the work was as follows :

16—Portables—These proved very useful in supplementing the power from the Power House.
1—Sentinel Steam Engine.
1—Fowler Steam Engine.
15—Centrifugal pumps, size 8″ to 14″.
12—Electric pumping sets, size 10″ to 15″.
24—Electric pumping sets, size 6″ to 8″.
21—Electric pumping sets, size 3″ to 4″.
74—Electric pumping sets, size $1\frac{1}{2}$″ to 2″.
11—Bernard sets, size 4″ to 6″.
2—Merry Weather Engines, oil fired.
6—Air Compressors.
9—Cubic yard concrete mixers.
10—$\frac{1}{4}$ Cubic yard concrete mixers.
20—Vibrators.
6—Grouting machines.
3—Pile Drivers complete.
2—Pile Drivers without derricks.
2—Bucyrus Excavators.
2—35 H. P. Ruston Engines.
4—10 Ton Cranes.
1—Steam Hoist.
4—B. G. Locos.
276—B. G. Trucks.
2—2′ Gauge locomotives.
500—2′ Gauge tip waggons.

Programme of Work

The programme was essentially governed by the limitations of budget on account of the war. The general programme was, however, as follows :—

1939-40

(*a*) The acquisition of land and completion of buildings so that the staff could be properly housed.

(*b*) The completion before the flood season of all works necessary for the defence of the working area against river attack, *i.e.*, the first line of defence, the ring bund, the Left Marginal Bund and the bund round the station area.

(*c*) Outside the Weir area of the excavation of only such lengths of the protection works as could be immediately given the necessary stone aprons and pitching, as in a sandy soil with high spring level, the bank will fall in very soon after construction, unless the stone is immediately placed. This meant the completion of Right Guide Bank U/S 1,000—3,500 and Left Guide Bank U/S 1,000 to nose. A strong temporary nose was provided for the Left Guide Bank as this was expected to meet strong river action.

(*d*) Inside the Weir area, the opening up of only so much work as we would have funds to work steadily, so as to keep the pumping charges to a minimum. This enabled about 50 per cent. of the excavation to be completed.

1940-41

The funds at our disposal allowed for the completion of the D/S guide banks, the Right Undersluices, including the right flank and the right Divide Wall and 41 out of the remaining 49 Weir and Left Undersluice-bays.

The Left Undersluice work was, however, given preference to the Weir as it was desirable to do the deeper work while the river levels were low, as this would not only be more economical but would also mean a sounder job. Owing to shortage of funds, work in the Weir had to go slow and work was also slowed while plant was being transferred from the right to the left pocket.

By speeding up the release of pumps in the right pocket and prompt overhaul of all the repairable plant available, it became possible to start the excavation in the left pocket on 5th November, 1940. A detailed programme was then framed aiming at the completion of all work up to floor level by 31st March, 1941, *i.e.*, in about half the time taken in the right pocket. Arrangements for labour were accordingly made on this basis and the work completed well within the desired period, thus taking full advantage of the low river conditions. The floor of the last Weir bay was also completed by this date.

1941-42

The programme for this year provides for the completion of the barrage including the Road Bridge, erection of gates and gearing, silt extractors and diversion cuts within the bunds. The river diversion is however not to be taken in hand till the gates and gearing have been erected.

Closing the Pakki Creek

As already mentioned, the proposed site of the Headworks was on a *bela* between the central and the left creek of the river. It was therefore essential to close this left creek, called the Pakki Creek, as early as possible to enable the railway line, required for the carriage of materials, to be completed up to the Headworks and to provide suitable access for the labour also from the left bank to the *bela*.

At the time of its closing in October 1939, Pakki Creek was carrying a discharge of 4,050 cusecs out of a total discharge of 36,000 cusecs in the river. It was fed by three heads taking 400, 950 and 2,700 cusecs.

The smallest creek was the first to be tackled. Gunny bag bunds with sand bunds D/S were advanced from both ends till the velocity became so high that gunny bags could not be placed in water. Rope trangars $4' \times 2' \times 2'$ filled with gunny bags were used at this stage and the bunds advanced till these joined in the centre. Both the smaller creeks were closed in this way without much difficulty. It was seen that velocities up to 6 ft. per second caused no erosion in the shingle bed.

The closing of the third creek taking 2,700 cusecs was also started in a similar way, but when a 50′ gap was left, the velocity became so high that the bed was scoured by about 3′. As trangars filled with sand bags would not stand at this stage, these were filled with shingle bags instead, and two of them tied together before dumping. When only a 10′-gap was left, 20′ long ballies were put in upstream abutting against the bund. These ballies then supported the trangars which were placed from boats on the upstream side. After completing the trangar bund, the gap was closed by advancing the earthen bund from either direction. The head across the bund at the time of closure was $2\frac{1}{2}'$.

The whole creek was thus closed in a week's time at a cost of about Rs. 2 per cusec.

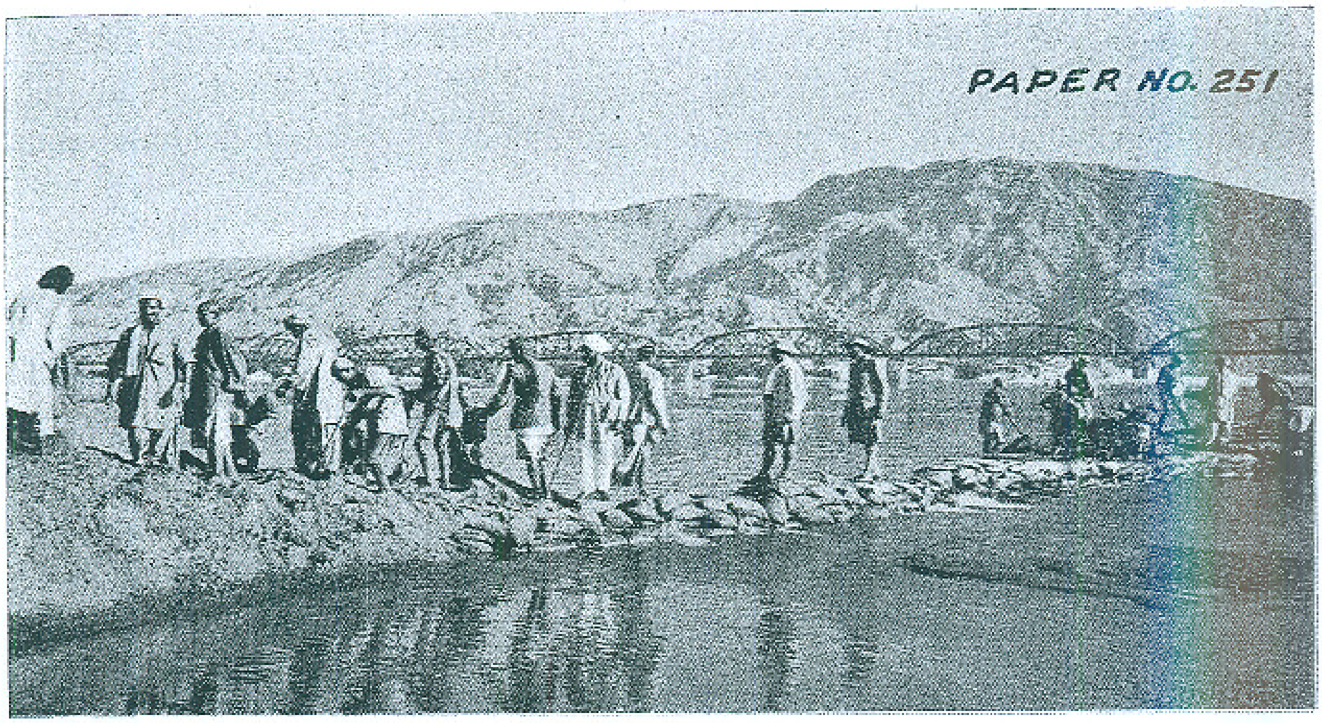
Lay-out

Two high pillars were made on either side of the Weir line for mounting a theodolite for checking it during construction. The cill girders and grooves were also aligned from these and all measurements of length were done by an Invar tape.

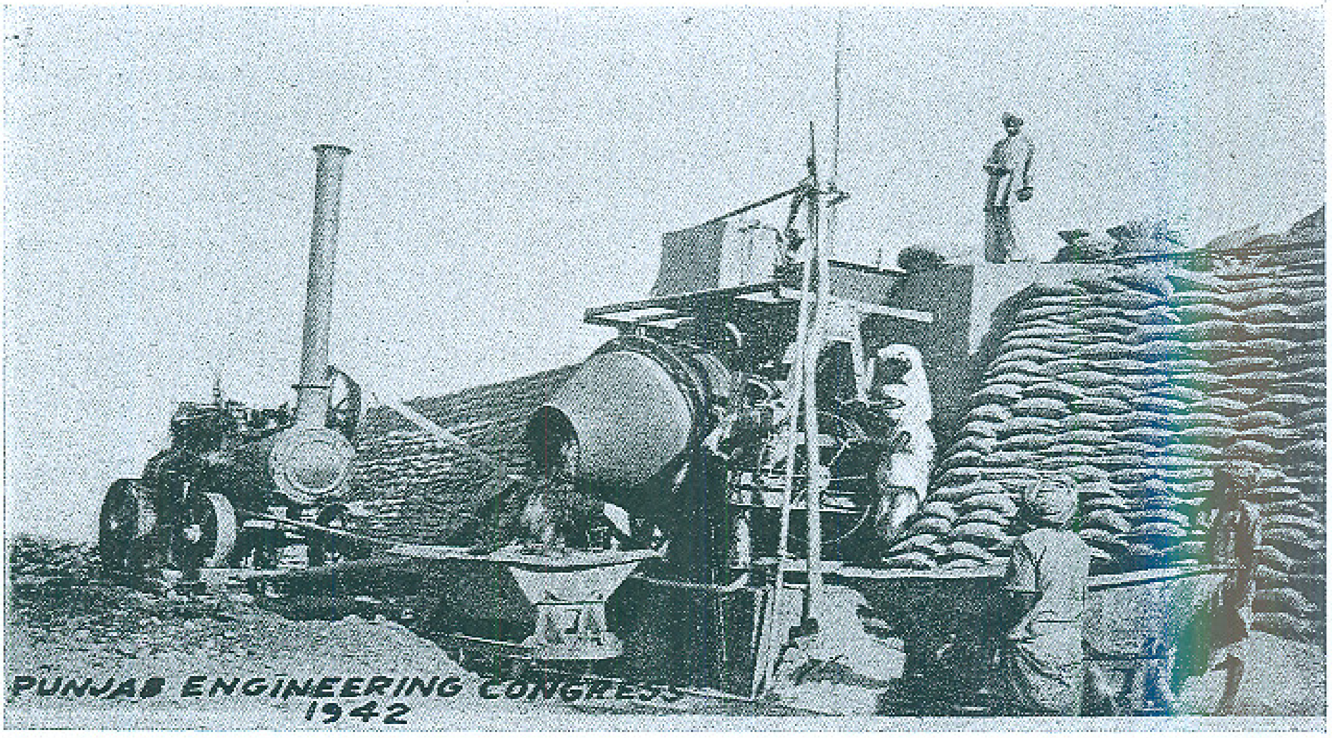
Excavation

The excavation in the Weir area was started on 25th September, 1939. The strata consisted of a layer of sand overlying a layer of shingle, the depth of which varied considerably from place to place. The sand and shingle layers alternated also at some places. The total excavation to be done was about 1,000 lakhs c.ft.

The general area to be excavated was taken from the designed sections to which was added a 10′ width on the upstream and downstream as well as on the flanks for possible drains, etc. For the purpose of estimating, the side slopes were taken as 3 to 1. Actually, however, the slopes assumed in the sand layers on account of sloughing were 5 to 1, though in the shingle layers the slope was generally 1 to 1.



CLOSING THE PAKKI CREEK



MIXER BEING RUN BY A PORTABLE

The sand was laid out to form ring bunds and the remainder thrown out as spoil inside the ring bund. Some of it was also utilized in making railway embankments. Gaps were left in the spoil at the sites of the proposed diversion cuts. Separate stacks had to be made for the shingle excavation as this had to be screened and utilized for shingle. To avoid heavy leads, the disposition of the sand spoil as well as shingle stacks had to be decided in advance, taking into consideration the position of the various Mixers.

The spring water level when excavation started was 684 and this was taken as the saturation level in the estimate. Actually, however, the saturation level was approved in advance by the Executive Engineer in each individual case, depending on the spring level and the pumping conditions available. All measurements were done by reading the excavated levels as borrow-pit and stack measurements could not be very reliable under these conditions.

Sheet Piling

The total sheet piling to be done was 34,000 s.ft., only one pile line 7½′ deep being put in at the downstream end of the glacis. In view of the fact that the piling had to be driven in shingle, only universal piles were used. These went through the shingle without giving any trouble and we were able to attain a progress of 80 piles per day. Pile driving was started on 18th March, 1940, and the last pile was driven on 21st February, 1941.

Due to a change in design, the piles in the left pocket had to be lowered by 4′. To lower the curtain wall was first suggested which would have meant heavy local pumping, causing denudation of sand in the shingle foundation, which was not desirable. The sheet piles, some of which had been already driven, were accordingly extended by 4′ by adding an extra piece with a suitable fish plated joint. This joint was broken by driving alternate piles 9″ deeper.

Well Sinking

A considerable amount of well sinking had to be done as over 70 sumps were required for the pumping. It became obvious from the very beginning that the normal method of well sinking which was appropriate for a sandy soil was not good enough for sinking through shingle, as the usual sand grab proved to be an utter failure in this case. A heavy grab with steam hoist was then tried. The progress thus obtained was about 0·2′ per day and taking the cost of a steam winch as 25 per day, the cost of sinking worked out to about Rs. 125 per ft. or over Rs. 1,000 per thousand c.ft. This was simply prohibitive. An excavator was then tried but this also did not give good progress. Considering that the cost of working the Excavator for one shift of 8 hours was Rs. 65, this was even more costly than the steam hoist.

The method finally adopted was to unwater the well approximately to curb level as far as possible and excavate the shingle inside and outside the well by hand. The cost was more reasonable by this method which had the merit that excavation could also proceed with the sinking. The detailed procedure was :—

(*a*) To make the wells reasonably small, *i.e.*, not more than 10′×10′ inside dimensions.

(*b*) To make the steining only of a sufficient height to take the well down from its starting R. L. to that of the shingle, as determined by probings.

(*c*) To start pumping and sand excavation as soon as the well reaches shingle.

(*d*) When the water level in the well is controlled down to 1′ above shingle level, to put in men to excavate shingle by hand.

(*e*) To excavate outside the well as low as possible and immediately round it, so as to obviate the friction on the outer face.

(*f*) To keep sinking going on continuously for all the 24 hours and have fairly heavy pumping all through.

The pumping units were installed either outside the wells using long suctions or on special flexible cribs, so as to cause the least dislocation in pumping as the well was going down. Generally, an 8″ pump was found to be good enough for sinking a 7′×7′ sump and the average daily progress varied from 0·3′ to 0·5′.

The labour charges paid for sinking were as follows :—

Well sinking through sand—90 % c.ft. of soil displaced.

Well sinking through shingle—200 % c.ft. of soil displaced.

The mechanical charges for pumping, etc., in the case of the latter worked out to about Rs. 50 per hundred c.ft. of sinking.

Pumping

The programme was first to open up the right pocket and as much of the Weir area as possible. Two main sumps were accordingly provided in the right pocket, one on the upstream and the other on the downstream side, in addition to a number of small sumps along the guide banks for laying the apron. The downstream curtain wall was to be poured at a level of 659 and so the water level aimed at in the drains outside the main sumps was 658.

Two main sumps were also provided for the right Divide Wall, one upstream and the other downstream. The foundation in these cases had to be taken down to 654 and as the delivery was at a level of 692, it was not possible to raise the water in one lift. Small subsidiary sumps had, therefore, to be put in at each end and double stage pumping resorted to for putting in the deep foundations. Another subsidiary sump had to be put under the fish ladder portion as the foundation level at the toe of the glacis was lower than that on either side. The same pumping plan was adopted for the right Divide Wall also.

In the Weir, there were six main sumps on the downstream side spaced about 400′ apart, as shown in plate III. The level aimed at in the drains in the case of these sumps was 661 as the downstream curtain wall had to be put in at a level of 662.

The bottom of pier foundations was, however, 657·5 in the case of Weir and 654·5 in the Undersluices. It was not possible to put these in with the help of the main pumping as this would have meant a lot of extra excavation and a considerable increase in the pumping. Local pumping had therefore to be resorted to for putting these in by providing a subsidiary sump 7′×7′ at the downstream end of each pier, as shown in plate VI. Tube-well pumping was not possible in this case as strainers could not be driven through the shingle. A coffer dam construction for the pier foundations also could not be adopted as sufficient piles required for the purpose were not available.

For lack of power, the original pumping in the Weir was restricted up to R. D. 1,150 by putting a bund at this site. This was subsequently extended in September, 1940, to R. D. 640, where another bund was put in. At the time of taking the work in the left pocket in hand, the water levels on either side of this bund were 665 and 678. Two 8″ syphons were accordingly installed which proved effective in lowering the water level on the left side.

Profiting by the experience in the right pocket, the plan of pumping in the left pocket was suitably modified. Two main sumps were provided on the downstream side against one in the right pocket, with a common outfall drain. These sumps were also connected by a drain in the flexible protection so that in case of any failure on one, the other could come to the rescue and avoid water levels rising too high. On the upstream side, there was one main sump which had later to be supplemented by four subsidiary sumps, to enable the deep curtain wall round the Silt Excluder and the Head Regulator foundations to be poured.

The discharge on the main sumps varied from about 5 to 8 cusecs, depending on the stage of the work nearby and an attempt was made to equip each of these with a suitable number of electric and steam units, so that there might be no serious set back to the work in case of any breakdown in the Power House. The total discharge generally varied from 30 to 50 cusecs during 1940-41, when the main concreting was done, the maximum being 58 cusecs in July, 1940. To limit the pumping discharge, the upstream and donwnstream stone aprons were put in as soon as possible and were followed by the curtain walls.

A depth of at least 1½′ of water was maintained in the leading drains and their slopes were also kept as flat as possible to prevent excessive sand sloughing in and choking the foot valves. This was done at places by providing artificial gunny-bag falls in the drains.

The sumps consisted of masonry steining built on R. C. curbs and had about 2½′ wide rectangular gaps left in the sides in the top 3′, instead of the usual triangular holes, as this facilitated dredging operations considerably.

The water from the sumps was discharged in iron troughs supported on Sal Ballies which in turn discharged in open drains. A masonry wing wall was provided at the downstream end of the troughs to avoid any breaches in the outfall channel which in the early stages, when no such protection was provided, proved a nuisance. Meter flumes were also built in the outfall drains to measure the discharge being pumped.

A very important factor to ensure efficient pumping is the provision of suitable outfalls and the maintenance of the outfall drains. In the case of the Weir, gaps were made in the downstream ring bund opposite all the main sumps as leading these on to one common outfall considerably reduced the head available, thus inducing silting up of the drains which in turn affected the head against which the water had to be pumped. Gangs were also employed to keep these drains silt-cleared. The gaps were closed before the flood season and a few piped culverts left in.

In the right pocket, no suitable outfall had been provided on the upstream side, and the drain was allowed to spill over a sandy shore. Some of this water naturally seeped back in the pocket and increased the pumping difficulties. To avoid this trouble in the left pocket, where even a more extensive pumping had to be done on account of the Silt Excluder and the Head Regulator, a proper culvert 88′ long was made under the upstream ring bund and the outfall drain was allowed to discharge in the apron of the upstream Guide Bank.

Concreting

Arrangements.—There were 9 one cubic yard and ten $\frac{1}{4}$ cubic yard mixers available for the job, the maximum number in actual use at any stage however was 7 big and 9 small mixers.

The two types of big mixers in use were Ransom's and Millar's. The latter type was found to be more efficient on account of the ease with which concrete could be tipped in the trucks. Both types were normally fitted with 20 B. H. P. motors but some of the Millar's were converted steam drive, which involved fitting a special bevel gear, to conserve the electric energy for the pumping sets. A $1\frac{1}{2}''$ electric pump was fitted with each big mixer for feeding it with water and washing ballast.

The layout of these mixers is shown in Plate II. These were kept in use as long as the lead did not exceed 1,000′. They were situated at the edge of the excavation and fitted on masonry foundations. There was a separate bin and godown for each mixer. The bin, which was located on a B. G. Line could generally accommodate 6 truck-loads of shingle and had a dry brick flooring with a drain in front to lead away the water used in washing. An N. G. Line was laid in front of the bin for carrying the shingle loaded in tip waggons to the mixer site. Coarse, clean sand, obtained from the excavation, was also stacked near the mixers.

The small portable mixers were carried from place to place so as to be as near the area to be concreted as possible. These were used to supplement the supply from the big machines and at places where only small quantities of concrete were required, as in the case of curtain walls, etc. All concreting for the over-bridge was also done by small machines to avoid excessive leads.

Batching.—In America, practically all batching is done by weight, as this is not only more accurate but has another commendable feature that the weight of any concrete ingredient is directly related, through specific gravity, to the solid space which the material occupies in the concrete.

At Kalabagh, however, adequate weighing arrangements were not available and so the shingle was measured by volume in trucks, which were filled upto a certain line. As the shingle used was of a uniform quality, the variations in quantity could, however, only be negligible.

The sand also was measured by wooden boxes after making due allowance for bulking, which was measured every morning. The extra sand to be used to allow for bulking varied from 15 to 20 %.

The cement added was generally in full bags, which was rendered possible by suitably adjusting the quantity of the aggregate in a batch. Thus 20 c.ft. of shingle, which was the normal quantity used in a big mixer in one batch, required 2 bags of cement for 1 : 4 : 8 mix and 4 bags for a 1 : 2 : 4 mix.

Grading.—According to the Indian Roads Congress standard specifications, the grading aimed at for high class concrete should be as follows :—

Aggregate

Maximum size of aggregate.		% retained in sizes of sieves $1\frac{1}{2}''$	$\frac{3}{4}''$	$\frac{3}{8}''$	$3/16''$	Fineness Modulus
3″	..	10—40	50—80	90—95	95—100	7·35—8·15
$1\frac{1}{2}''$	..	0—5	30—70	70—90	95—100	6·95—7·65
$\frac{3}{4}''$	..	0	0—5	40—70	95—100	6·35—6·75

Sand.

Size of sieve		4	8	16	30	50	100	Fineness Modulus
% retained	..	0—5	0—15	15—45	40—70	70—90	95—100	2·2—3·25

It may be noted that the fineness modulus of sand is computed by adding the cumulative percentages of sand which are retained on six standard screens, from No. 4 to No. 100 size inclusive and dividing the total by 100. In the case of aggregate, this is calculated by adding the cumulative percentages retained on standard screens, from the largest to the No. 4 size inclusive, dividing the total by 100 and adding 5·0 to the result. This 5 represents the total of percentages retained on the fine sand screens, finer than No. 4, divided by 100.

The size used for mass concrete was upto 3″ and the percentages of various sizes available in the local shingle, as actually determined were as follows :—

$$1\tfrac{1}{2}'' - 3'' - 44\%,\ \tfrac{3}{4}'' - 1\tfrac{1}{2}'' - 32\%,\ \tfrac{3''}{16} - \tfrac{3}{4}'' - 24\%.$$

As the percentage of fine gravel was not sufficient, 10% extra of this size was added in the aggregate before use. The grading of the shingle as actually used was thus as follows :—

$1\tfrac{1}{2}'' - 3'' - 40\%$
$\tfrac{3}{4}'' - 1\tfrac{1}{2}'' - 29\%$ say 30%
$\tfrac{3''}{16} - \tfrac{3}{4}'' - 31\%$ say 30%
} Fineness Modulus = 8·05

This was considered to be quite satisfactory.

For the Road bridge where a high grade concerete was desired since the value of f_c had been assumed as 950 in the design, the maximum size of shingle used was $\tfrac{3}{4}''$. An actual analysis of the shingle available showed the following percentages :—

$$\tfrac{3}{4}'' - \tfrac{3}{8}'' - 82\%,\ \tfrac{3}{8}'' - \tfrac{3''}{16} - 15\%,\ \text{under } \tfrac{3''}{16} - 3\%.$$

As the $\tfrac{3''}{16} - \tfrac{3}{8}''$ size present in the shingle was not considered to be enough, an additional 20% of this size was added making the grading of the shingle actually used as follows :—

$\tfrac{3}{4}'' - \tfrac{3}{8}'' - 68\%,\ \tfrac{3}{8}'' - \tfrac{3''}{16} - 30\%,\ \text{under } \tfrac{3''}{16} - 2\%$, Fineness Modulus = 6·66.

In the case of sand, however, it was not possible to follow the Indian Road Congress specifications, as even the best river sand available was too fine.

An analysis of the sand actually used is as follows :—

Size of sieve	4	8	16	30	50	100	Fineness Modulus
% retained	..	..	..	..	2	56	98	1·56

Slump and consistency.—A low water cement ratio is the first essential of good concrete.

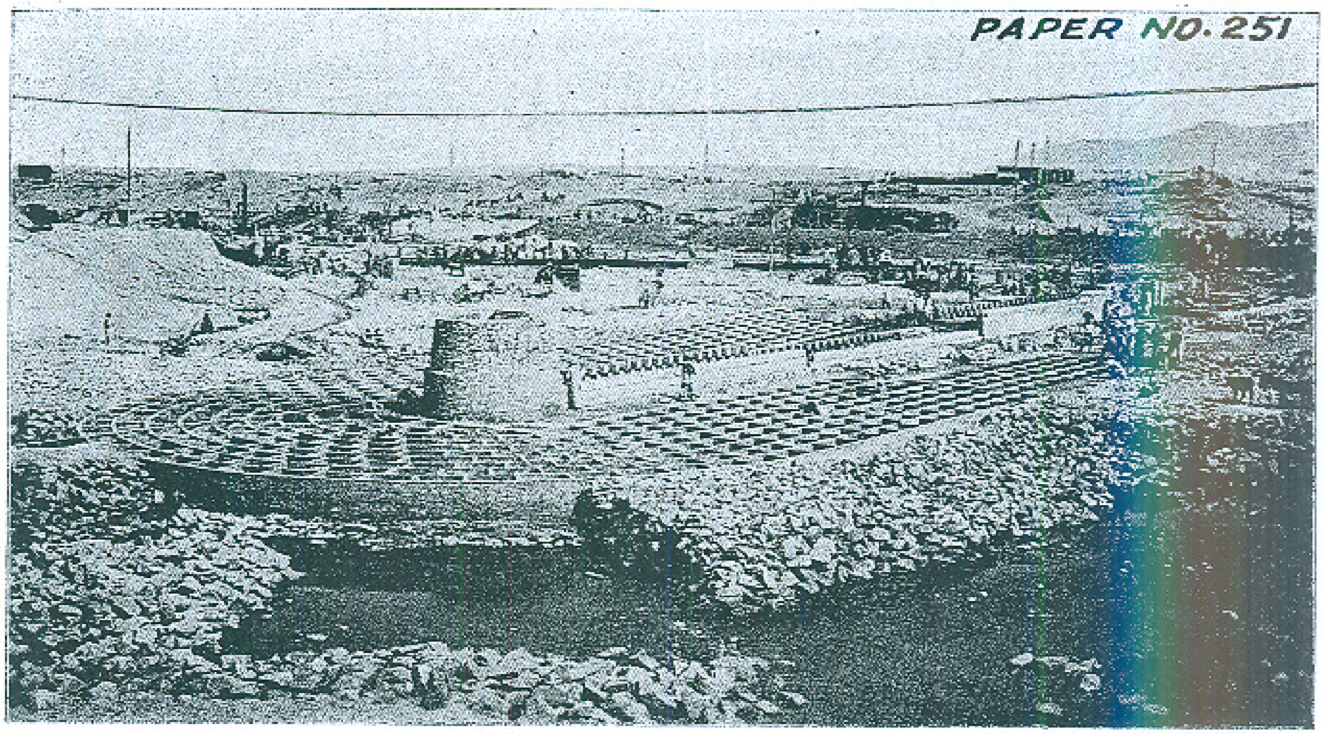
According to Lyse's equation, we have

$$S = A + B\frac{C}{W}$$

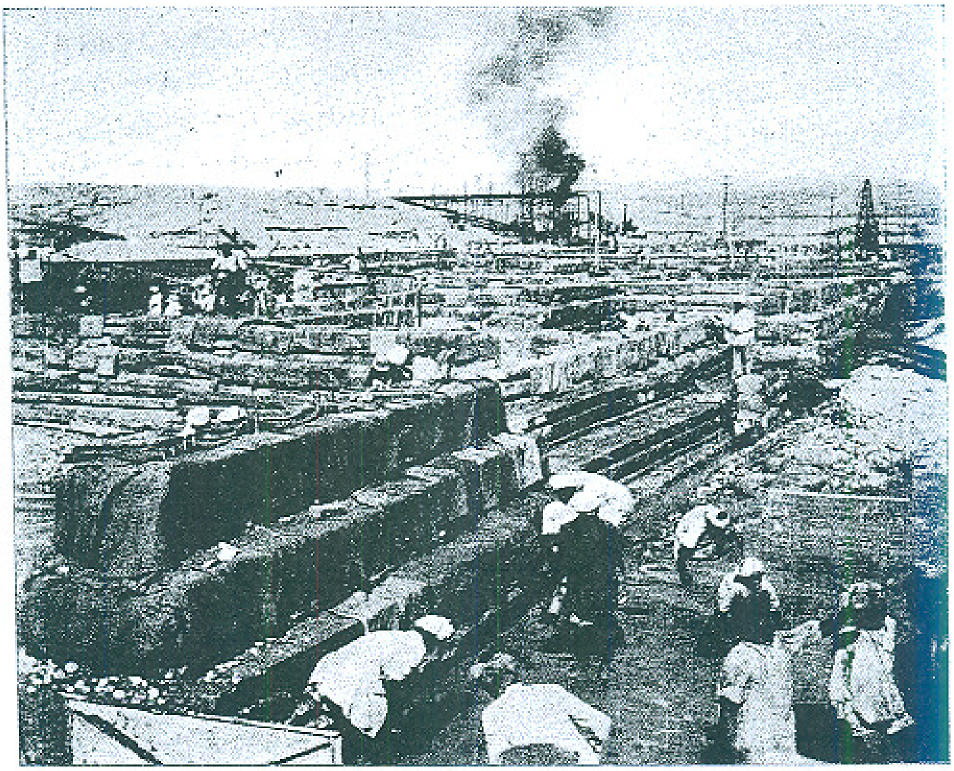
where S = compressive strength

A and B are constants dependent upon the materials and conditions of tests.

C/W = cement water ratio by weight.



BLOCKS ROUND LEFT DIVIDE WALL READY FOR CONCRETING



COMPARTMENT WALLS SHOWING WATER-BARS

The compressive strength is thus directly dependent on the cement water ratio and we should have as low a slump as possible, consistent with the condition that the mix should be workable. A slump of ½″ was used for all mass concrete on the Kalabagh barrage to get as high a density as possible. This would seem to be rather on the low side, but this was rendered possible by the use of mechanical vibrators as described later. The quantity of water used in the case of aggregate upto 3″ size was 18 to 20 gallons for 2 cwt. of cement in a 1 : 4 : 8 mix and 23 to 25 gallons for 4 cwt. of cement in a 1 : 2 : 4 mix, depending on temperature, humidity, etc. Allowing for the free moisture in the shingle and sand, the average value of W/C was found to be 0·95 for a 1 : 4 : 8 mix and 0·60 for a 1 : 2 : 4 mix. It may be added that in all dam construction in America, W/C is kept = 0·58, as any lower water ratio indicates a lack of economy, due to the cement content being higher than necessary. In this connection, it would be interesting to note that each 1″ change in slump (the mix proportions remaining the same) is roughly equivalent to 0·02 change in the water cement ratio.

Slump tests were carried out every morning to serve as a rough guide for the quantity of water to be used, but the final adjustment was generally done by trial, after seeing the workability of the concrete at site.

Placing Mass Concrete.—The trucks conveying the concrete from the mixers were dumped on sheet iron floors from where it was carried to the work in baskets, as this gave a more uniform concrete than that obtained by direct tipping.

The thickness of 1 : 4 : 8 concrete in the Weir floor varied from 4·25′ to 7·5′, and there was a lively discussion as to the best way of pouring this concrete. It was originally suggested by R. B. L. Kanwar Sain to lay the concrete in layers of 18″ to 21″ thickness and to bond these by hooks ⅝″ diameter, spaced 3′ apart in addition to the provision of plums, so as to provide against any shear stresses that were likely to develop to separate the different layers from each other. He also suggested that there would not be any chance for the separation of layers, as happened in the case of Islam, Marala, Rasul and Ferozepore Headworks if the following precautions were observed :—

(*a*) Mix too high in slump that would tend to segregation bleeding and formation of excessive laitance at the surface to be avoided.

(*b*) Traffic on the freshly laid concrete to be reduced to minimum.

(*c*) Before laying the second layer, surface of the old concrete to be thoroughly cleaned up so as to remove all foreign matter and laitance. A mortar layer ½″ thick of proper quality and consistency to be thoroughly broomed into all the irregularities and depressions of the joint surface, immediately prior to placing new concrete.

(*d*) Dry concrete surface to be kept wet for a period of at least 72 hours before new concrete is to be placed.

(*e*) The concrete surface when laid to be covered with a substantial layer of sand or gunnies for curing treatment in preference to the use of standing water.

(*f*) Thorough tamping or vibrating by mechanical Vibrators.

Of these (*a*), (*b*) (*e*) and (*f*) are essential for all good concrete.

It was contended, however, by Mr. Foy that even with all these precautions, there were bound to be horizontal planes of weakness extending over the whole length and width of the Weir. These combined with the vertical contraction cracks, which exist in all mass concrete, would have been a source of danger resulting in possible failure.

It was therefore proposed to lay the concrete in blocks and each bay was divided into 16 blocks of concrete by a system of partition walls as shown in plate VI. The size of these blocks was fixed at the maximum which would not crack on contraction when the concrete was setting and would also be easily poured in one day, the quantity of concrete in the various blocks ranging from 800 c.ft. to 4,500 c.ft. The provision of leaving expansion joints between adjacent blocks was also considered but was dropped as it was thought that the pumping which would have to be done for finishing these off would cause movement of sand from under the completed work.

FIG. 3
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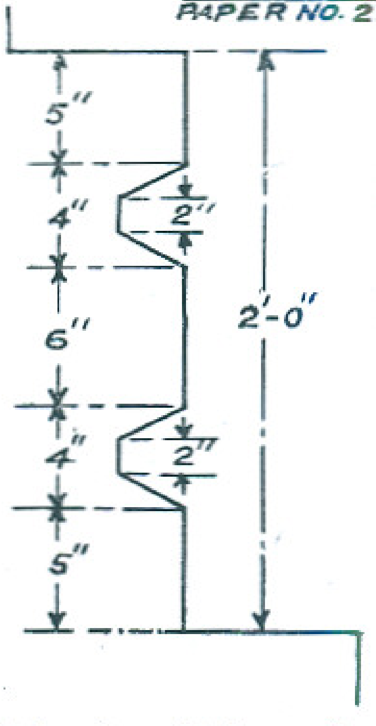
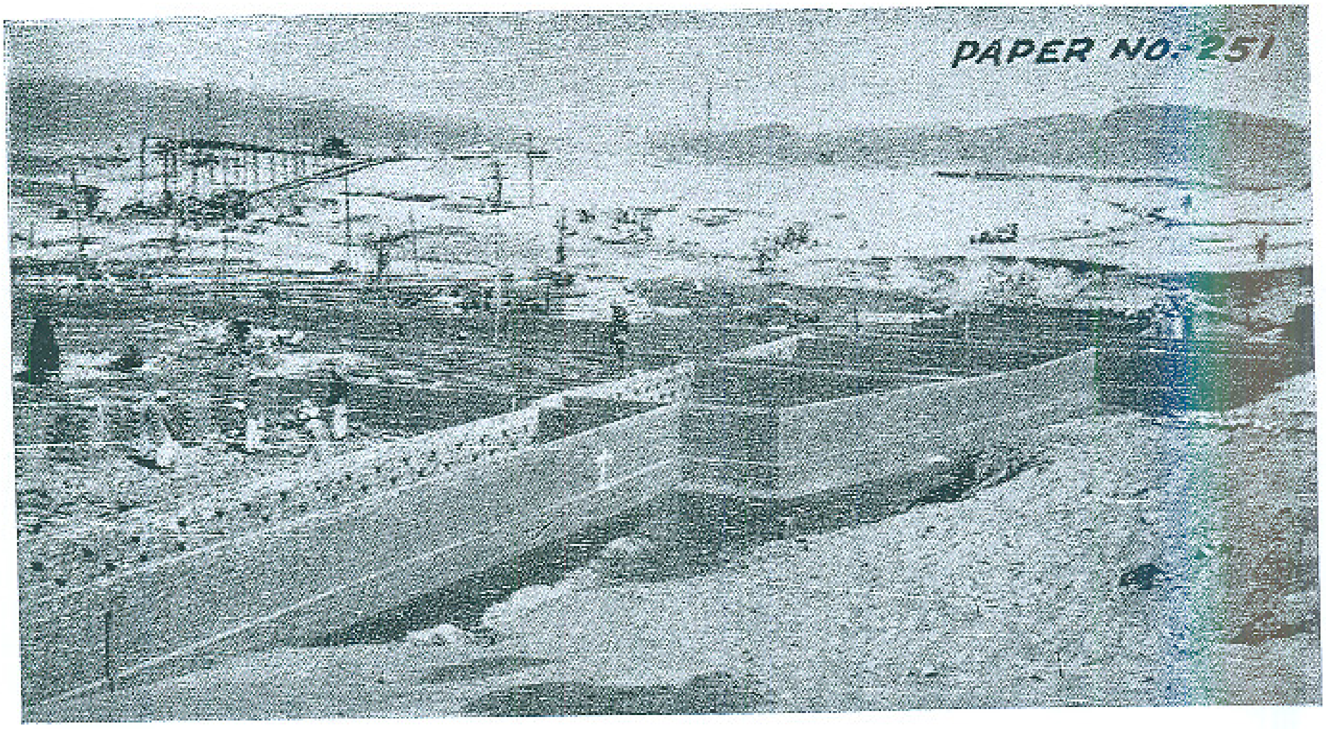
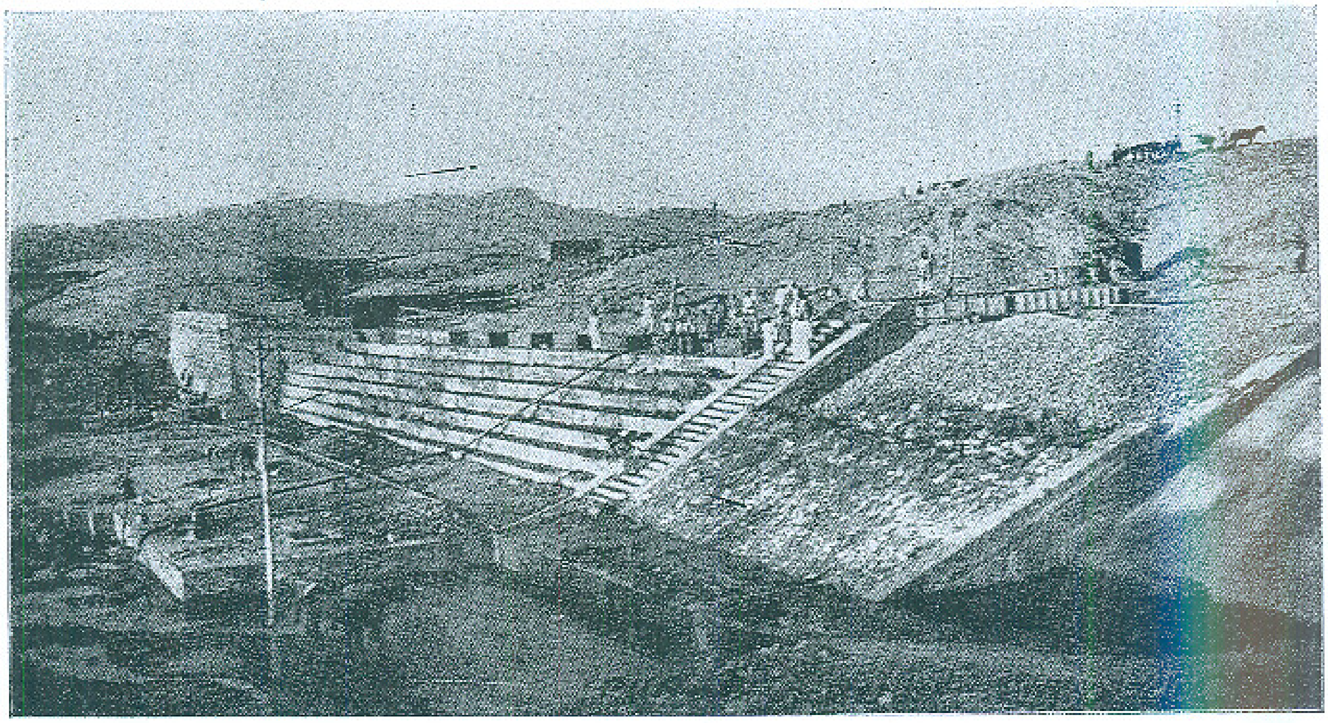


These partition walls which were 2′ to 3′ wide at top were constructed first and were made at least one ft. deeper than the adjacent weir profile. They were provided with 1′ steps at 2′ intervals on which the weir profile was expected to slide with expansion and contraction and which increased the length of path of any escaping water. This length was further increased by the water bars provided on the sides of the wall, as shown in Fig. 3.

The order of concreting was to do the lowest blocks first. This was very important as otherwise there would be a danger of denudation of sand from under the completed work. As a further precaution, all drainage from under the completed work was made to pass through a "Bajri Filter," which was graded from 3/16″ size bajri to 3″ ballast, the finest material being on the side furthest away from the sump. No open flow was thus allowed between the bottom of the floor and the foundation subsoil.



FOUNDATION OF LEFT FLANK WALL SHOWING COMPARTMENTS FOR CONCRETING



LEFT FLANK WALL SHOWING DEVELOPED BLOCKS UNDER CONSTRUCTION

Plums were put in the concrete at every 2′ depth and hooks $\frac{1}{2}''$ diameter, spaced 3′ apart in both directions, were left at the top to bond with the stone masonry or the 1 : 2 : 4 top layer, which was laid as soon after the 1 : 4 : 8 layer as possible. All precautions (*a*) to (*f*) detailed above were observed before laying the stone masonry or the 1 : 2 : 4 concrete, special attention being paid to the thorough cleaning of the bottom concrete.

The concreting of the Divide Wall and flank foundations was done in compartments. These compartments were alternately 6′ and 15′ to 20′ wide, the size of the latter being kept on the basis of the maximum concrete that could be conveniently poured in a day from a big mixer, *viz.* about 3,000 c.ft. The bigger compartments were poured first and after this concrete had contracted due to shrinkage in setting, that is after an interval of about 10 days, the smaller compartments were concreted. This device helped in reducing the shrinkage cracks to a minimum.

All concrete for the Road Bridge was carried over specially designed inclined gangways having a landing half way between the floor and the overbridge level, as shown in one of the photographs.

Plugging a sump.—The plugging of local sumps at the downstream end of the piers had to be done after concreting the next adjoining bay. This was a bit of a problem in the early days as the suctions had to be gradually withdrawn in the last stages, when concreting had to be done in rising water. This was not a satisfactory procedure, even though grouting pipes were left in at different levels. A satisfactory solution for this was however, devised by Mr. Handa. The pump suction pipe, which was enclosed in a pipe made of $\frac{1}{8}''$ iron sheet, was attached to a conical perforated metal casing, shrouded by a *bajri* filter and the foot valve was fixed in it above the floor level, as shown in plate X. A further improvement was later effected by the Author in that the well was filled with *bajri* upto the top of the perforated metal casing to avoid its getting choked and thus stopping the pump during concreting. This arrangement enabled the water to be kept depressed below the concrete level and it was thus possible to put it in dry without any trouble even under 5′ to 7′ head of water. The water level was kept depressed for 3 to 4 hours afterwards, to enable the concrete to get its initial set, before being subjected to any strain due to the uplift pressure of water. The conical strainer was left in and the suction pipe withdrawn after unscrewing. The casing pipe was later grouted with cement through a $1\frac{1}{2}''$ pipe, after filling the annular space with 1 : 2 : 4 concrete.

Concreting a toe wall.—The concreting of the bottom 2′ of all the toe walls was done by using wooden shuttering which was kept in position by binding it with No. 8 G. I. Wire and using a few sand bags to prevent its falling in. The portion of the toe wall above the bottom 2′ was generally made by constructing 0·4′ thick walls in cement masonry with occasional headers protruding inside. These walls, which served as a shuttering, thus formed part of the concrete toe wall.

Where a toe wall had to cross a drain leading to a sump, a culvert consisting of precast units, with the top slab below the designed bottom of the concrete, was built in advance. This was later grouted with cement through a pipe which was left in. This procedure enabled the toe wall to be easily concreted all through its length and saved heavy pumping which would normally be required for completing this bit afterwards.

The following precautions were observed in the concreting of toe walls :—

(*i*) A drain was constantly maintained on either side to avoid cross flow under the concrete.

(*ii*) A little extra excavation was done in each case, as the quality of the bottom 6″ of concrete is generally doubtful.

(*iii*) A richer mix was used in the bottom 1′ to compensate for any possible loss of cement in water.

(*iv*) A little standing water in the foundation was preferred to springs blowing out.

(*v*) The reach farthest from the sump was started first and the work progressed towards the sump.

(*vi*) Concreting was invariably done towards a spring and not from a spring outwards.

(*vii*) Grouting pipes with right angled bends were left at each spring. These were subsequently grouted with cement.

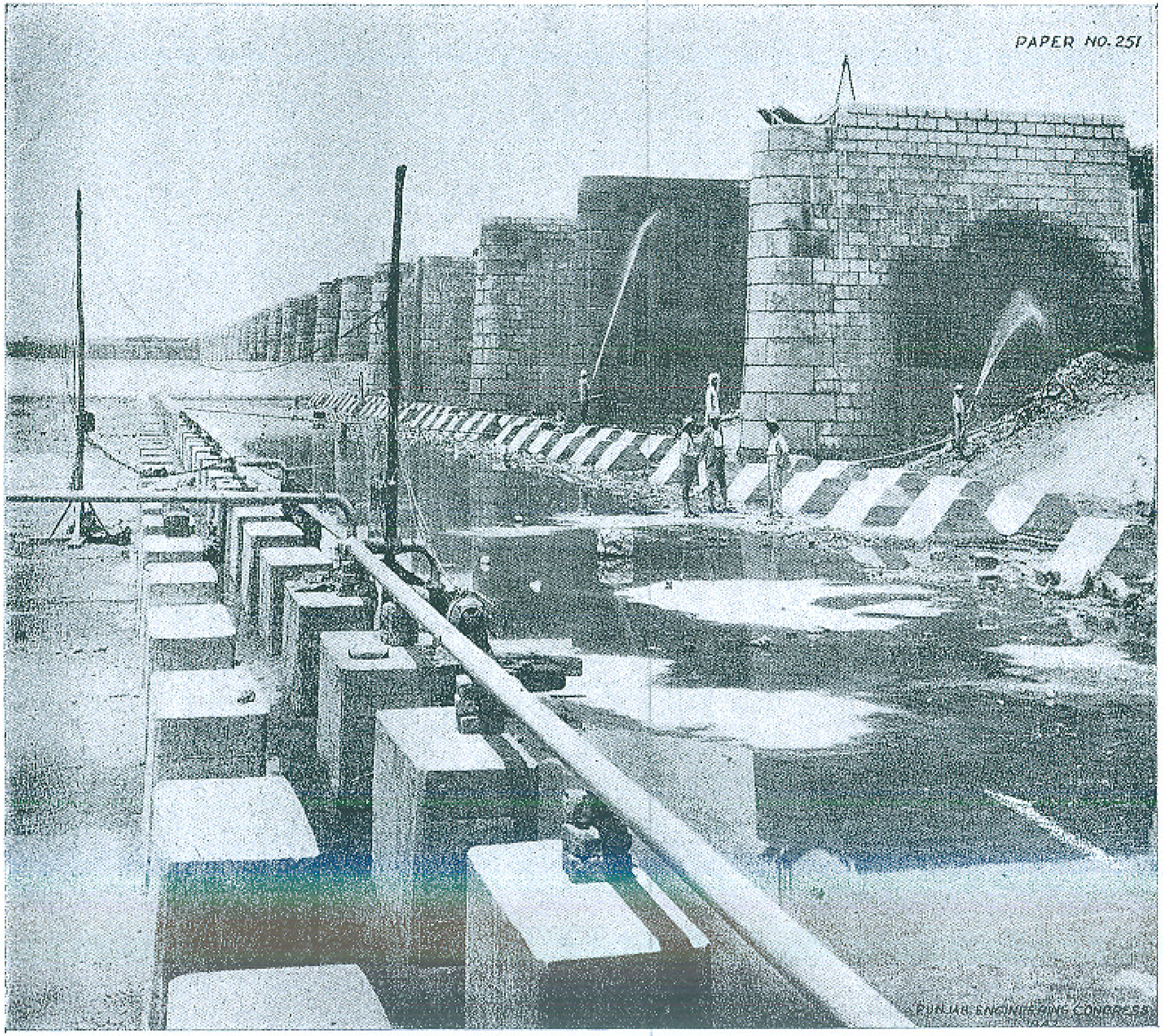
(*viii*) A mechanical vibrator was invariably used to get better compaction. This also facilitated the closing of springs.

(*ix*) If the toe wall was likely to head up any water, a drain was left in for its passage at a suitable level. This was subsequently grouted by leaving a grouting pipe. The leaving of these drains in suitable positions avoids a lot of unnecessary worry afterwards.

(*x*) If any spring started flowing from under a completed wall, a liberal supply of fine *bajri* was put in to prevent its blowing out any sand.

Vibration.—This is the first barrage in this Province where all the concrete, except for a small quantity in the right pocket in the early stages of the work, was mechanically vibrated. The main purpose of all wriggling is to make the distribution of all component parts as uniform as possible and to expel any air entrapped in the concrete. This can be best achieved by Mechanical Vibrators which give a better compaction, a greater density and a greater ease in placing comparatively dry mixes, which in turn adds to the strength of the concrete and reduces shrinkage.

The wriggling had however to be judiciously controlled as over-wriggling causes undesirable segregation. Care has also to be exercised in drawing out the Vibrator from the concrete which should be done slowly to avoid any pockets being left. It was found that a Vibrator could easily tackle depths upto 2′ at a time.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The Vibrators which were supplied by Messrs. Ingersoll Rand are delicate instruments and have to be handled with care, special attention being paid to lubrication and keeping the air lines clear. The simple precaution of holding the vibrator with point up in the air for a few minutes after 3 to 4 hours use resulted in increasing its working life considerably, as this permitted all condensate to drain from the motor and exhaust hose. Special care was also taken to see that the Vibrators were run as little as possible, when not actually in use. When not in operation, they were hung point up in brackets on wooden stands.

An air compressor in good condition was able to work 3 Vibrators which were good enough for wriggling 7,500 c.ft. of concrete a day. The average cost of working a compressor for 8 hours came to Rs. 11-5 and including 6 coolies at As. 8 each for working the 3 Vibrators, the rate for wriggling with mechanical Vibrators works out to As. 3 % c.ft. On the other hand, the cost of hand wriggling for which we require 16 men to wriggle 3,000 c.ft. in one day works out to As. 4 % c.ft. It thus pays every time to discard hand wriggling completely in favour of mechanical vibration.

Curing.—According to the Reclamation Bureau specifications, the concrete should be protected from the direct rays of sun during the first three days and kept moist for a minimum period of 21 days. Tests reveal that there is a rapid gain in compressive strength for the first 28 days after which there is a continual slower increase for an indefinite period so long as the concrete is kept moist. All concrete was accordingly kept moist for a minimum period of 28 days.

A pipe line was run all along the work fitted with pumps at suitable intervals and connections were taken off in each bay for curing the weir floor. For the curing of the Divide walls and Friction blocks, large mattresses made of gunny bags sown together were used for covering the exposed surface and these were kept moist by a water jet playing over them.

The curing of the piers presented a problem as their height from the d/s floor in the case of the Weir was 30·5′ and 33·5′ in the case of the Undersluices. This was solved by putting 8″ pumps on the weir sumps, spaced 400′ apart, and boosting up the pressure by fitting 4″ high lift pumps on either side of the pipe line leading from the 8″ pump, as shown in Fig. 4. The jet thus obtained could throw the water well over the pier top.

FIG. 4
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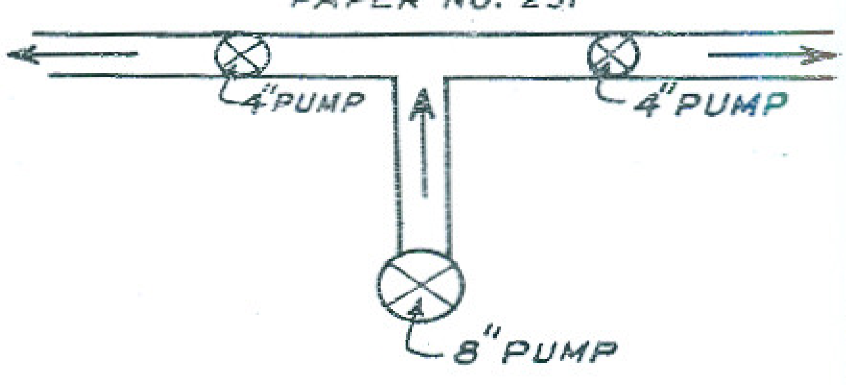

General.—The total quantity of concrete on the Kalabagh barrage was 69 lacs c.ft. The maximum poured in any one day was 55,000 c.ft. on 23rd March, 1941, which is a record for the department. The maximum in any one month was 6·75 lacs in March 1941 and the total for 1940-41 was 50 lacs, which also is a record. Of this 28 lakhs were poured in the last 6 months.

Form work

The use of precast shells avoided any extensive form work on the Weir. These shells were generally fixed in a height of 2′ and concreting was done on the third day after giving them 24 hours to set. The progress obtained on piers and sections of divide wall, etc. was thus 2′ in three days.

On the downstream noses of the piers, where the batter was 1/12 up to R. L. 676 and 1/18 afterwards, the portion below 676 level was made by having false work of *kacha* masonry. Its inside was cement plastered and rubbed with a solution of soap and oil. Wooden lathes were fitted inside to reproduce the effect of joints. It was thought that the use of *kacha* masonry for the remaining 24·5′ height would be rather expensive in view of the large number of bricks required. Iron moulds were accordingly made, one set of which was in three and the other in two pieces, to get a break in the vertical joints. Details of these are given in plate X. These were found to be very successful and all the 53 piers were completed with three such sets.

Ordinary wooden shuttering, which was rubbed with oil inside, was used for the partition walls. This was in 2′ wide pieces and had wooden battens, to reproduce the water bars, fitted inside. Wooden shuttering was also tried for the developed blocks but was later given up as the blocks bulged in the centre giving a wavy edge. Suitably stiffened iron sheets $\frac{1}{8}''$ thick were then used and gave very good results.

Brick shuttering 5″ thick was used for the blocks in the flexible protection. Occasional headers protruded inside to bond with the concrete and the masonry thus formed part of the finished block. In cases where 5″ wide *jhirries* had to be left in between the blocks, the same were kept clean by leaving a wooden *chaptie* (which was the size of the *jhirrie*) inside, with a wire loop attached to the top. This was pulled out on the completion of the adjoining block and any debris, etc. that had fallen in was thus brought out without any waste of labour.

The forms for the road bridge were of deodar wood faced with 24 gauge galvanized iron sheeting built on to a structural steel framework, as at Trimmu. This shuttering was supported on 12″×6″ girders which in turn rested on four 2·25′ thick masonry pillars in each span. These pillars were made in mud plaster and had 6″ height laid in cement after every 2′. Their toes butted against the friction blocks to avoid any sliding.

As the bridge was concreted when most of the other work had been practically completed, the number of forms required was fixed with the consideration that the labour should remain continuously employed. The processes involved in the construction were :—

(*i*) Dismantling and erection of the bottom and side forms ;
(*ii*) Erection of reinforcement ;
(*iii*) Concreting and setting time side forms ;
(*iv*) Extra setting time for bottom forms.

To keep the labour in continuous employment each process should occupy a number of days equal to the total period for the completion of a span divided by the number of forms. Taking a basic period of 6 days, (*i*) would require two periods and the others one each. For the continuous spans, five sets of bottom forms were thus found to be suitable and we needed only three side forms as these would be erected one period later and released one period earlier. For the suspended spans, two extra periods are required as the bottom forms are delayed while the second span is being erected and while reinforcement is being placed in it. We thus required 7 sets of bottom forms in this case and 3 only for the sides.

The programme of work was thus as follows :—

Span	No. of periods.				
	Erection of			Setting period for side forms.	Extra setting period for bottom forms.
	Bottom forms.	Side forms.	Rein-force-ment.		
1. Continuous ..	1	2	3	4	5
2. Suspended ..	1	4	5	6	7
3. Continuous ..	2	3	4	5	6
4. Suspended ..	2	5	6	7	8
5. Continuous ..	3	4	5	6	7

and so on.

As there were 29 continuous and 27 suspended spans, the total periods required for the completion of the bridge were $29+4+1=34$ or 204 days.

Stone Masonry

The method adopted for doing the stone masonry of the floor was as follows :—

The main concrete of the weir profile was first thoroughly cleaned with water jets and then with wire brooms which also roughened the surface. Cleaning with wire brooms was kept on all through while the work was in progress. A layer of 1 : 2 : 4 concrete 3″ thick was then laid in a sufficient width to enable the setts to be finally aligned and wriggled in position, before the concrete had taken its initial set. After placing the first line, 9″ deep concrete was placed round the root of the sett and thoroughly worked in. The second line was then placed in a similar way, keeping the joints ½″ wide. After three rows of setts had been placed, the top 6″ was grouted with a fairly liquid 1 : 2 : 4 grout, the size of aggregate used being 3/16″ to ⅜″. The grout was worked in with iron rods ¼″×1″ and 15″ long with wooden handles fitted on the top. After the grout had been thoroughly worked in, it was finished off flush with the stone surface.

Stone Aprons

Before filling stone in the aprons, a wall 3′ wide and upto the full height was first made to prevent sloughing. The drain required for the passage of water to the sump was maintained outside this wall. The bottom 2′ of the apron, stone for which was carried by donkeys was then filled in. Stone for the top 2′, which was filled after completing the lower layer, was carried by coolies and not donkeys, as the Kharkars have a natural tendency to load only small sized stone on the donkeys. The coolies carried selected large stones for the top layer and the interstices only were filled with small stone.

The stone apron of the guide banks was taken down sufficiently to enable it to rest on a layer of shingle. In the case of the right guide bank, it was noticed that there was a layer of 2′ of shingle resting on a 3′ to 5′ layer of sand, which in turn rested on a deeper layer of shingle. The apron in this case was therefore taken to the lower layer of shingle.

Where the defence bunds joined on to the guide banks, a suitable cut-off was provided under the bund in the stone apron as well as in the sloping pitching of the guide bank, to avoid any leakage of water at the junction. This cut-off consisted of a two feet thick concrete wall with 0·4′ brick shuttering on either side and was taken 2′ below the bottom of the apron with its top 2′ above the apron top level. In the sloping portion this was taken up to 5′ above the high flood level. The lack of a suitable cut-off during the construction of Suleimanki Headworks caused a serious breach which resulted in a lot of worry and expense.

Erection of steel work

Setting the Cill Girders—A trench 2′ wide and 18″ deep was left in the crest of the weir along the alignment of the cill girders. Pockets 2′ square by 6″ deep were left along this trench at suitable intervals to receive the feet of the cast iron stools of the adjusting device.

When cill girders, which comprised three lengths for one span, had been roughly aligned and levelled in a particular bay, these pockets were filled in with concrete and allowed to set after which the final levelling up and aligning of the cill girders was done. The next stage was to cover the bottom flanges of the cill girders to a depth of about 3″ throughout the whole length with cement concrete.

After this concrete had properly set, the cill girder was firmly held along its whole length and stone setts of normal section but of slightly reduced depth were then laid to fill in gaps on either side of the cill girder.

The setts were raised $\frac{1}{4}$″ above the cill girders on the upstream side and were fixed level with them on the downstream side to prevent damage to the girders by the rolling shingle.

Fixing the grooves—The pier was built with a gap 2′ wide for the grooves up to a height of 7′, the two portions being bonded together with two $1\frac{1}{2}$″ bars at 2′ intervals in height. After removing the kacha masonry shuttering on either side of this gap, the bottom groove, which was 15′ in height in the case of the Weir and 18′ in the case of Under-sluices, was placed in position. This was fitted to the cill by means of pins which were hammered through the groove foot and the cill top flange. The groove was then plumbed and checked with a theodolite, after which it was grouted with 1 : 2 : 4 concrete laid in layers of 2′. As soon as this concrete had set, the pier was taken to the full height of the groove, the two portions on either side of the grooves being made monolithic.

The same procedure was repeated for the second half of the groove, which was 12′ in height.

The pier was splayed out 3″ in a length of 4′ and in a height of 2′ from the cill level to protect roller trains from the rolling shingle.

Skids—All gates and gearing received from the Central Workshops, Amritsar, were stored on six sets of skids. These consisted of two lines of rails supported on firwood sleepers which were carried on masonry pillars of gradually increasing height, spaced 15′ apart. The rail level at the loading end was the same as that of the floor level of a standard truck and at the unloading end it was the same as the top of the special material trolly which had to feed the erection at the Weir. The steelwork was slid on to these skids by crab winches and was stored in such a way that it could be forwarded to the Weir in correct order at the time of erection.

Erecting the gates gearing—This work is held up at present for want of steel wire ropes, the supply of which is still awaited. The gantries used for erection at Trimmu have been modified to suit Kalabagh. One leg of the gantry will work on the 13½′ bridge, while the other will be carried on a track fixed on to a run-way girder carried by the downstream end of the piers. Bolts to receive these girders were left during the construction of the piers. The track and in one unit and six such made girder are units have been manufactured, as the track will be taken up from behind and laid down in advance of the gantries as the erection proceeds. This will be done by means of two 5-ton cranes, working from a B. G. track laid on the overbridge, which will place the track and girder on special erection trolleys.

Pressure observations

A large number of pressure pipes have been installed for measuring the actual pressures under the barrage floor with a view to watching the safety of the work. Each pipe is fitted with a 3′ length of strainer shrouded in graded *bajri* which in turn had a covering of at least 1′ depth of sand, so as to prevent its getting choked by cement grouting.

During the unwatering of the foundations of the barrage, specially those of the piers, it was observed that sand was being brought out from the interstices of the shingle by the pumping and, as shingle, the interstices of which are not filled with sand, can only have a negligible resistance to seepage flow, it was decided to take pressure observations in the Right Undersluices and 9 completed bays of the Weir to see whether they would conform to those for which the Weir was designed.

It was realized that the seepage in-flow due to the general unwatering of the construction still in progress would interfere with these observations and to eliminate this as far as possible, three sets of observations were made :

(*a*) With upstream and downstream levels at a predetermined low level ;

(*b*) With downstream at the low level and upstream at a predetermined high level ;

(*c*) Upstream and downstream at the predetermined high level.

The ratio of (*b*)—(*a*) to (*c*)—(*a*) at any point gave the value of ϕ for that point, as shown clearly in Fig. 5.

FIG. 5
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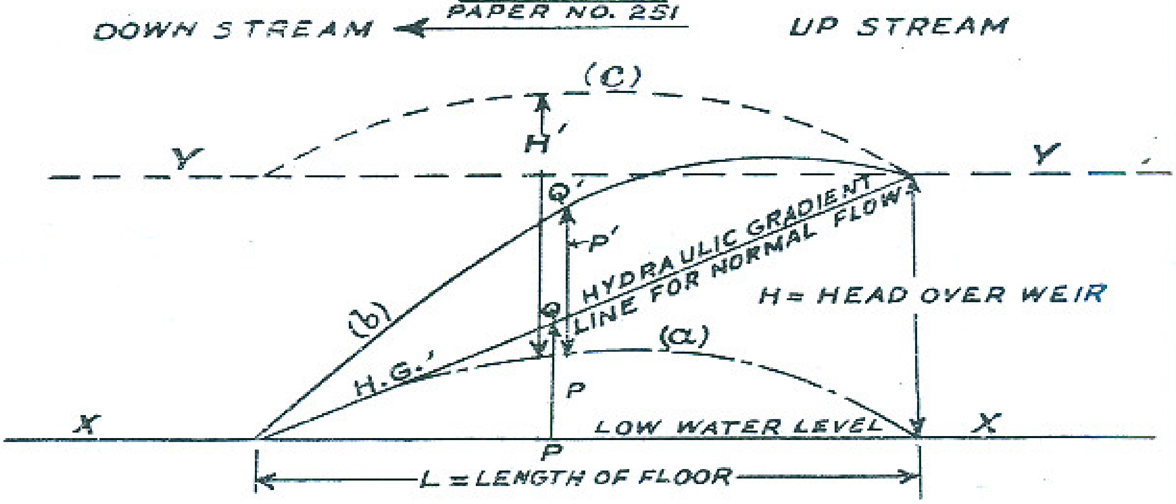


The results indicated that the actual pressures were from 10 % to 20 % higher than the theoretical assumed in the design.

It was pointed out by Mr. Khosla, however, that the above analysis was qualitatively in the right direction but that the results may not be quantitatively correct as the observations had been taken only under low heads and the value of ϕ was considerably distorted due to the cross flow on account of high spring level on one side and low levels due to pumping on the other.

In view of these observations, the question of weighting the floor or extending it on the upstream side was discussed at a meeting of the Chief Engineers on 29th January, 1941. It was decided, however, that in view of the safety factors implicit in the design, *i.e.* (*a*) the specific gravity of concrete had been assumed as 2·25 against an average of 2·36 measured at site, (*b*) the reduction of pressures due to the blinding of the sub-foundation by fine silt, and (*c*) the fact that the 22′ head on which the work was designed included 2′ for future raising of the pond level and 2′ for retrogression both of which were not likely to occur at the same time, the weighting of the floor or its extension was not necessary at present.

It was decided, however, that it was essential to ensure, as far as possible, that no hollows remain under the work to which end grouting must be done with great care and pressures kept under observation. It was also decided that when the Weir was first brought into use the pond should be raised by stages with the previous approval of the Chief Engineer and that pressure readings be recorded as it rises, so that if it proves necessary, the question of weighting the floor or its extension upstream may be reconsidered.

Precautions adopted in the work

For the work, which was already in progress, the following precautions were adopted in addition to a more extensive grouting :—

(*i*) The shingle in bays 1 to 7 of the Left Undersluices and 8 to 13 of the Weir was excavated to the lowest level upto which there was any possibility of runnel formation and was replaced by pure sand which was well compacted in compartments. This extra excavation did not involve any additional cost as the shingle thus obtained fully paid for the same.

(*ii*) All cross walls were taken down to rest on undisturbed soil and not on any filling.

(*iii*) As soon as the concreting of the deep pier foundations was completed, the water in the sump well was raised as high as possible, consistent with the conditions of work outside.

(*iv*) All drainage water was passed through *bajri* filters thus avoiding any open flow between the bottom of the floor and the foundation subsoil.

(*v*) The sump wells at the end of the downstream noses of the piers which rested on shingle were not plugged during the pumping operations as it was considered that with the use of the perforated metal casing and *bajri* shrouding, this would help in preventing undermining of the floor and relieve the strain on the filters at the floor foundation level. A grouting pipe was left inside to grout the well after pumping had been stopped.

(*vi*) The order of pouring the concrete blocks so as to do the lowest level work first, was rigidly observed.

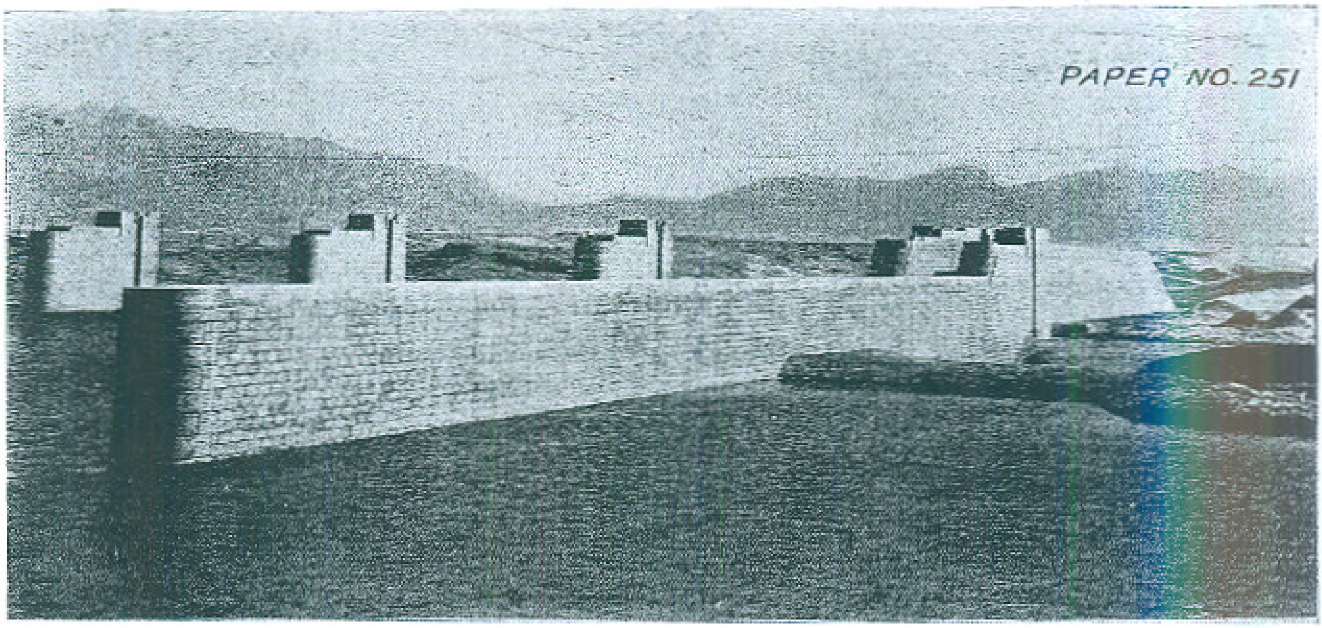
(*vii*) The differential head across any completed portion of the structure was kept as low as possible.

(*viii*) The sheet pile line in the Left Undersluices was lowered by 4′.

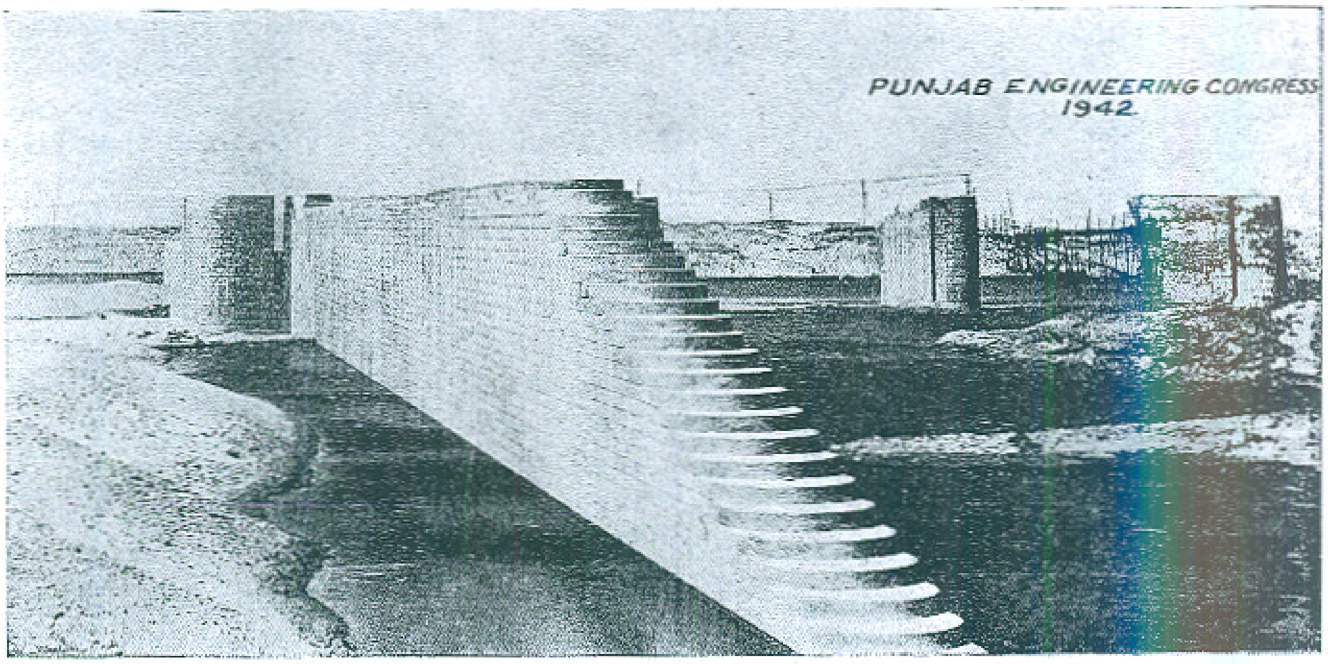
Perforated pipes for grouting

In bays No. 1 to 16 where grouting pipes had yet to be fixed, a set of 33 pipes per bay were put in with their bottoms at the lowest possible levels at which runnels could form. The portion below the bottom of the concrete floor consisted of perforated pipes $\frac{3}{4}''$ internal diameter, made of 1/16″ thick M. S. Sheets, so as to tap the runnels at all levels.

In bays where grouting was in progress, the full number of 33 pipes was made up by putting in additional pipes. In the remaining bays, however, where grouting had been completed through ordinary pipes going to the bottom of the concrete, 20 more pipes with perforated lengths at the bottom were put in at key points, in each bay.



A GENERAL VIEW OF THE RIGHT DIVIDE WALL



RIGHT DIVIDE WALL UPSTREAM

The boring of holes in the concrete was done by 4 No. Jack Hammers having attachments for working dry and in water and the depths bored ranged from 3′ to 11′. In all, 910 such holes had to be bored and the cost including the fixing of the perforated pipe worked out to Rs. 8-1 per hole.

One Jack Hammer could on an average bore 3 holes per day and the Jack bits, which were $2\frac{1}{4}''$ in size, could be used thrice after resharpening.

In addition to the perforated length at the bottom, a $1\frac{1}{2}'$ long pipe, $1\frac{1}{2}''$ diameter, was fixed in the concrete with its top 6″ above the floor level, to enable the delivery from the grouting pipe to be fitted on to it. Great care was exercised in the fixing of these small lengths of pipes, as in case the pipe gets loose under pressure, when the grouting is in progress, no further grout would go in and there would thus be a chance of some possible cavity being left untapped.

Cement grouting

The total grout taken by all the pipes put in is about 19,000 cement bags, the maximum grout taken by any one pipe being 383 bags in a pipe on the crest in bay No. 37.

The pipes which took the maximum grout were those near the sump and on the crest. This was due to the fact that cavities formed in the lower part of the glacis which normally got filled up by the flow of sand from above so that cavities were eventually left at the upper end. Another place where cavities appeared likely was the upper end of the pier foundation block laid on made earth at a higher level. It was also found that bays in front of the main sumps generally took more grout than the others.

The consistency of grout used was 1 in 6. Sometimes grouting done in one pipe choked a few others nearby which simply indicated that cavities under all these pipes had been properly filled. Most of the grout went in under 50 lbs. pressure, but there were cases when the pressure after exceeding 100 lbs. dropped down suddenly, indicating the opening of another side cavity and an appreciable quantity of cement was consumed before the pressure went up again. All grouting was accordingly done with pressures ranging from 125 to 140 lbs. per sq. inch and the machines had to be kept in good order to develop this pressure.

It is hoped that with such an extensive cement grouting all possible cavities have been tapped and the barrage made perfectly safe.

Clay Grouting

In addition to the extensive cement grouting described already, it was decided to do clay grouting under the blocks on the upstream side along with sand grouting in the stone filling upstream of these blocks, as this would virtually have the effect of extending the uptream floor by 36′ and correspondingly reducing the pressures under the floor. The idea of clay grouting originated with Mr. Haigh, who considered that the main desideratum for passing any solution through the grouting machine was that all particles coarser than 0·1 m.m. in size should be excluded. An experimental grouting with a solution of 25% clay and 75% sand was first tried but was found to be a failure. Later clay grouting was tried as an experiment in a 2′ depth of shingle laid in a pit 30′ diameter and found to be an unqualified success. In this connection, it may also be mentioned that sand grouting tried at Islam indicated that a cone of sand was formed immediately under the pipe and the cavity remained unfilled.

The stone upstream of the blocks was first sand-grouted with a Merry Weather jet. Holes were then bored 20′ apart in the blocks for doing clay grouting. The local clay available contained about 10 % of sand, which is defined as particles coarser than 0·05 mm. in diameter. A depth of 4″ of this clay was put in an iron tank 8′×8′ to which was added 1′ depth of water. The mixture was then thoroughly stirred and grouted in the holes by gravity. This was followed by grouting under pressure, with a grouting machine, through the same holes. To prepare a suitable mix for the grouting machine, a 1 : 3 solution was made as before and to this was added 0·35 lbs. of sodium carbonate per c.ft. of clay to facilitate the dispersion of the clay particles. The solution was then allowed to settle for 4 minutes and decanted into another tank from which grouting was done. This gave a 5 % solution of clay and its composition was of the following order :—

Sand (particles over 0·05 m.m.) 4 to 6 %.

Silt (particles ·005 to 0·05 m.m.) 60 to 64 %.

Clay (particles under 0·005 m.m.) 32 to 36 %.

As the sand particles left over were less than 0·1 m.m. in diameter, which is the same as the size of the coarsest particle in cement, no trouble was experienced in working this mix in a grouting machine. The sediment left over from decantation was re-used in the grouting done by gravity feed. The maximum pressure registered by the grouting machine was 10 to 15 lbs., as at this stage the grout spurted out from one point or the other through the 4′ layer of stone.

Later, clay grouting by gravity was replaced by grouting with a high lift 1½″ or 2″ pump, as this was a much quicker operation and hence more economical.

The section to be grouted was 11′×2′ and even assuming 50 % voids in the stone, the quantity normally expected to be consumed was 11 c.ft. per ft. run against which the average actual consumption was 24 c.ft. This was mainly due to the fact that the grout found its way in the cavities which existed in the shingle lying below the stone. The chance of its entering cavities under the impermeable floor was remote as the bottom of the adjoining curtain wall was 4′ below the bottom of the stone filling under the blocks.

The gravity feed accounted for about 70 % of the total grouting, the remaining 30 % having been grouted by the grouting machine. The total cost of this clay grouting worked out to about Rs. 590 per chain or Rs. 24 % c.ft. of clay grouted.

This clay grouting offers an ideal solution in cases where grouting is periodically done through certain pipes left in the floor and it is hoped that a more extensive use of this will be made in the future.

River Diversion

It is not proposed to take the river diversion in hand at present as the gates have not yet been erected and necessary funds also have not been made available. The minimum discharge to be tackled will be of the order of 25,000 cusecs. The present idea is to first close the main channel on the right and then take up the central channel. This closing will be effected by advancing a shingle bund from either side as far as it can be conveniently done. A trestle bridge composed of units which can be readily erected as well as dismantled, as shown in Plate X, will then be built in the remaining portion in running water. This will carry an N. G. track from which stone will be dumped direct from the trucks. The slope which the stone will assume and the quantity thus required has been determined already from experiments.

General

It is not possible to give the detailed figures of expenditure as the work has not yet been finally completed. It is anticipated however, that the total expenditure will not exceed Rs. 1,60,00,000 against a project provision of Rs. 1,88,00,000.

Analysis of rates for working various mixers, pumps and compressors are given in the appendices attached.

Acknowledgments

The author gratefully acknowledges the ungrudging help and guidance given by Mr. Haigh in all stages of the construction. Thanks are also due to Mr. Handa for his co-operation during the period that he worked as Executive Engineer, Power Division, and to the Sub-Divisional Officers, Messrs. Sally, Kalra, Ravikant, Alexandar and Speirs for putting their very best in the job.

APPENDIX I.

ANALYSIS OF RATES FOR WORKING VARIOUS MIXERS PER SHIFT OF 8 HOURS.

Items.	One C. Yd. Steam driven.		One C. Yd. Electric driven.		¼ C. Yd. Electric driven.		¼ C. Yd. Diesel driven.	
	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount
I.—Labour.		Rs. a. p.		Rs. a. p.		Rs. a. p.		Rs. a. p.
Driver @ Rs. 45 p.m. ..	1 No.	1 8 0	..	..	..	..	..	..
Driver @ Rs. 35 p.m. ..	..	..	1 No.	1 2 8	1 No.	1 2 8	1 No.	1 2 8
Fireman @ Rs. 25 p.m. ..	1 No.	0 13 4	..	..	..	..	..	..
Waterman @ Rs. 16 p.m.	1 No.	0 8 6	..	..	1 No.	0 8 6	1 No.	0 8 6
Gangman Plant and machinery @ Rs. 16 p.m. ..	1 No.	0 8 6	1 No.	0 9 7	1 No.	0 9 7	1 No.	0 9 7
Chowkidar @ Rs. 12 p.m.	1 No.	0 6 5	1 No.	0 6 5	1 No.	0 6 5	1 No.	0 6 5
Electric Pump Driver @ Rs. 25 p.m. ..	1 No.	0 13 4	1 No.	0 13 4	..	..	..	..
Fitter @ Rs. 50 p.m. ..	1 No.	1 11 0	½ No.	0 13 6	½ No.	0 13 6	½ No.	0 13 6
Fitter coolie @ Rs. 18 p.m.	1 No.	0 9 7	½ No.	0 4 10	½ No.	0 4 10	½ No.	0 4 10
Foreman @ Rs. 70 p.m. ..	¼ No.	0 9 4	¼ No.	0 9 4	⅛ No.	0 4 8	⅛ No.	0 4 8
Fireman Lighter @ Rs. 25 p.m. ..	⅓ No.	0 4 5	..	..	..	..	..	..
Total ..	..	7 12 5	..	4 11 8	..	4 2 2	..	4 2 2
Say ..	..	7 12 0	..	4 12 0	..	4 2 0	..	4 2 0

II.—Stock.								
Steam coal @ Rs. 20/13 per ton ..	0·65 ton	13 8 0	..	..	..	..	..	..
Cylinder Oil @ Re. 1/10 per gal. ..	0·3 gal.	0 8 0	..	..	..	..	..	..
Axle Oil @ Rs. 1/5 per gal.	0·5 ,,	0 10 6	..	..	..	..	..	..
Diesel Oil @Rs. -/8/6 per gal.	..	..	..	..	..	..	2·5 gal.	1 5 3
P.T.E. Oil @Rs. 2/10 per gal.	..	..	..	..	..	..	0·5 gal.	1 5 0
Cotton Waste @As. 4/6 per lb.	1 lb.	0 4 6	..	..	..	..	1 lb.	0 4 6
Electric stock ..	L. S.	..	L. S.	0 5 0	L. S.	0 2 0	..	..
Electric energy @ -/-/11 per unit ..	..	..	150 units	8 10 0	60 units	3 7 0	..	..
Miscellaneous Stores ..	L. S.	0 8 0	L. S.	0 8 0	L. S.	0 6 0	L. S.	0 8 0
Repairs ..	L. S.	1 8 0	L. S.	1 0 0	L. S.	0 8 0	L. S.	1 0 0
Total ..	..	16 15 0	..	10 7 0	..	4 7 0	..	4 6 9
Say ..	..	..	..	..	..	..	..	4 7 0
III.—Initial Charges.								
Loading, unloading and carriage of mixers and engines to site ..	..	0 12 0	..	0 6 0	..	0 3 0	..	0 3 0
Preparing foundations, fixing at site and shifting ..	..	2 1 0	..	0 12 0	..	1 4 0	..	1 3 0
Piping and water connections ..	..	0 13 0	..	0 13 0	..	0 13 0	..	0 13 0
Total ..	..	3 10 0	..	1 15 0	..	2 4 0	..	2 3 0
GRAND TOTAL I, II & III ..	..	28 5 0	..	17 2 0	..	10 13 0	..	10 12 0
Say ..	..	28 0 0	..	17 0 0	..	11 0 0	..	11 0 0

APPENDIX II.

ANALYSIS OF RATES FOR WORKING CENTRIFUGAL PUMPS PER SHIFT OF 8 HOURS

Item	Portable Steam Engine. 12 H. P.		Oil Engine.	
	Quantity	Amount	Quantity	Amount
I.—Labour.		Rs. a. p.		Rs. a. p.
Driver @ Rs. 45 p.m.	1 No.	1 8 0	..	..
Driver @ Rs. 35 p.m.	..	..	1 No.	1 3 0
Fireman @ Rs. 25 p.m.	1 No.	0 13 0	..	..
Gangman @ Rs. 14 p.m.	1 No.	0 8 0	1 No.	0 8 0
Total ..	..	2 13 0	..	1 11 0

II.—Stock.

Steam coal @ Rs. 20/13/- per ton	0·65 ton	13 8 0	..	..
Cylinder oil @ Re. 1/10/- gallon	0·3 gal.	0 8 0	..	..
Axle oil @ Re. 1/5/- gallon	0·5 gal.	0 10 0	..	..
Cotton waste @ As. -/3/- lb.	1 lb.	0 3 0	1 lb.	0 3 0
Petrol @ Rs. 2/1/- gallon	..	..	0·25 gal.	0 8 0
Kerosene oil @ Rs. 4/1/- tin	..	..	¾ tin	3 1 0
D. T. E. oil @ Rs. 2/10/- gallon	..	..	0·4 gal.	1 0 0
Miscellaneous stores	L. S.	0 8 0	L. S.	0 4 0
Repairs and renewals	L. S.	1 8 0	L. S.	0 8 0
Total ..	..	16 13 0	..	5 8 0
Deduct for 1 day's shut-down during the month ..	..	0 9 0	..	0 3 0
Net stock	..	16 4 0	..	5 5 0
GRAND TOTAL I & II ..	..	19 1 0	..	7 0 0
Say ..	..	19 0 0	..	7 0 0

APPENDIX III.

ANALYSIS OF RATES FOR WORKING ELECTRIC PUMPS PER SHIFT OF 8 HOURS.

Item	15″×12″		12″		10″		8″		6″		4″×3″	
	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount	Quantity	Amount
		Rs. a. p.		Rs. a. p.		Rs. a. p.		Rs. a. p.		Rs. a. p.		Rs. a. p.
I.—Labour.												
Driver @ Rs. 30 p.m. ..	1 No.	1 0 0	1 No.	1 0 0	1 No.	1 0 0	1 No.	1 0 0	1 No.	1 0 0	..	..
Driver @ Rs. 25 p.m. ..	..	..	..	..	..	..	..	..	..	..	1 No.	0 13 0
Pump attendant @ Rs. 16 p.m. ..	½ No.	0 4 3	½ No.	0 4 3	½ No.	0 4 3	½ No.	0 4 3	½ No.	0 4 3	½ No.	0 4 3
Total ..	..	1 4 3	..	1 4 3	..	1 4 3	..	1 4 3	..	1 4 3	..	1 1 3

I.—Stock.

	unit		unit		unit		unit		unit		unit	
Electric energy -/-/11 per unit	190	10 14 0	125	7 3 0	100	5 12 0	80	4 9 0	65	3 12 0	30	1 12 0
Electric stock ..	L. S.	0 5 0	L. S.	0 5 0	L. S.	0 5 0	L. S.	0 5 0	L. S.	0 4 0	L. S.	0 3 0
Cotton waste @ /3/ per lb. ..	⅓ lb.	0 1 0	⅓ lb.	0 1 0	⅓ lb.	0 1 0	⅓ lb.	0 1 0	⅓ lb.	0 1 0	⅓ lb.	0 1 0
Repairs and renewals ..	L. S.	0 2 0	L. S.	0 2 0	L. S.	0 2 0	L. S.	0 2 0	L. S.	0 1 0	..	..
Total ..	..	11 6 0	..	7 11 0	..	6 4 0	..	5 1 0	..	4 2 0	..	2 0 0
Deduct for one day's shut-down during the month ..	..	0 6 0	..	0 4 0	..	0 3 4	..	0 2 8	..	0 2 0	..	0 1 0
Net stock ..	..	11 0 0	..	7 7 0	..	6 0 8	..	4 14 4	..	4 0 0	..	1 15 0
Total I & II ..	..	12 4 3	..	8 11 3	..	7 4 11	..	6 2 7	..	5 4 3	..	2 0 3
Say ..	..	12 4 0	..	8 11 0	..	7 5 0	..	6 3 0	..	5 4 0	..	2 0 0

APPENDIX IV.

ANALYSIS OF RATES FOR WORKING COMPRESSORS FOR BORING HOLES.

Item	Electric-driven Air Compressor		Diesel-driven Air Compressor		Petrol-driven Air Compressor	
	Quantity	Amount	Quantity	Amount	Quantity	Amount
I.—Labour.		Rs. a. p.		Rs. a. p.		Rs. a. p.
(a) *For working Air-Compressor*						
Driver @ Rs. 40 p.m.	1 No.	1 6 0	1 No.	1 6 0	1 No.	1 6 0
Cleaner @ Rs. 16 p.m.	1 No.	0 9 0	1 No.	0 9 0	1 No.	0 9 0
Chowkidar @ Rs. 12 p.m. ..	1 No.	0 6 0	1 No.	0 6 0	1 No.	0 6 0
Total ..	..	2 5 0	..	2 5 0	..	2 5 0
(b) *For boring holes and drilling perforated pipes.*						
Erector Jamadar @ Rs. 40 p.m. ..	1 No.	1 6 0	1 No.	1 6 0	1 No.	1 6 0
Gangmen @ Rs. 18 p.m.	10 No.	6 0 0	10 No.	6 0 0	5 No.	3 0 0
Fitter @ Rs. 50 p.m.	1 No.	1 11 0	1 No.	1 11 0	1 No.	1 11 0
Fitter coolie @ Rs. 18 p.m. ..	1 No.	0 10 0	1 No.	0 10 0	1 No.	0 10 0
Total ..	..	9 11 0	..	9 11 0	..	6 11 0
Total I (a+b) ..	..	12 0 0	..	12 0 0	..	9 0 0

II.—STOCK.						
Electric energy @ -/-/11 per unit.	176 units	11 0 0	..	..	..	..
Lubricating Oil @ Re. 1/8/-per gallon..	⅙ gal.	0 4 0	¼ gal.	0 6 0	¼ gal.	0 6 0
Fuel oil @ Re.-8-6 per gallon ..	..	..	12·5 gal.	6 10 0	..	..
Petrol @ Rs. 2/1/- per gallon ..	..	..	..	..	8 gal.	16 8 0
Cotton waste @ As. 4 per lb. ..	1 lb.	0 4 0	1 lb.	0 4 0	1 lb.	0 4 0
Petty stores	L. S.	0 4 0	L. S.	0 4 0	L. S.	0 4 0
Repairs and renewals	L. S.	0 8 0	L. S.	1 0 0	L. S.	1 0 0
Jack bits @ Re. 1/8/- each ..	4 No.	6 0 0	4 No.	6 0 0	2 No.	3 0 0
Perforated pipe @ Re. -/4/6 per feet ..	42·6 lft.	12 0 0	42·6 lft.	12 0 0	21·3 lft.	6 0 0
Cost of cleaning Jack rods, sharpening bits, making hammering rods, etc. ..	L. S.	1 8 0	L. S.	1 8 0	L. S.	0 12 0
Total stock ..	..	31 12 0	..	28 0 0	..	28 2 0
Total I & II ..	..	43 12 0	..	40 0 0	..	37 2 0

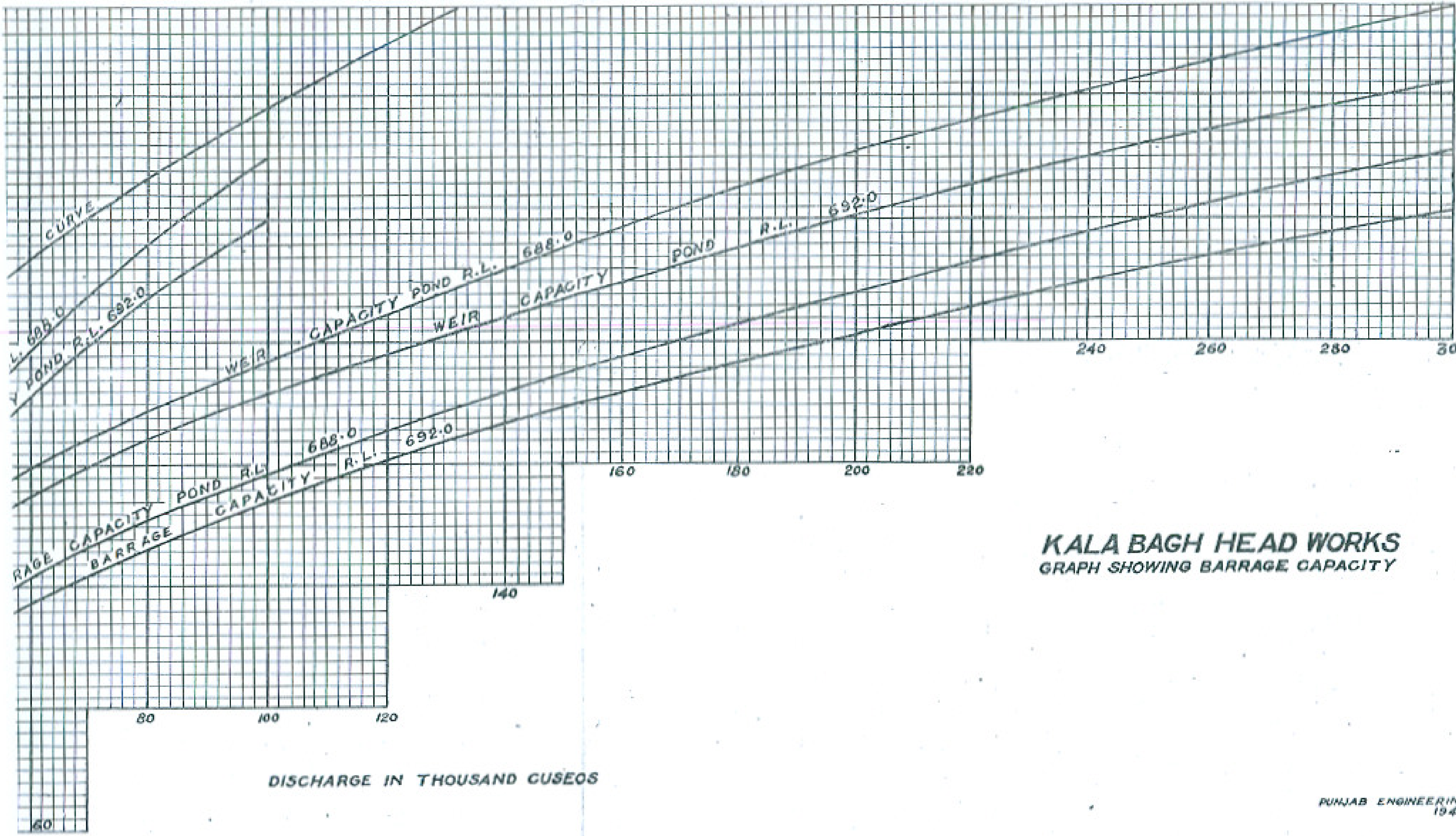
No. of holes bored per shift .. 6 Nos. 6 Nos. 3 Nos.

Total cost of boring 15 holes .. 43 12 0 + 40 0 0 + 37 2 0 = 120 14 0

∴ Cost per hole, including fitting of perforated pipe .. .. = 8 1 0

LIST OF PLANS ATTACHED

PLATE I
PAPER NO. 251



KALA BAGH HEAD WORKS
GRAPH SHOWING BARRAGE CAPACITY

PUNJAB ENGINEERING CONGRESS
1942