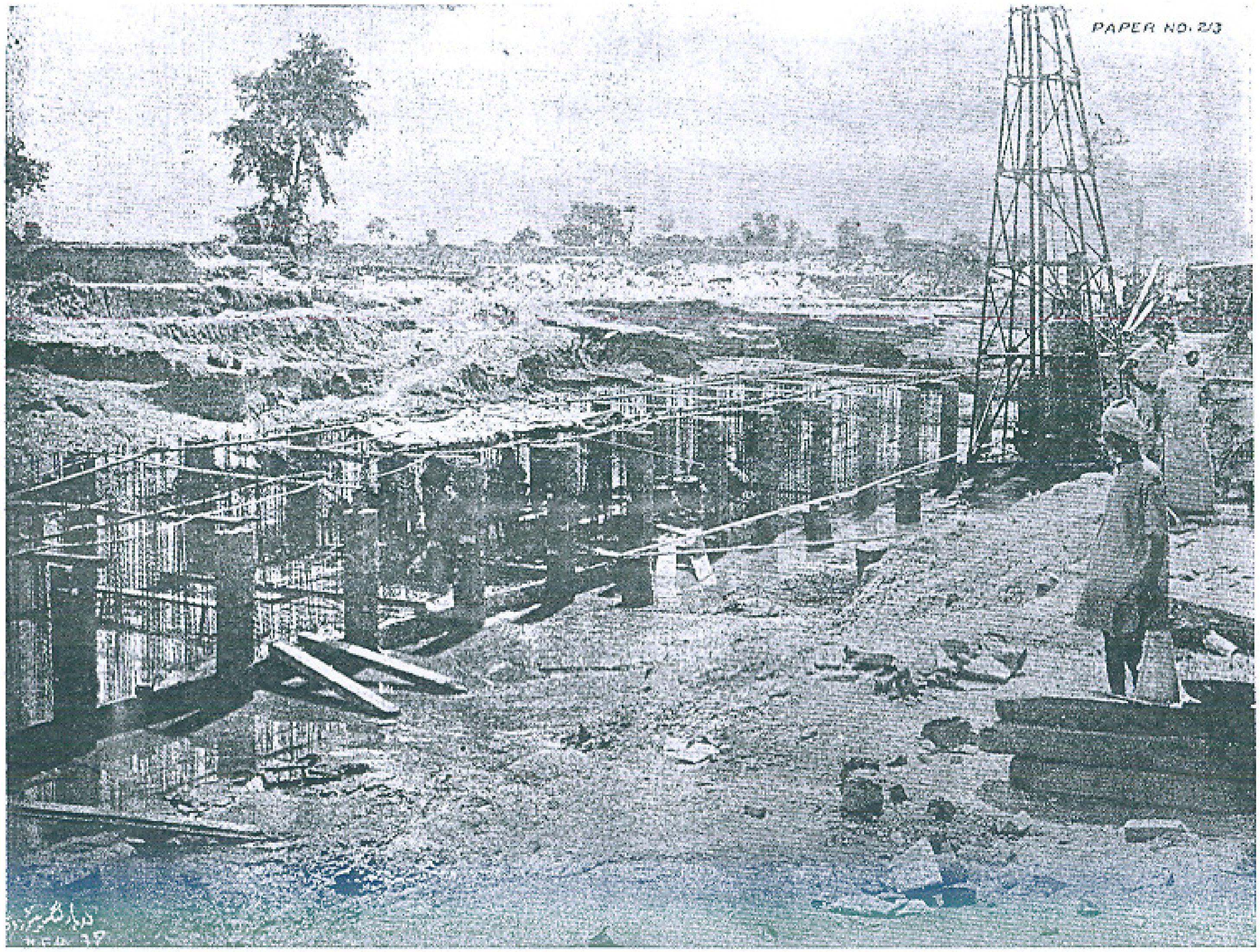
When the floor slab was being laid, special arrangements had to be made by erecting masonry columns with wooden frame work on top to keep the vertical reinforcement of the columns in position as shown in photo VI.

The total thickness of the walls was only 2·5 feet out of which 1·0 foot on face was point dressed Baghanwala stone masonry and 1·5 feet at the back brickwork. All this was intertwined between the 9″ square concrete columns at both faces. Grooves were cut in the stones to accommodate the horizontal bars at every foot. To ensure proper bonding of the column concrete with its surrounding masonry, alternate stone coarses were made to protrude into one column and correspondingly recede from the next, thus forming toothed projections. Similarly every fourth layer of bricks was cut short by about 1″ to form a projection of the concrete into the masonry. A toothed structure in elevation was got, which ensured proper bond.

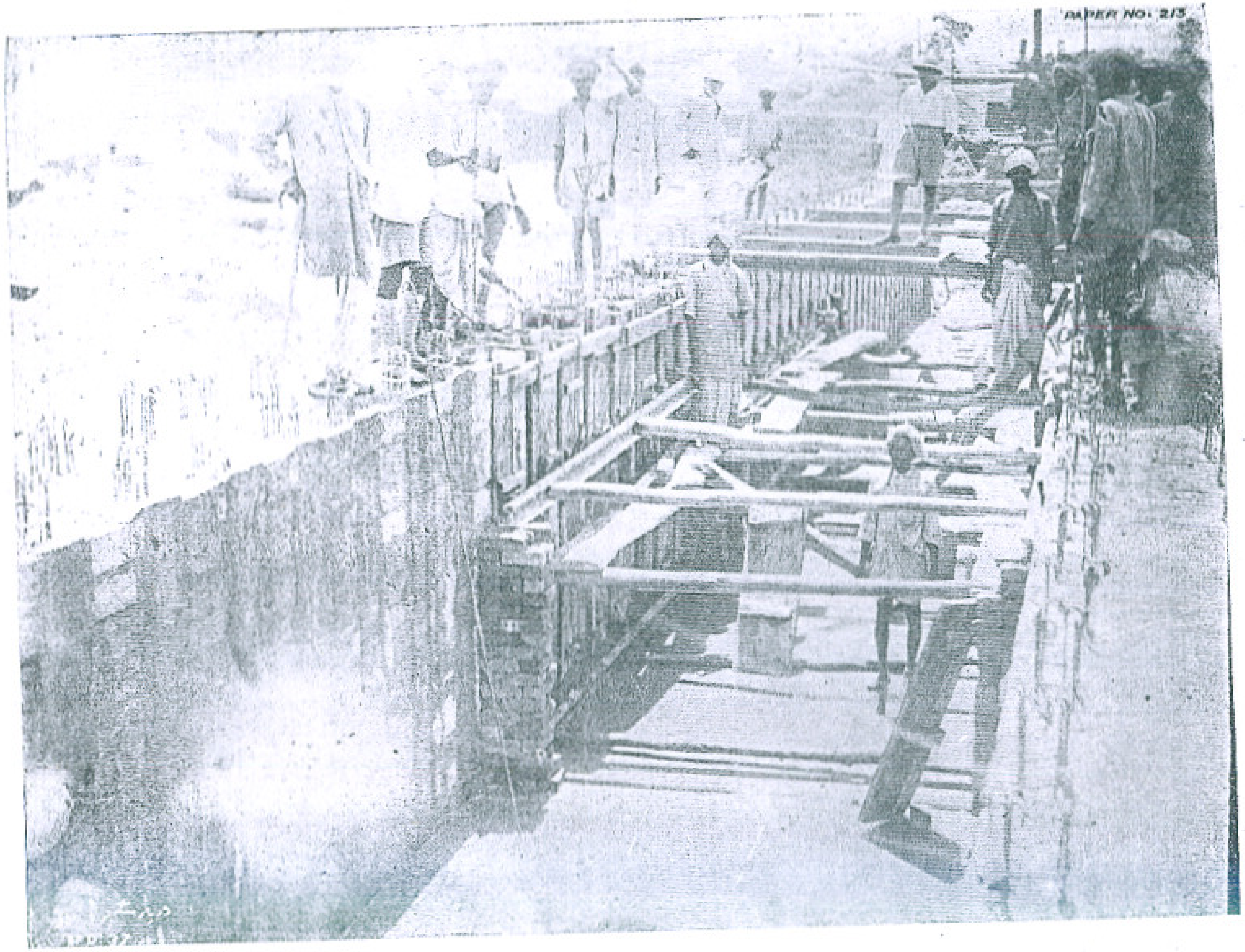
As the columns were to act as slabs between the top and bottom supports, the masonry was completed to full height and the cement concrete columns were filled afterwards. As a 9″ square hole, 7½′ height had to be filled in, it could not be done in one height and a special sort of shuttering shown in photo No. VII was adopted. The full height was divided into two bits and boards 10″ wide and 4 feet and 3½ feet high respectively were prepared. These were made to rest against the walls by means of B. G. rails and struts as shown. At first the first 4 feet from the bottom were filled up and then the shuttering for the upper 3½ feet was placed similarly in position and the top portion completed.

The concrete for this was made a little more plastic and workable, as the mortar had to find its way in all the recesses and hollow points of masonry. A comparatively liquid concrete was needed because of the column being high and narrow.

A slump up to 4″ even was allowed for this work to avoid honeycombing and to ensure a homogeneous and compact structure. The progress on this work was slow. The whole of the work in the barrel



VI Barrel reinforcement and concreting.



VII. Shuttering for columns in barrel walls.

walls was very complicated and difficult. The stone-cum-brick masonry with a network of reinforcement embedded in it and the concrete columns all required expert supervision.

The shuttering of the columns was removed after 48 hours after which the concrete was kept wet. Only 40 sets of shuttering were prepared which were used by turn in the columns.

Roof Slab.

After completion of the barrel walls up to the top, the roof slab was started. For centering, sand filling being the cheapest method was used. On the sides, masonry walls of proper thickness were erected and in the barrel wet sand was filled. It formed a compact mass for the centering.

On top of the sand filling, brick on flat floor was erected which was covered with $\frac{1}{4}''$ thick cement plaster, finished off with 1 : 2 thin surface.

A boiled mixture of oil and soap was used for coating the surface of centering. This when dried formed a good surface which did not grease the reinforcement bars. The reinforcement was placed on this on the same lines as in the case of the bottom slab. The barrel reinforcement was tied to the main reinforcement to form a compact joint with the slab. A 3" grove was dug out on top of the barrel walls to form proper T shaped bond, with the vertical arm extending into the walls.

The cement concrete consisting of properly designed mixture was laid by the same process as described under the floor slab.

Test cylinders of this were also sent to Rasul for testing the crushing strength and results are shown in Appendix I.

The centering was removed after 21 days and the surface obtained was very good. The banks on top of the slab were started after 28 days.

Upstream Drop Wall.

This consisted of hammer dressed stone masonry and was constructed along with the upstream wings. The top R. L. is at the bed of the upstream drain.

Permeable Protection.

Adequate permeable protections have been constructed in continuation of both the upstream and downstream approaches. The details of the inverted filter and stone pitching are shown in the drawings on plate III. Originally brick pitching was provided which was changed to stone pitching in the downstream portion to avoid damage by kallar. In the upstream portion where repairs are easy, the brick pitching has been allowed to stay.

Photo No. VIII shows the completed upstream portion of the syphon.

Pressure Pipes.

An adequate number of pressure pipes has been erected in the work in consultation with Rai Bahadur A. N. Khosla. Plate V shows both in plan and elevation the position of these pipes.

Due to transfer of the Author, correct readings and their scrutiny could not be made. It is desirable that readings of these pipes should be taken. The sub-soil water level has since the design risen by about 5 feet from 646 to 651, which may have increased the pressure under the work.

Rates.

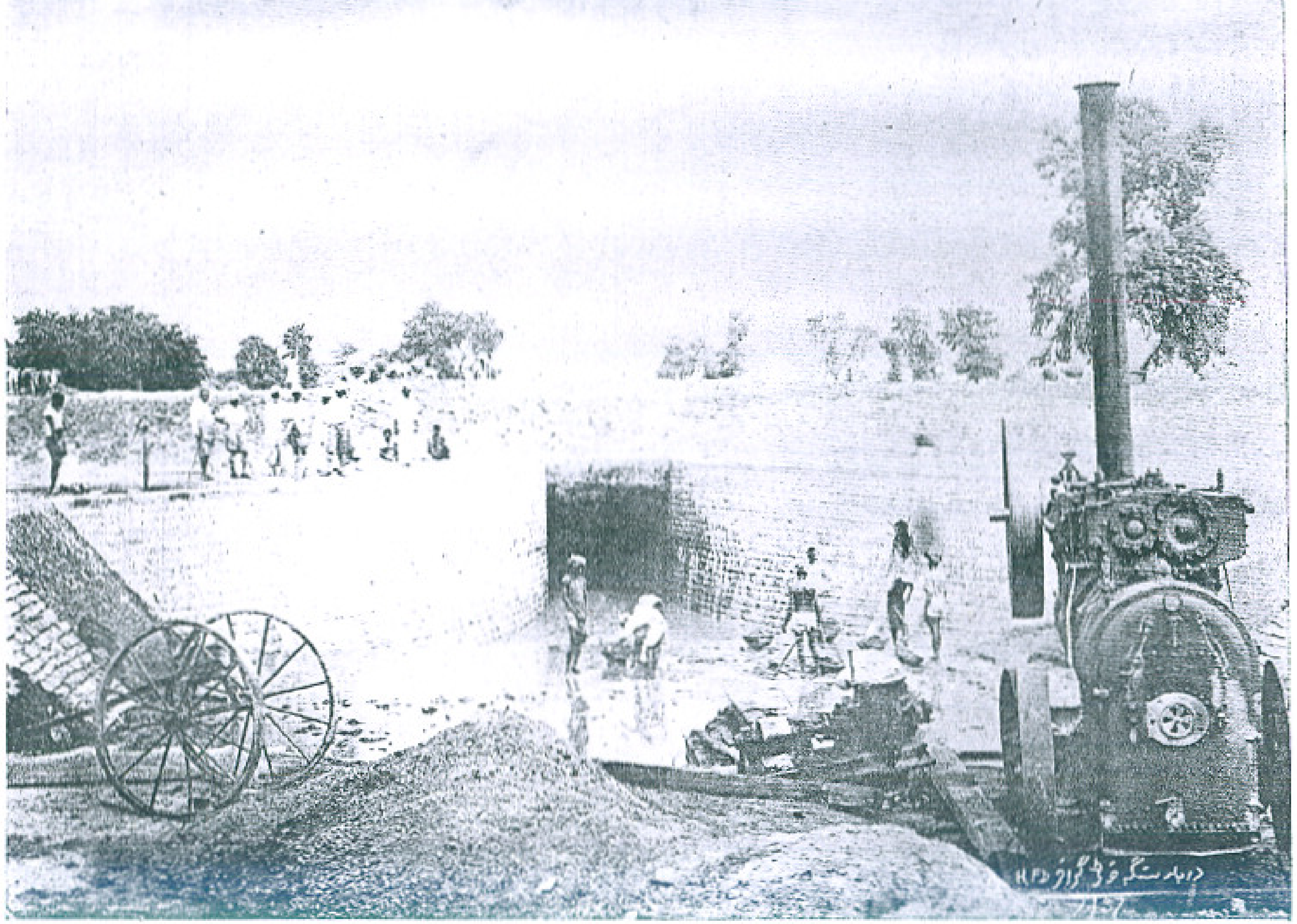
The rates paid on this work were decided upon after comparison with the rates on the four important works recently carried out, viz., reconditioning of Marala and Khanki Weirs, Deg Diversion and Jhang Branch Syphon. The least of the rates on the above works were accepted for this work. For machine mixed reinforced concrete a rate of Rs. 4/- per cent cubic feet was paid. In addition to this -/8/- per cent cubic feet was paid for basket work and -/8/- per cent cubic feet for wriggling concrete. The rates for earthwork and slush were as per schedule.The rate for piles worked out to be as normal as on other works.

Acknowledgements.

Acknowledgements are due to Messrs. McLeod and Jefferis for their valuable instructions and guidance during the construction of the work. Thanks are due to Messrs. Khosla and Wadehra for the help and interest taken by them in this work.

The successful completion of the work is mainly due to the hard work and energy exhibited by Mr. Panna Lal Malhotra, the Sub-Divisional Officer, who in spite of great personal inconvenience continuously stayed on the job and had practically every basket of concrete laid in his presence. The Author takes this opportunity of thanking him for his hard work and the interest taken by him in completing this job.

PAPER NO. 213



VIII. Completed Syphon—Upstream.

APPENDIX No. I.

Temperature, humidity, water cement ratio, bulking of sand and slump observations for Rakh-Branch Syphon.

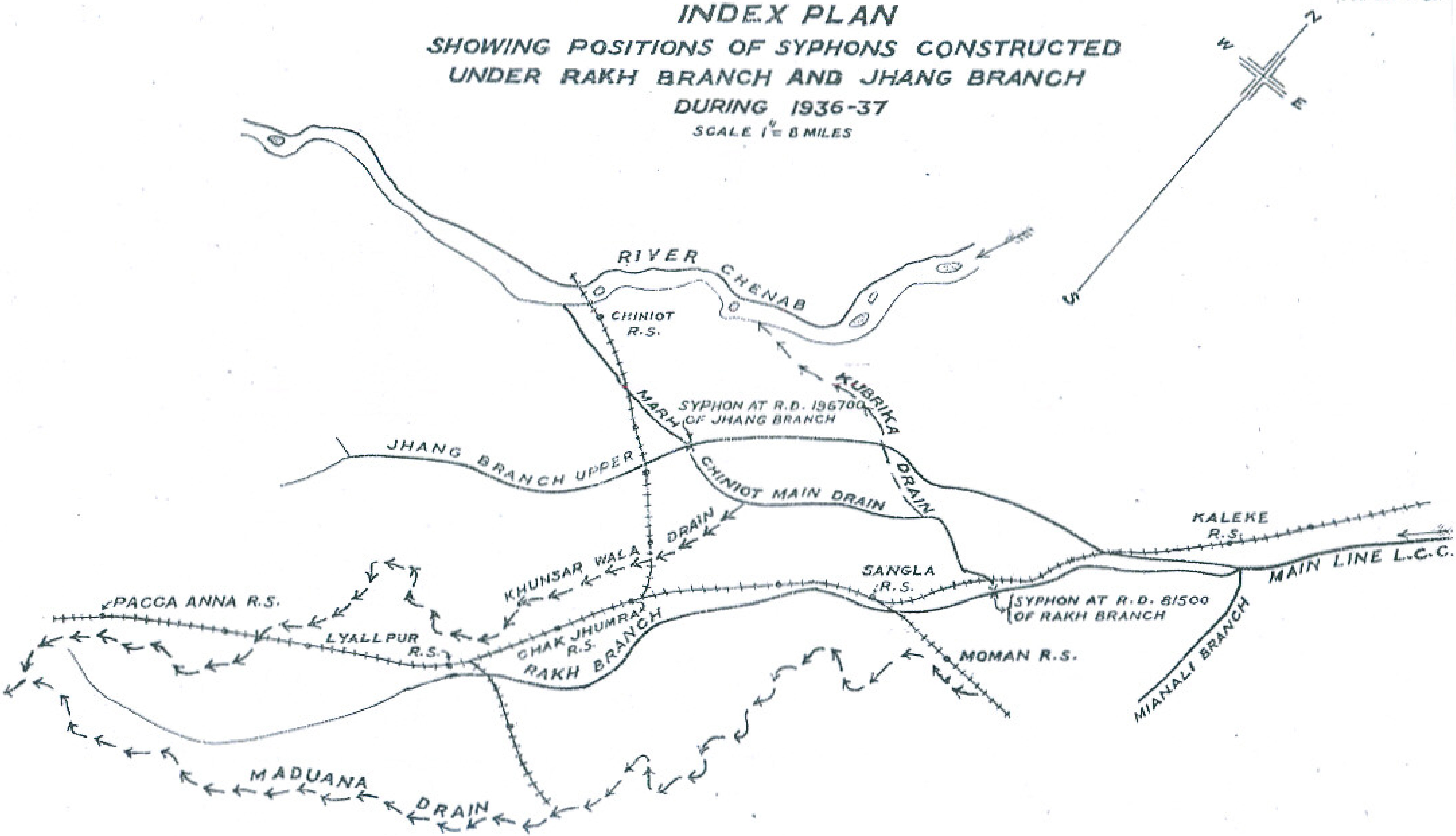
Dates.	Morning.					Noon.				Evening.					Remarks.
	Tem-perature. F°	Humi-dity per cent.	Water. Gallons.	Bulk-ing of Sand in 24″.	Slump	Tem-perature. F°	Humi-dity.	Water.	Slump	Tem-perature. F°.	Humi-dity.	Water.	Bulk-ing.	Slump	
1-5-37 ..	84	64	5	3½	1½	96	45	6	1½	90	50	5½	2″	1½	
2-5-37 ..	84	63	5½	3¼	1½	98	47	5½	1½	90	55	5¼	3″	1½	
3-5-37 ..	88	64	5½	3½	2½	98	44	6	2	92	52	5½	2½	2	
4-5-37 ..	84	64	5½	3⅞	2½	96	45	5¾	2½	94	54	5½	2	2½	
5-5-37 ..	86	66	5½	4″	2½	94	45	5½	2½	94	52	5½	2	2½	
6-5-37 ..	86	66	5½	4″	2¼	98	46	6	2½	95	53	6	2	1¾	
7-5-37 ..	84	66	5	3⅞	2	96	45	5½	1½	95	52	5	2	1¾	

APPENDIX II.

Compression tests of concrete made at Rasul for the Rakh Branch Syphon

No.	Date of casting.	Date of breaking.	Age.	Strength, lb. per sq.inch	REMARKS
1	4-7-37 ..	3-8-37 ..	29 days	4596	Average 4
2	Do. ..	Do. ..	Do.	4120	
3	Do. ..	Do.	Do.	4734	
1	5-7-37 ..	Do. ..	28 days	4081	Average 4
2	Do. ..	Do. ..	Do.	3962	
3	Do. ..	Do. ..	Do.	4120	

INDEX PLAN
SHOWING POSITIONS OF SYPHONS CONSTRUCTED UNDER RAKH BRANCH AND JHANG BRANCH DURING 1936-37
SCALE 1" = 8 MILES



DIAGRAMATIC SKETCH OF SYPHON

SHOWING POSITION OF SUMPS AND GENERAL ARRANGEMEN

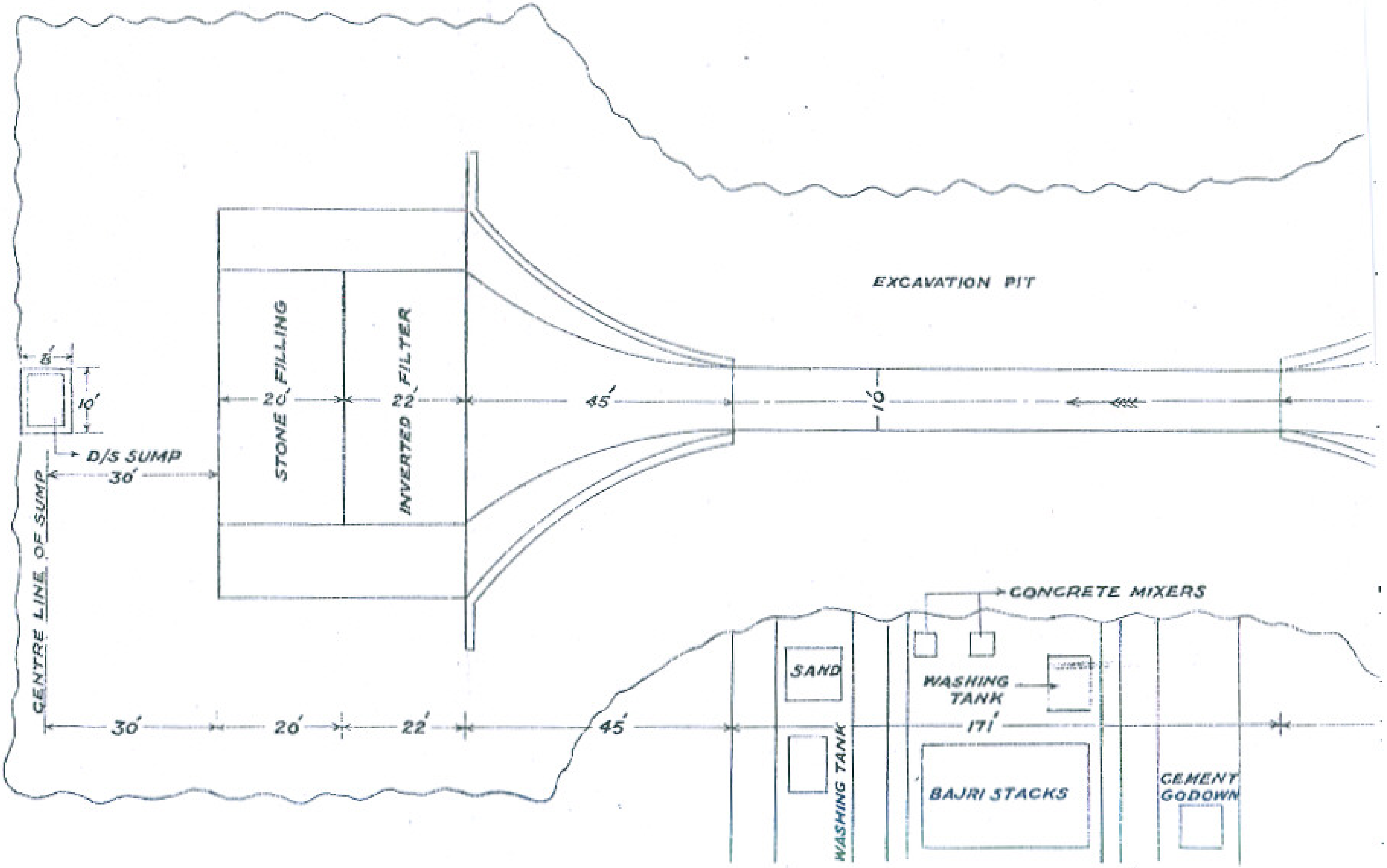
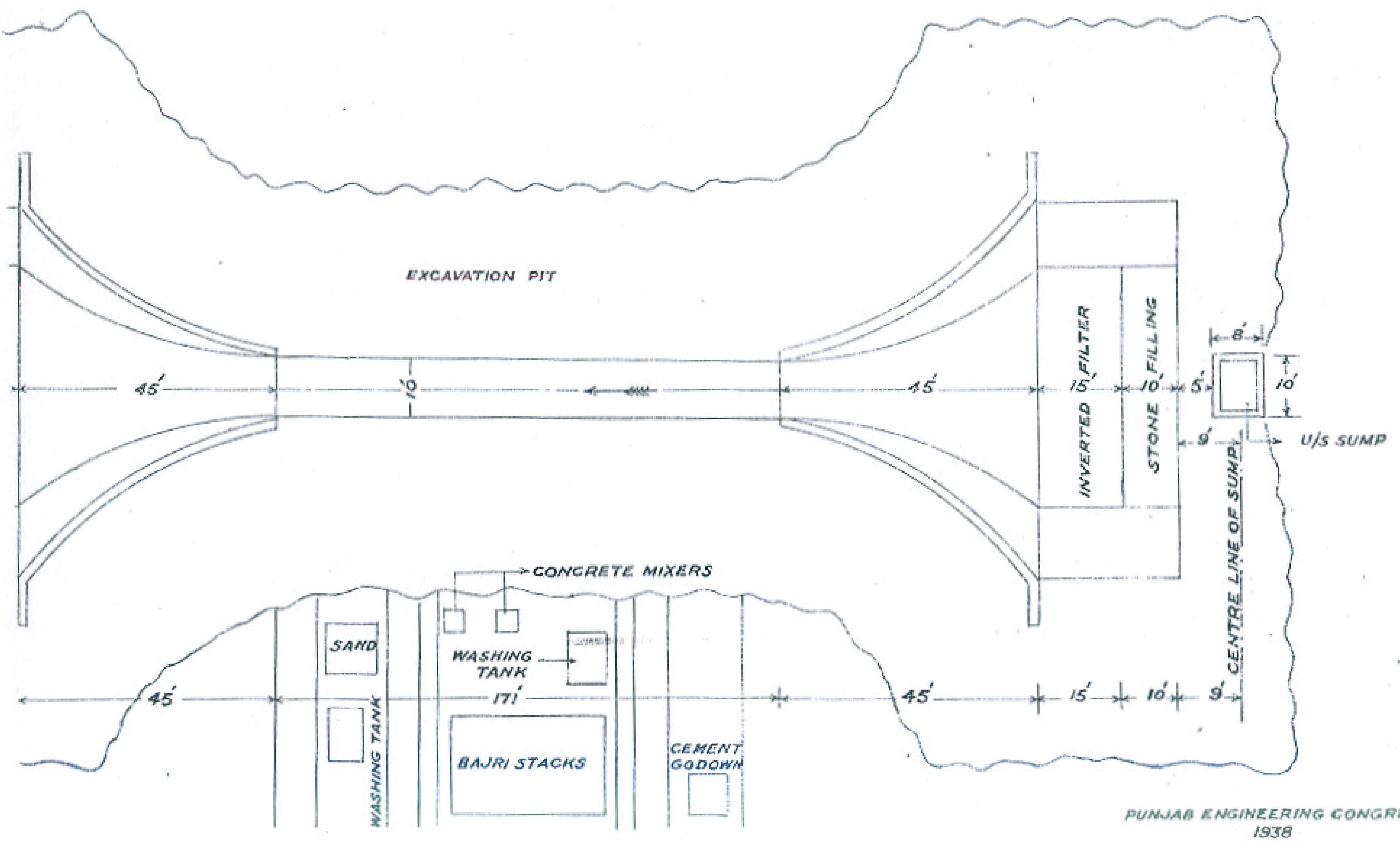


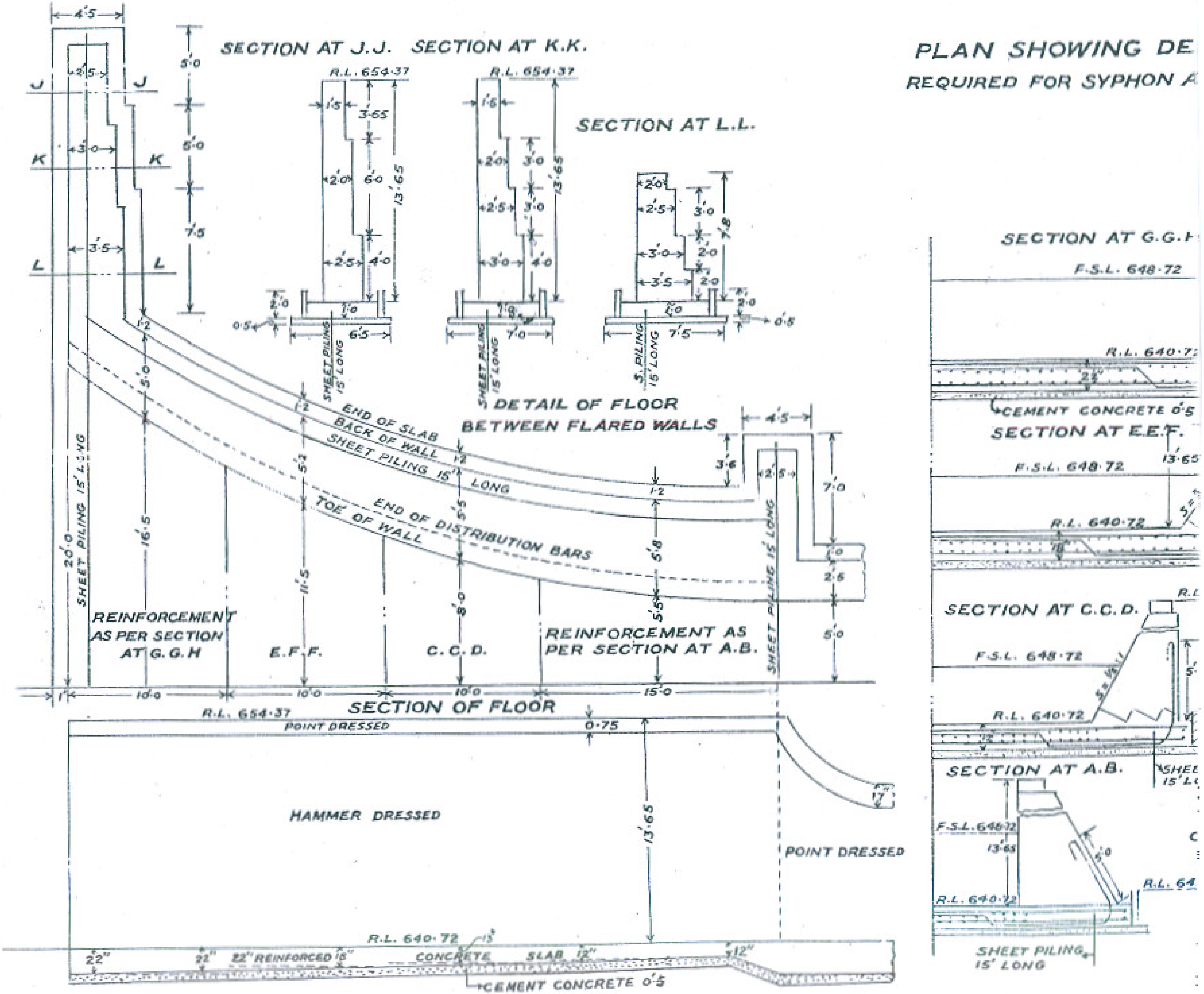
PLATE II
PAPER NO. 213

DIAGRAMATIC SKETCH OF SYPHON

SHOWING POSITION OF SUMPS AND GENERAL ARRANGEMENT OF WORK



PUNJAB ENGINEERING CONGRES
1938

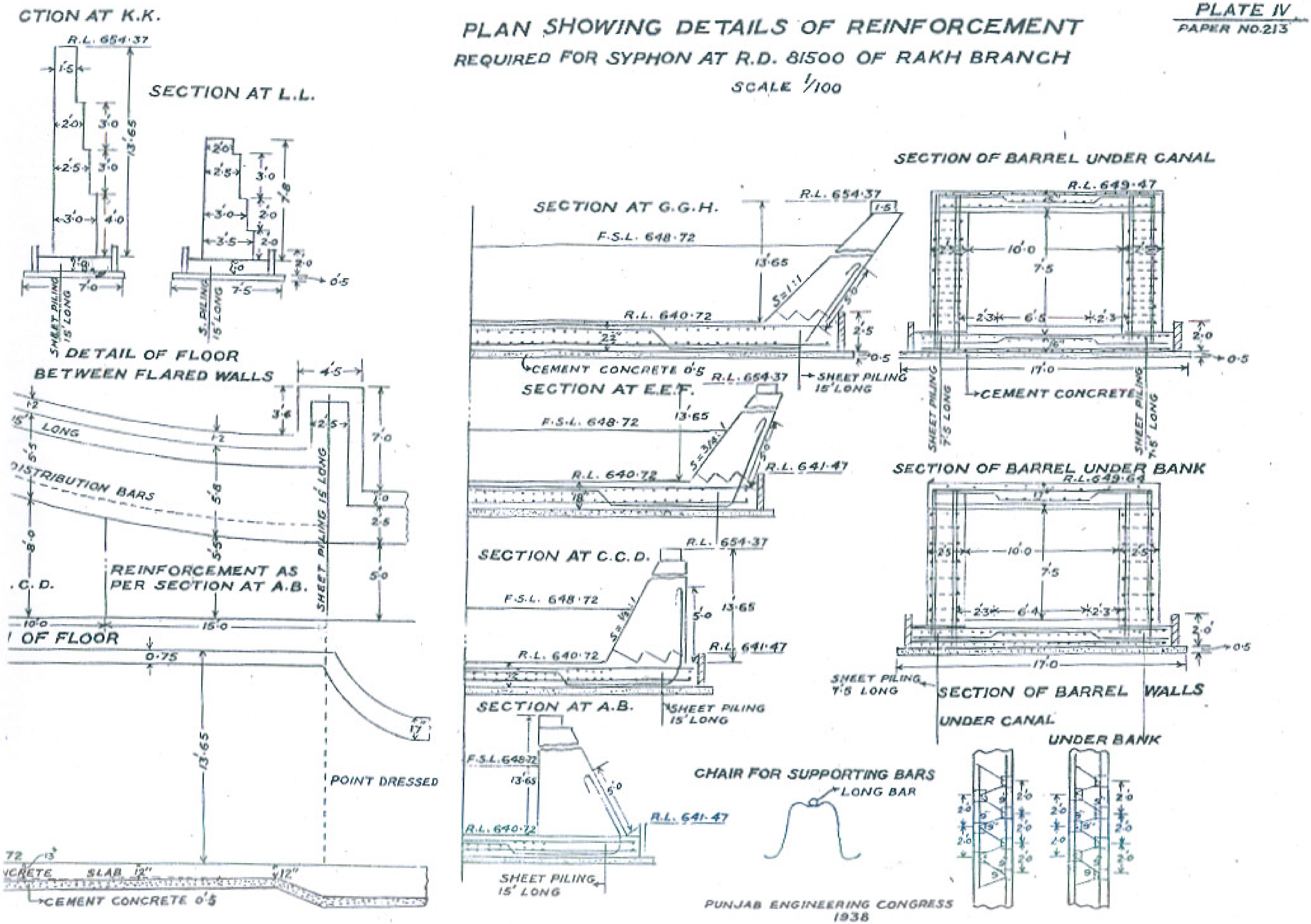


SECTION AT J.J.
SECTION AT K.K.
SECTION AT L.L.
R.L. 654·37
SHEET PILING 15' LONG
S. PILING 15' LONG
DETAIL OF FLOOR BETWEEN FLARED WALLS
END OF SLAB
BACK OF WALL
SHEET PILING 15' LONG
END OF DISTRIBUTION BARS
TOE OF WALL
REINFORCEMENT AS PER SECTION AT G.G.H
E.F.F.
C.C.D.
REINFORCEMENT AS PER SECTION AT A.B.
SECTION OF FLOOR
POINT DRESSED
HAMMER DRESSED
R.L. 640·72
22" REINFORCED
CONCRETE SLAB
CEMENT CONCRETE 0'5
PLAN SHOWING DE
REQUIRED FOR SYPHON A
SECTION AT G.G.H
F.S.L. 648·72
SECTION AT E.E.F.
SECTION AT C.C.D.
SECTION AT A.B.

PLATE IV
PAPER No.213

PLAN SHOWING DETAILS OF REINFORCEMENT REQUIRED FOR SYPHON AT R.D. 81500 OF RAKH BRANCH

SCALE 1/100



PUNJAB ENGINEERING CONGRESS
1938

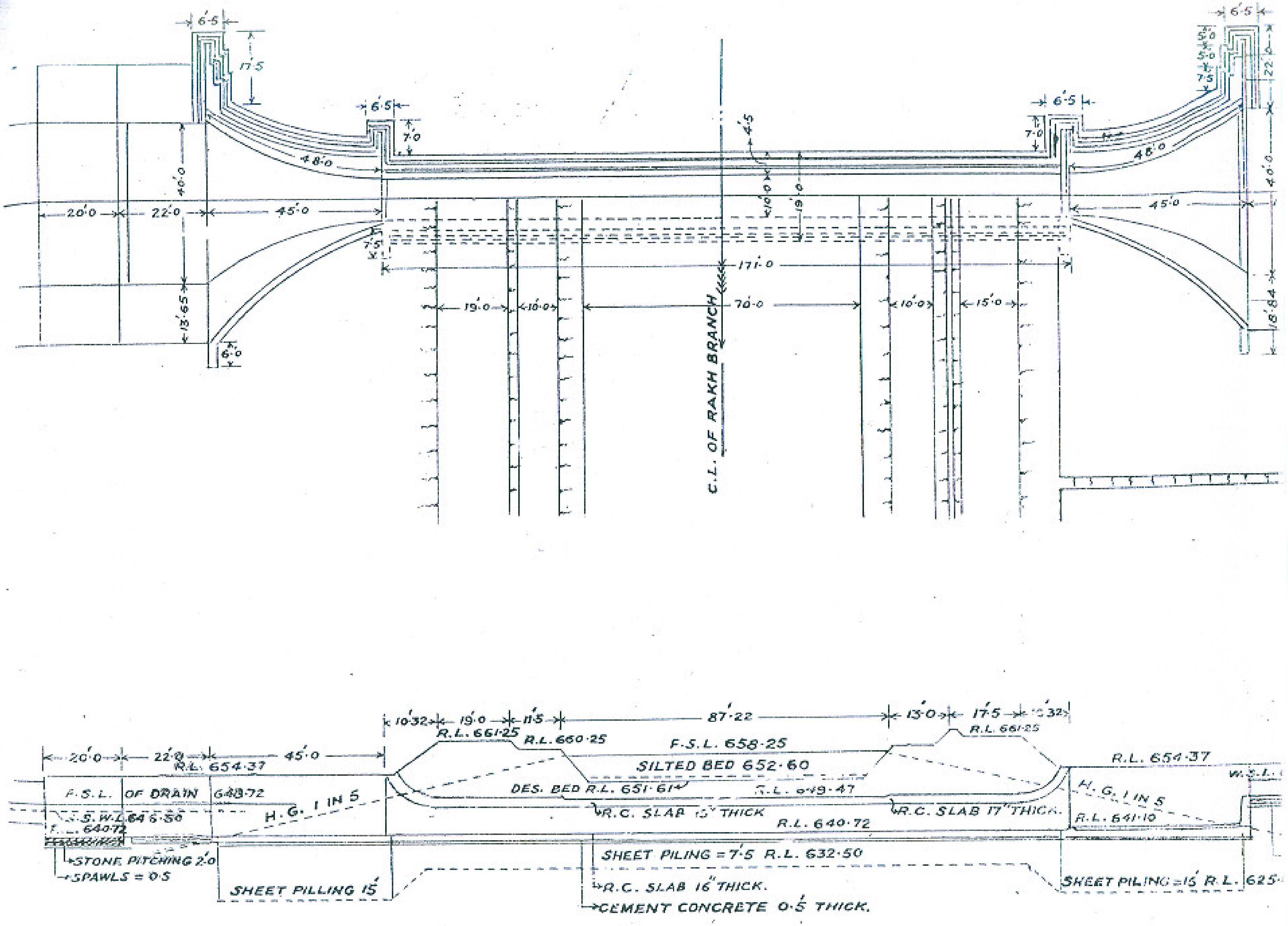
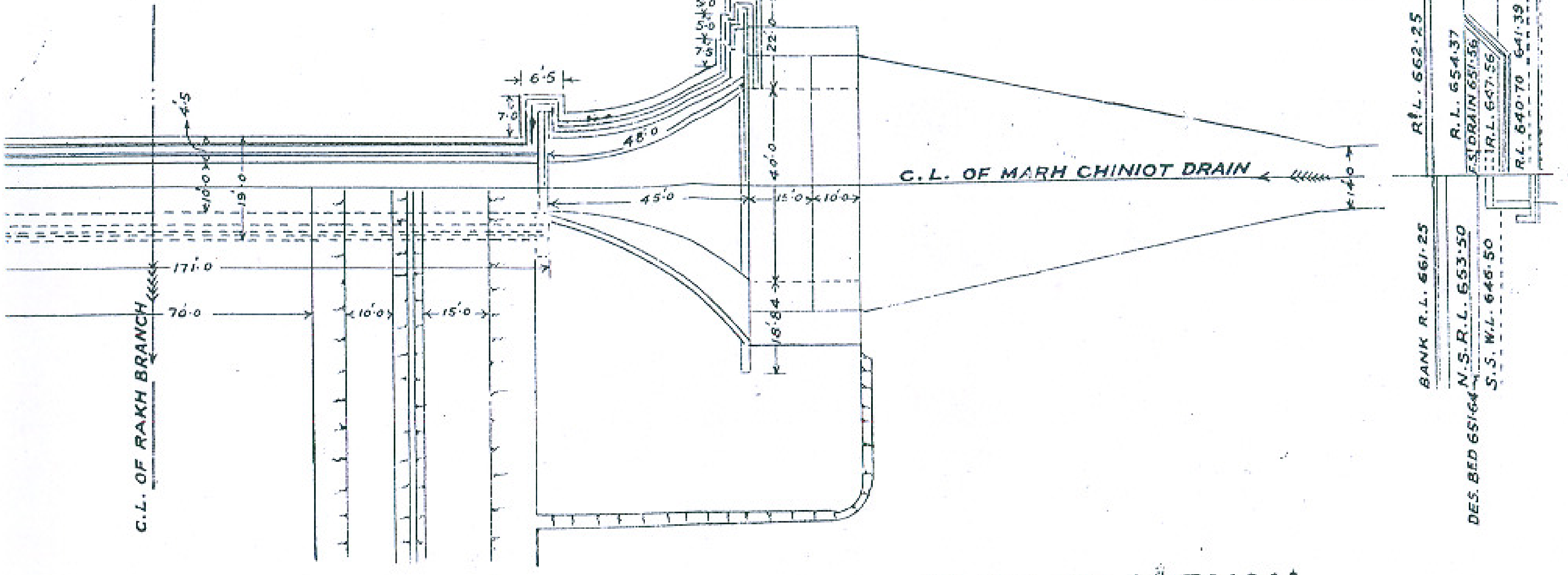
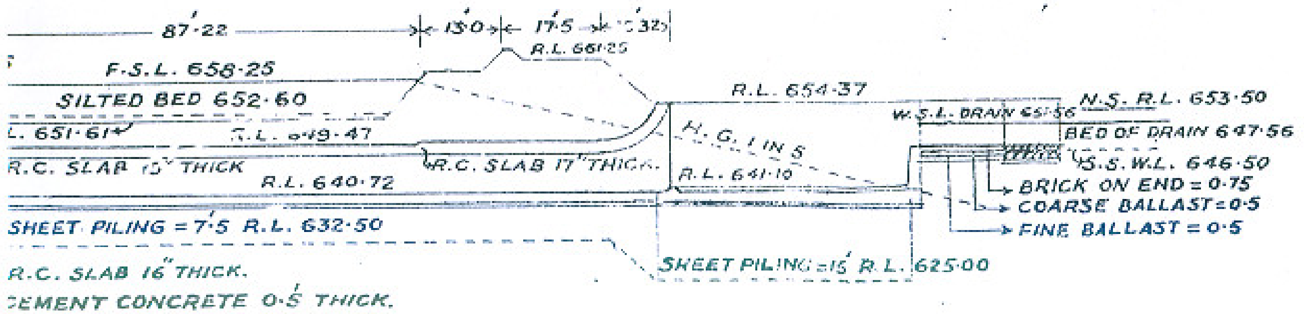

6·5
17·5
7·0
48·0
40·0
20·0
22·0
45·0
7·5
13·65
6·0
4·5
10·0
19·0
171·0
70·0
15·0
18·84
C.L. OF RAKH BRANCH
10·32
11·5
87·22
13·0
17·5
R.L. 661·25
R.L. 660·25
F.S.L. 658·25
SILTED BED 652·60
R.L. 654·37
F.S.L. OF DRAIN 648·72
DES. BED R.L. 651·61
H.G. 1 IN 5
R.C. SLAB 17" THICK.
R.L. 640·72
R.L. 641·10
W.S.L.
STONE PITCHING 2·0
SPAWLS = 0·5
SHEET PILLING 15'
SHEET PILING = 7·5 R.L. 632·50
R.C. SLAB 16" THICK.
CEMENT CONCRETE 0·5' THICK.
SHEET PILING = 15' R.L. 625

PLATE III
PAPER NO. 213



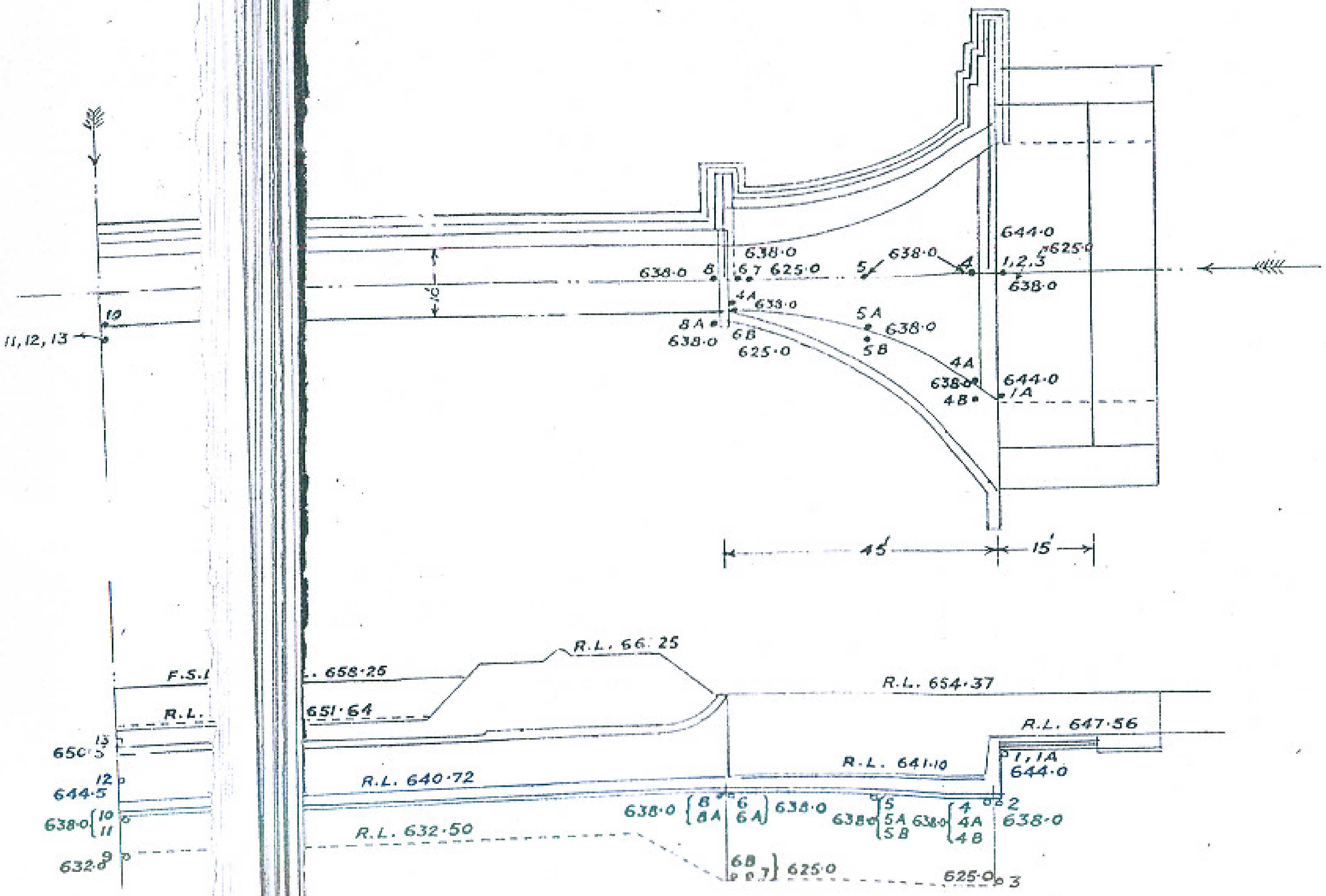
PLAN OF SYPHON
AT R.D. 81500 OF RAKH BRANCH
SCALE 1/400



PUNJAB ENGINEERING CONGRESS
1938

PLAN SHO[...]WING POSITIONS OF PRESSURE PIPES WITH THE[...]IR R.Ls. USED IN RAKH BRANCH SYPHON CONSTR[...]UCTED AT R.D. 81500 DURING 1937

SCALE 1/300



DISCUSSION

The **Author** while introducing his Paper said that the syphon consisted of a reinforced concrete box culvert except that the side walls had been replaced by reinforced brick and stone work for the sake of economy and without in any way reducing the strength of the work. Such hydraulic structures, constructed under sub-soil water level, were now common in the Irrigation Branch and the methods employed were known to practically all the engineers. The main point worth noting in this Paper was the care and attention given to the scientific manufacture of the concrete. The success attained in the construction was indicated by the result of the test cylinders, cast at the time of concreting. The strength of the concrete reported by the Principal, Rasul School, exceeded even the designed figures. This was due to the care in controlling the manufacture of concrete, for which all factors, viz., water-cement ratio, bulking of sand, etc., had to be minutely watched. As cement concrete was the order of the day in all hydraulic structures, he would like to suggest that more care should be given to its scientific manufacture than had hitherto been done. Small equipments for determining the fineness moduli of the aggregates could be kept handy, and the concrete mixture designed on the latest lines and as carried out on this work.

The cheapness of this design could not be questioned as a syphon for the same drain (carrying this drain under the Jhang Branch) with a barrel of practically the same section but 100 ft. longer, built in brick masonry, had cost about three times that of this syphon, the extra cost being more than the proportional increase in length of the barrel. As explained in the Paper, the floor had been designed as a slab partially fixed between the walls and to withstand a load of 1300 lb. per sq. foot which consisted of the weight of the superstructure and the superimposed load due to water and wet earth. The side walls too had been designed as slabs partially fixed between the top and the bottom, with a load of 6000 lb. per foot width for pressure due to submerged earth plus a head of 12 ft. of water. The top slab was designed to stand a load of about 1000 lb. per sq. ft. due to the water and earth on top of it. The whole structure had been tested as a box culvert and found to be quite safe.

The subsoil water level at the site was only about two feet below natural surface and elaborate pumping arrangements had to be made. To indicate the future safety of the work, pressure pipes had been fixed at points decided upon in consultation with Mr. Khosla. It was desirable that a careful watch be kept over the behaviour of the pressures underneath the floor, though the barrel remained always submerged due to the rise in the subsoil water level and there was therefore no danger to the safety of the work.

Mr. **P.L. Malhotra** said that the Author had dealt so exhaustively with the design and constructional details that there was not m room for comment. There were, however, one or two points to wl he would like to draw the attention of the Congress.

It was by very careful borings that an accurate forecast of subsoil conditions had been predicted and the suitability of the for this work determined. The results of the borings were founc be very accurate indeed. Not only had the suitability of the substrat under the concrete raft been determined in this manner but also condition of the soil strata at the bottom end of the sheet piles. T latter point was very important because if the sheet piles ended in clay stratum it would result in undue ponding up of pressure.

In the previous session a good deal of interest had been evinc during the discussion on the construction of the Deg Diversion on t use of tubewells for the drying out of foundations. Experience on t Rakh Branch syphon had been similar to that on the Deg Diversic For purposes of excavation, open pumping had been found quite suf cient. By the time foundation level was reached, tube wells had be installed and worked in addition to open pumping for keeping foundatio dry for laying the raft concrete. To prevent cracks in the raft due uplift and the consequent development of springs which would ha interfered with the laying of the R. C. floor these tube wells had bee worked continuously day and night until the whole of the reinforced co crete floor had been laid and cured for over a week.

The barrel walls constructed in reinforced brick-cum-ston masonry were said to be the most novel feature of this work; but th design as it finally emerged, after modifications, had not been found t be so practical from the builder's point of view. It had all the demerits o being too theoretical. The thickness of the walls was only 2·5 feet con sisting of 1·0 ft. of facing of point dressed Baghanwala stone and 1·5 ft brick masonry backing. The reinforcement consisting of 8 No. 3/8" bars at intervals of 2·0 ft. at both faces was embedded in 9"×9" cemen concrete poured in recesses left in the masonry. There were horizonta stirrups at 1·0 ft. vertical intervals for which grooves were cut in the stones and bricks for proper embedment in mortar.

With all these conflicting features the production of a homogeneous leak-proof wall was a problem, and a good deal of ingenuity was exercised in thinking of arrangements to ensure the proper bonding of the stone facing with the brickwork backing, of concrete columns with the stone and brickwork and of the horizontal stirrups in both stone and brickwork. The outside columns were concreted first. As water rose behind the barrel walls (before, of course, the concreting of the inside columns) it was found to be leaking through the 1·5 ft. brickwork backing at one or two points at places where recesses had been left for the inside columns. Plastering on the outside of the walls stopped these petty leakages and the concreting of the inside columns was then successfully completed. On completion, as was evident from photo No. 7, page 103, the barrel walls had been found to be leak-proof but that did not rule out the existence of hollows in the body of the wall.

It might be argued that this form of construction saved the cost of shuttering, but one should not forget that even here the 9″ concrete columns both at the back and front required shuttering of practically half the length.

The facing of Baghanwala stone was provided as a safeguard against disintegration of bricks from attack by *kallar*. Disintegration however only occurred when the structure was exposed to sun and weather. But in this case, due to high spring level, the barrel was liable to remain under water and the danger of damage from *kallar* was extremely remote. The bricks dug out of the foundations of the old Marh Escape Head at this very site had been found to be in perfect condition. The Baghanwala stone was expected therefore to serve little useful purpose beyond complicating construction and increasing its cost. No such precaution had been considered necessary on the Jhang Branch syphon which had to work under exactly similar, if not worse, conditions. The orthodox reinforced concrete wall would have been a much sounder proposition.

Mr. **Nand Gopal** said that the members should be thankful to the Author for giving details of this very interesting work. He wished he had known about it when it was being designed and constructed. If an opportunity had been possible for the Congress to visit this work when under construction he was sure it would have helped forward the most difficult and baffling problem of Waterlogging which was still before Punjab engineers, as cross-drainage works of this nature though not very great in cost, offered various problems for solution at reasonable cost.

The Author had given, on page 90, the total cost of the works as Rs. 1,00,000. It would have been more useful if he had split up expenditure into (*i*) diversion of canal, (*ii*) digging foundations, (*iii*) piles, and (*iv*) reinforced concrete work; just as he had given a separate figure for (*v*) pumping Rs. 20,000 on page 29. The Author had said he had to use old engines and pumps and had great difficulty in the execution of work. He had not given the number of days for which pumping had to be done but from the speed at which work was completed, it would not be more than 100 days. His discharge was 10 cusecs. On this assumption, if he had bought one large or two small Diesel engine sets it would not have cost him more than about Rs. 5,000 to 6,000 and pumping costs would not have been more than Rs. 15 per day for one large pump and Rs. 22 if two smaller ones were used. Allowing another Rs. 2,000 for fixing sumps and pumps, etc., a liberal figure would have been Rs. 10,000 and practically new pumps and engines left over for use elsewhere. This policy of using obsolete types of pumps involving waste of money in working expenses to an extent that more than covered the price of new plant, required serious consideration by all engineers who had to do this kind of work.

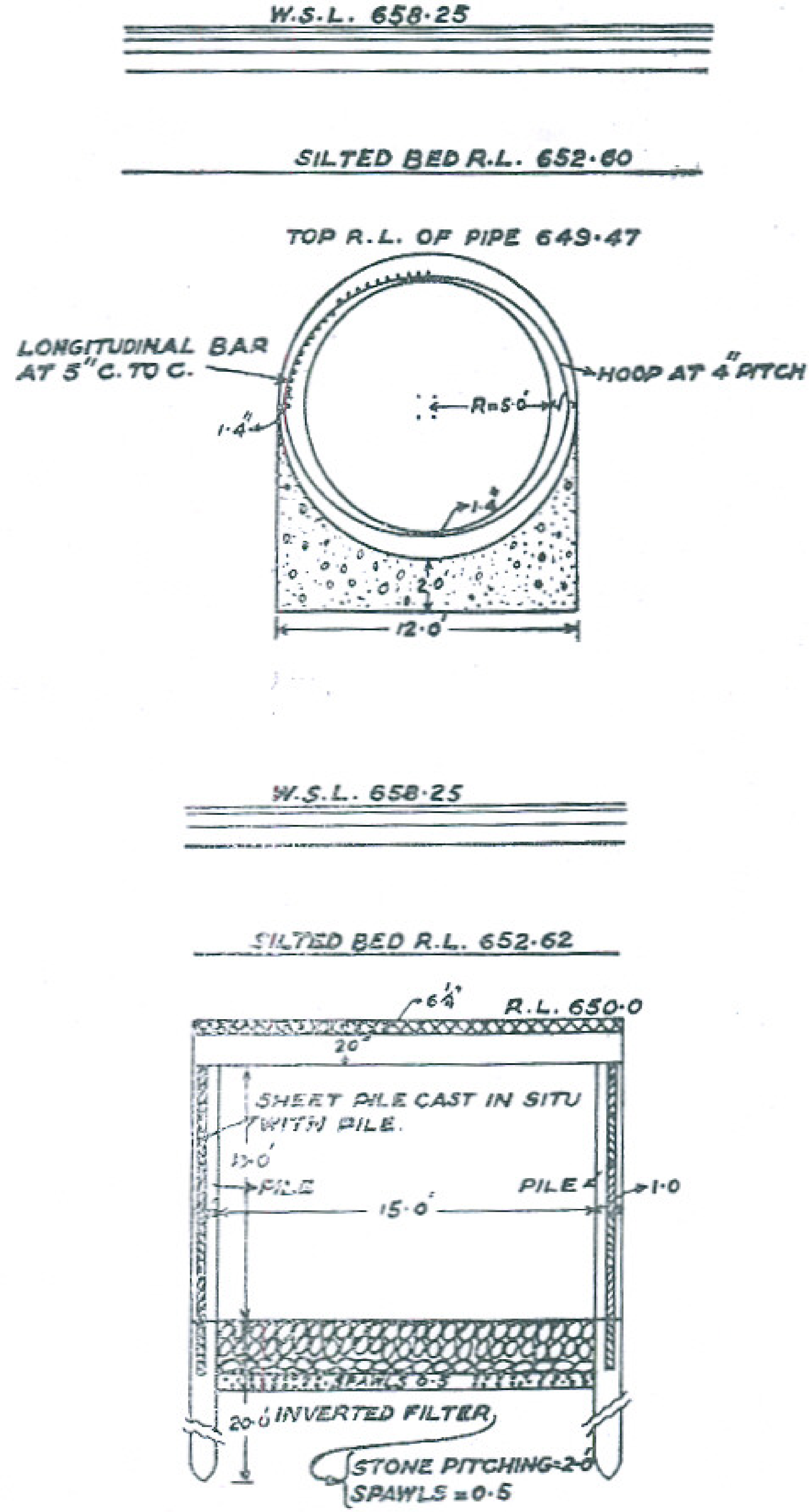
The design allowed for a maximum discharge of 900 cusecs through the syphon barrel which had a sectional area of 75 sq. ft. only. This meant an exit velocity of 12 ft. per second which, the Speaker was afraid, would play havoc with the downstream protection, and would require heavy cost in maintenance. It would have perhaps been cheaper to have a bigger section or to have added more protection. The bed slopes of the drain were not given but instead of 3·0 ft. drop at the upstream end of the syphon a steeper slope in the drain would have been more useful. Drains, that had to carry seepage water, did not seem to obey Kennedy's laws of earthen channels, nor more recent findings of Lacey, Sharma, or R. K. Khanna. They had dealt with canal water flow, but seepage water was very different. Drains constructed with slopes as steep as 1 in 1000 were known to silt and unless the Author had that or a steeper slope which was very improbable, it would have been better to have used the fall in steepening the slope. Drains in the Punjab did not require falls.

From approximate calculations made, it appeared that if the whole load was supported on piles, skin friction per sq. ft. would be about 700 lb. per sq. ft. If the whole were taken by the soil below, it would be about 1300 lb. (0·6 ton) per sq. ft. Separately taken, both would be unsafe. Even allowing for uplift pressure due to high spring level, a reduction of about 100 lb. per sq. ft. could be assumed (but this could not and should not be depended on as it might fall at any time due to anti-waterlogging measures). The Speaker continued that he would be grateful if the Author would give safe loads for skin friction of piles and soil below and if both were taken to share the load, on what principle distribution had been based. It looked as if either piles or r. c. floors were unnecessary.

It would be interesting to know what alternative designs, if any, had been considered and why they had been given up. It appeared to him that a considerably cheaper design would have been :—

(*i*) An r. c. barrel 10 ft. diameter which would give slightly greater sectional area. No piles need be put in. The soil under it, enclosed as it would be from all sides, would stand any pressure. No wing walls would be required if the barrel was made long enough, right up to the toe of the slope of the canal banks, which should be pitched with stone. The fall on the upstream side was unnecessary, as he had already explained. Again on approximate calculations the cost worked out cheaper as compared with the corresponding item of r.

FIG. I


W.S.L. 658·25
SILTED BED R.L. 652·60
TOP R.L. OF PIPE 649·47
LONGITUDINAL BAR AT 5" C. TO C.
HOOP AT 4" PITCH
R=5·0'
1·4"
1·4"
2·0'
12·0'
W.S.L. 658·25
SILTED BED R.L. 652·62
R.L. 650·0
20"
SHEET PILE CAST IN SITU WITH PILE.
PILE
PILE
1·0
15·0'
INVERTED FILTER
STONE PITCHING=2·0
SPAWLS =0·5

concrete and masonry given above. The cost of piles would be a saving and shuttering would not be more expensive than in the design adopted.

(*ii*) Another alternative worth the trouble of detailed investigation would have been one comprising (*a*) vertical r.c. concrete piles with an r. c. slab, extending to full length and up to pitched canal slopes with no wing walls and (*b*) a pervious floor like the one used at the ends in the design adopted so that seepage water could come through and help in dewaterlogging the area around, instead of being choked with a very expensive impervious floor in the middle and inverted filters at the ends only. He was sorry he had not had the time to work out the cost of this design, but he was sure it would be far cheaper than the present structure.

These alternatives were given on Fig 1. It would be seen that it would not cost very much in the second alternative to double the waterway by making an r. c. slab of 15 ft. span on two lines of r. c. piles, 10·0 ft. apart, which would reduce the velocity at maximum discharge to 6 ft. per second and thus save not only the damage downstream and expensive maintenance but also required not so heavy a floor.

In conclusion, he would like to say that the effort at design had not resulted in the best and cheapest form. With any of the alternatives that he had ventured to propose, and more efficient pumping in the way suggested, a better work could have been produced at 25 to 50% less cost.

Mr. **S. L. Kumar** remarked that he had failed to understand why reinforced brickwork had been used for the barrel walls. If reinforced concrete could be trusted to carry the loads on the roof and floor, it could be relied on to carry the lateral pressure on the barrel walls also. This would have obviated the use of stone facing to protect brickwork against *kallar*. On the other hand the use of reinforced concrete throughout would have ensured uniformity of strength in all parts of the structure and would also have facilitated calculations. The only argument which the Author might advance against the use of r. c. barrel walls was the additional cost of shuttering required for such walls. As a matter of fact shuttering had been used by the Author for casting thin r. c. columns. In addition to this the design had involved the additional expense of stone facing and of bonding the reinforcement in the columns to this facing work. Further, out of the total thickness of 2·5 ft. of barrel walls, only 1·5 ft. could be figured for strength. Walls of reinforced concrete 12″ to 15″ thick would have been quite adequate and would surely have been economical in materials and cost.

The Author had carefully avoided in the Paper any reference to safe stresses (f_c and f_s) adopted for design of the structure. On enquiry, he had informed the Speaker that f_c and f_s had been taken at 600 lb. per sq. inch and 16,000 lb. per sq. inch respectively. It was not understood why with f_c equal to 600 lb. per sq. in., a 28-day strength of 2600 lb. per sq. inch was required of finished concrete. According to the Revised British Code of reinforced concrete a 28-day strength of 2160 lb. per sq. in. was all that was necessary.

The Author had not indicated the correct method of designing the real mix but had assumed independently of each other the three elements, namely the 28-day strength of concrete, the water cement ratio and the real mix of concrete. As a matter of fact all these elements were interdependent. The correct way in which the Author should have determined these elements was as follows:—

$$f_c = 600 \text{ lb. per sq. in.}$$

Requisite 28-day strength of concrete $= 600 \times 3{\cdot}6$

$= 2160$ lb./in., according to the Revised British Code. According to tables given in the Railway Board's Technical Paper No. 291 or on page 14 of "Design of Concrete Structures" by Urquhart and O'Rourke a water cement ratio of 1·125 was required for this strength of concrete.

Therefore, quantity of water required per cu. ft. of cement

$$= \tfrac{9}{8} \times \tfrac{25}{4} = 7 \text{ gallons.}$$

The real mix could be worked out from the formula

$$G = A.\,K.\,(V_c + \tfrac{3}{4}\,V_{rm})$$

(Vide formulae in Railway Board's Technical Paper No. 291).

Where G is water required in gallons

V_c is volume of cement in cu. ft.

V_{rm} is the volume of mixed sand and shingle

A and K are constants.

In this case $A = 1{\cdot}0$ and $K = 1{\cdot}1$

Since $7 = 1{\cdot}0 \times 1{\cdot}1\ (1 + \tfrac{3}{4}\ V_{rm})$

Then $\tfrac{3}{4}\ V_{rm} = \dfrac{7}{1{\cdot}1} - 1$

$$= 6{\cdot}36 - 1 = 5{\cdot}36$$

$V_{rm} = 5{\cdot}36 \times 4/3 = 7{\cdot}12$

So the real mix should have been 1 : 7·12 instead of 1 : 5 assumed by the Author.

On page 97, the Author had assumed that for the observed bulking of sand, it must have contained 2% by weight of water. It was the easiest thing for him to dry the sand and to find the actual quantity of water content in the sand instead of basing it on its bulking percentage. The danger involved in the assumption was indicated by the experiments on bulking of sand reported in the January 1936 issue of "Concrete and Constructional Engineering" by Oscar Faber. The graph plotted therein indicated that sands having a bulking percentage of 12 had either ½% by weight of water or 13½%. The Speaker was inclined to think that sand obtained from the foundation pit under 13 ft. head of water had contained the higher percentage rather than the lower.

The Author had tried to indicate that the amount of water determined from the formula in the Speaker's Paper No. 202 was more than that he had found necessary. This was based on faulty arithmetic. According to the figures given on page 97, G should have worked out as 11·95 instead of 13·1 gallons. The Author's own method, *viz.*, 5 gallons to a cubic feet of cement gave G equal to 11·70 gallons which compared very well with the Speaker's figure of 11·95 gallons.

The Speaker concluded by saying that the object in controlling concrete was to get the maximum quantity of finished concrete of desired strength for each bag of cement. To him, it appeared to be a sheer waste of money to design for $f_c = 600$, assume a 28-day strength of concrete of 2600 and use a rich mix. In spite of this the Author had claimed that the concrete had been scientifically designed.

Mr. **R. S. Talwani** said that the Author's Paper was a very useful contribution, particularly from the point of view of actual execution of work, especially important r. c. work. But there were some points which still required clearing.

On page 95 the Author had written "so long as a workable consistency is obtained or in other words so long as a mixture is plastic and workable for a constant water ratio, the strength of the concrete is fixed irrespective of the quantity of aggregate." Again on page 99 he wrote: "Consistency and workability of the concrete were carefully regulated by means of slump tests. This was a matter of great importance as excessive water reduces the strength of concrete even to 40% of its designed value. The aim was to produce concrete of such a degree of plasticity as to work readily in the moulds and round reinforcement bars and to form a compact and dense mass of concrete." So it was clear that too much water decreased the strength and too dry a mixture resulted in honey-combed spongy concrete. But the slump tests did not show any sponginess. Would it not have been better, if apart from slump test, some samples of concrete with different water ratios had been made and their strength examined and then a happy mean between too much and too little water adopted which might have given the maximum strength?

Again, on page 96 he had written " The bulking of sand was found to be $\frac{1}{8}$ or 12%. Again, the bulking of shingle was negligible and only 2% allowed." On page 97 he had written that " the water in sand for the observed bulking was assumed to be 2% and in aggregate 1%". It had not been made clear how he assumed the bulking in sand equal to 2% when it was actually found by experiment to be 12%. Also it was not given how he found the bulking of shingle. Was it only assumed or was it actually determined and if so, how?

Further, he had calculated that water to be deducted from sand was 0·86 galllons and from shingle 0·97 gallons or a total of 1·83 gallons. But it was mentioned nowhere what amount of water per cu. ft. of cement he actually used.

For the under-water cement ratio, he had said 10 gallons were required for 2 cement bags. But 2 bags were equivalent to 2·34 or 2·35 c.ft. of cement. Hence, normally, the water required for 2 bags should have been 2·35 × 5 or 11·75 gallons. Deducting 1·83 gallons of water found by him in sand and shingle the balance remained 11·75—1·83 or 9·92 gallons. What did he actually use and with what results? Did this amount of 9·92 gallons give him the required slump and required consistency? How could the figure of 13·1 gallons of Mr. Kumar be compared with his unknown figure?

Mr. **G. R. Sawhney** said that it would be interesting to know what was worrying the Author in apologizing for presenting this Paper. Mr. Sawhney thought he should be congratulated for giving them such a good description of how an important work should be done.

The design of the syphon as well as the methods adopted for the execution of this work were no doubt good, well explained and interesting. Portable steam engines were always more reliable. It was a pity it did not strike the Author to get a couple on loan or hire from the B. and R. Branch and thus save himself all the trouble. Troubles usually had a nasty habit of appearing when we had started progressing.

He hoped the piles used had sufficient overlap, as some piles which manufacturers produced for constructing temporary coffer-dams had a bad habit of getting fixed in position as permanent cut-offs and then failed to do the trick. Had the Superintendent, Central Workshops been consulted before using these old piles?

If the quantity of aggregate did not matter then what use was there of fixing ratios of cement, sand and aggregate? The Speaker's experience was that a concrete which would flow round such bars would produce a certain wetness in mortar on the surface after tamping. What had the specially prepared platform been like? The Speaker thought that for such works, wheel barrows or at least mortar pans could be employed with much advantage as the removal by baskets even when they were lined with gunny did not seem to go well with the other precautio taken. Even if baskets were to be used they should at least have be lined with canvas instead of gunny.

Precautions taken to make sound joints at each day's wo were well considered, as many a syphon had shown bad leaks throu such joints afterwards, wherever this had not been done. What kin of masonry had been made for the columns to keep the vertical rei forcement in position, cement, *kacha*, *pacca*, or dry ?

What special arrangements had been made by the Author for th expert supervision of this work ? One generally found it quite difficu to find men who were able to exercise just "ordinary" or "good supervision.

What number of pressure pipes was considered adequate and wh had been demonstrated by their readings?

Mr. **Khosla** on being invited by the President to make som remarks regarding the design of the syphon, explained by means of diagram, the method of designing the side walls of the barrel. H explained that while designing the walls, full hydrostatic pressu had been added to the full earth pressure at the back of the wall which was the safe and correct procedure as had been found out in th latest researches.

The **Author**, replying to Mr. P. L. Malhotra, thanked him fo supplying the details regarding boring which had been omitted fro the Paper. Regarding the composition of the material of the barrel wal the Author said that the reinforced brick-cum-stone masonry wa accepted for economy, the stone work having been added to the surfa to withstand *kallar*. The constructional difficulties were not foresee then. It was certain that the work as designed was cheaper than pu reinforced concrete.

Replying to Mr. Nand Gopal, the Author said that the detaile estimates for the work could be had from the Hafizabad Division, Lowe Chenab Canal. The work had to be carried out in a hurry and th pumping sets available in the department were made use of. Attempt were made to exercise maximum economy, and the Author doubted i Mr. Nand Gopal's proposals for pumping would have been cheape There was no time to order new sets. Regarding the 3·0 ft. fall in th syphon, the drain at both ends had been designed independently and th upstream and downstream levels gave this fall. It would be quit useful if Mr. Nand Gopal's suggestions for steepening the slopes o drains were considered by the Drainage Circle while designing drain

Regarding the introduction of piles under the floors these wer provided to reduce the uplift pressures and were designed on the general principles of hydraulic works on sand foundations, recently enumerated by Mr. Khosla. There was no question of using these piles for carrying the loads on the subsoil. The barrel walls were expected to generate enough friction and the load of the superstructure was expected to appreciably diminish while being transferred to the founds, which were found to be safe even without any friction effect. The piles were not to function for the loads.

The alternative designs considered were the masonry barrels with arch roof, as constructed under the Jhang Branch, and a reinforced concrete box culvert. The final design consisting of reinforced concrete roof and bottom slabs, and side walls of reinforced brick-cum-stone masonry was a result of considering both these desings, as this combination was found to be the cheapest. The two alternative designs mentioned by Mr. Nand Gopal did not suit the situation.

It had been calculated that there would be 12·0 ft. head of water under the floor when the canal was full, and it was not understood by the Author, how the pervious floor under the barrel was considered practicable by Mr. Nand Gopal. The constructions and design of the reinforced concrete barrel involved a complicated design and might ultimately have been more costly. A simple box culvert of reinforced concrete, mixed with brickwork (as constructed) appeared to be the safest, the cheapest and most practicable at the site.

In reply to Mr. Kumar, the Author said that the reinforced masonry barrel walls were introduced only as a measure of economy and easy construction. The usual stresses of 650 lb. per sq. inch for concrete and 16, 000 lb. per sq. inch for steel had been assumed. The assumed stresses which appeared uneconomically low to Mr. Kumar, were considered suitable for this hydraulic work subject to all sorts of subsoil pressures. The concrete mixture had been designed on the lines given in "Modern Methods of Concrete Making," by A. E. Wyun and E. S. Andrews, and the Author thanked Mr. Kumar for showing a better and the latest method of designing concrete mixtures and giving references to the same.

Regarding the assumption of moisture by weight in the sand, the Author said that he had followed Wyun and Andrews' book, referred to by him. There were no arrangements at site for determining the moisture contents by weight. The Author pointed out that for a hydraulic work of the type under discussion, it was preferable to err on the safe side and manufacture concrete of sure strength as had been done by him.

In reply to Mr. Talwani the Author said that the precautions taken to ensure proper water-cement ratio were considered quite sufficient to meet the situation. It was not practicable to carry out strength tes and wait for their result before starting concreting. The bulking sand was not 2% as understood by Mr. Talwani, but the moisture conte for the observed bulking of ⅛th were assumed to be 2%. The bulkir of shingle was generally negligible and was assumed to be only 2% The quantity of water used in the manufacture of concrete per cu. f of cement was given in the statement in Appendix No. I. The Autho referred Mr. Talwani to the appendix wherein all the informatio regarding slumps and quantity of water used was given.

In reply to Mr. Sawhney the Author said that the piles used wer quite good and their sound interlocking was ensured at the worl The quantity of aggregate did matter, but according to the latest researche on concrete, the strength depended upon the water-cement ratio. Th platform under the mixer was of sheet iron. The lining of baskets wit gunny bags was found to be quite economical and suitable at site. For th columns, for keeping vertical reinforcements in position ordinar *kacha pacca* masonry had been used. The number and position o pressure pipes was shown in Plate No. V. The Author, concluding remarked that he had attempted to execute the concreting work o scientific lines and the results showed that the strength attained justifie the trouble taken in going into the minutest details of concrete manufac ture.

ERRATA.

Page	Line	For	Read
109	18	Rhebock	Rehbock
115	Photo 1	Universal Pitot tube	Universal Pitot tu and print gauge.
129	35 and 36	Sill as designed by Rhebock	Dentated Sill
131	Fig. 11(contd.)	Rehbock Dentated Sill	Dentated Sill
Plate I b		Rehbock Sill	Dentated Sill.