PAPER No. 127.

# EXTENSION OF THE TRAINING WORKS AT THE JUMNA BRIDGE NEAR KALANOUR (BETWEEN SAHARANPUR AND JAGADHRI).

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The Jumna River rises in Garhwal close to a peak of Himalaya called Bandar Punch 20,731 feet high. Its length from its source to the site of the bridge is about a hundred and fifty miles. A new bridge 300 feet upstream of the old one, now used as a road bridge, was built in 1911. This was described in detail by Mr. A. I. Sleigh in the proceedings of this Congress. The original project provided for eight spans of 200 feet clear with approaches and piers capable of taking a double line, but with only one track of girders up to standard B of 1903 plus twenty-five per cent. but eventually it was decided to further constrict the Jumna river to seven spans of 200 feet clear and build a double track girder bridge which was done.

In order to make use of the existing guide bank on the left bank of the river the angle of the left guide bank being 97°-27′ with the centre line of the bridge, the right guide bank had to be splayed out at an angle of 97°-27′ to the centre line of the bridge to keep it symmetrical with the left one. The length of the guide banks from abutment to Molehead was made 1,460 feet.

These guide banks acted successfully till the flood of 1924 when the river rose to 881'90 at the bridge with a discharge of about 250,000 cusecs and started making large embayments behind the Bell bunds and heavy erosion of both banks, owing to the fact that the stream had divided into two more or less equal portions at a point some 4 or 5 miles above the bridge. The left bank suffered badly, it was cut back 1,200 to 1,800 feet and the embayment threatened the Railway. A parallel bund constructed to safe guard the approaches of bridge in 1917 was attacked for a length of about five hundred feet. The matter was then considered sufficiently serious to require prompt action and for the time being arrengements were made to safeguard the parallel bund and the nose of Bell Bund by providing 2 lacs c.ft. of pitching stone, stacked along the apron of the parallel bund, for emergencies and increasing the apron by a height of 4 feet. In the early flood of 1926 the river changed its course and started attacking the right bank, the erosion of the right bank was quicker and some 800 feet had been taken away by the month of August, *i.e.*, in two months, after which the river again changed its course and ttacked the left bank cutting away the apron of the parallel bund by bout 8 feet for a length of 300 feet at the end of the flood season 1926.

An inspection by Mr. Pavry the Chief Engineer was made on 17th ebruary 1927 when it was decided to extend the main training bunds a length of 750 feet the last six chains being on a radius of 600 feet.

The total length of extension along the curve measured 1,200 feet. This extension was taken in hand on 20th October 1927.

## Description regarding design of bunds and aprons.

The extension of the bunds was made for a total length of 1,200 feet, the first 100 feet being on the straight and the remaining on a curve of 600′ radius. The embankment was kept 20′ wide on the top, with 2 to 1 side slopes, with a height, which allows five feet free board over any flood likely to rise on the front or rear of these bunds. A layer of 9″ clay was provided for on the top of the slopes to resist the action of the waves and encourage the growth of vegetation as far as possible. It was also considered desirable to check possible scouring of the slope by the use of 6″ of ballast or stone chips on the top of this clay during construction and this was done accordingly.

The pitching stone on the slopes was designed 3 feet thick.

The width of the apron was designed to be 70 feet throughout excluding the impregnable bends, where the apron was kept 100 feet wide. The apron was designed to be laid in steps but this could not be done where its bottom was below low water level. In these places the mean thickness of the apron was kept $5\frac{1}{2}$ feet.

The outer edge of the apron which fell under deep scour was given stone slope of 2 to 1. The portions over dry were left straight. The general design follows in fact pretty closely the rules given by Spring, the fall of the river being 2 feet per mile and the deepest s cour 35 feet.

## General Description.

The separate streams which followed the right and left banks met at the Molehead of the left guide bund, where a deep scour of 35 feet for a length of 4 chains resulted and, therefore, made the extension of the left guide bund a very difficult task as the extension had to cross this scour hole. The construction of this bund could not, therefore, be taken in hand till the stream from this Molehead was diverted. To carry this out the following works had to be executed :—

(1) To dig a channel 4,000 feet long across the island.

(2) To dam both branches of the river and divert them into the newly dug channel.

## Detail of temporary Channel and Dam.

The channel was dug to a section of 50′×8′ that is, roughly to a depth of about a foot below the lowest water level, which at the time wher the channel was opened was 872·24. The total length of the chann across the island and that in river bed measured 5,812′. The tot quantity of earth work in the excavation of this channel amounted to lacs c.ft. This being a large quantity, special arrangements to import large number of labourers from different places had to be made, to ensu

its completion within 20 days, failing this the actual costruction of left guide bund would have been seriously delayed, which one cannot afford to risk in a work like this. The work of digging channel was started on 17th October 1927 and completed on 7th November 1927, that is within 21 days the earthwork having been done at the rate of one lac c.ft. a day. Soon after the channel was ready for operation, a dam which may be termed the central bund was taken in hand on 11th November 1927, so as to divert the right bank stream into this newly dry channel and was completed on 18th November 1927 at a cost of Rs. 10,000 (plate No. 1). The top level of this bund was made about 7 feet above the lowest water level, and was fixed after a careful study of records shewing the highest winter flood during the previous years. To stop the flow across the site of the extension of the left guide bank the left bank stream had then to be closed by another bund at the upper end of the channel that is about a mile and-a-half above the bridge, which was started on 17th November 1927 and completed on 21st November 1927 (plate No. 1). Thus both the streams were diverted into the newly dug channel and still water was produced at the site of the extension of the left guide bund which could then be taken in hand. The top of this 2nd, *i.e.*, upper Bund was kept at a R. L. = 879·0, that is, 7 feet above lowest water level at this place, which at the time, was considered quite high enough to stand against the highest winter flood anticipated. This bund was built at a cost of Rs. 15,500.

Before continuing the description of the construction of the left guide bund, it is worth while to record the methods adopted in bunding up the river at both sites. The depth of water varied from 4 to 5 feet.

(1) To check the scour caused by the increase in velocity when the opening through which the stream passed became narrower and narrower at the time of bunding it up. The bed of the river at the site of the dam and for some distance above and below was first covered with a layer of sand bags.

(2) After carrying out item 1 above, the building up of bunds was started from both ends.

(3) After the actual operation of building the bunds was taken in hand the work was pushed through day and night without a break till the bund had risen above the water level.

(4) Great care to avoid deep scour at the time of closing up the bund, was taken. This could only be avoided by keeping a large number of sand bags ready for use near at hand to enable the labourers to place them as quickly as possible to bund up the fierce current.

(5) Sufficient care was taken to break joints and lay the bags in batter.

(6) The bags were not over filled as otherwise it is difficult to make the dam.

As soon as the stream had been diverted into the temporary channel it started to scour out the latter, as intended, especially at its lower end and in the old river bed where a strong tendency appeared to break through into its old course to the left molehead. To check this the left bank of the channel was revetted with stone and bags for a length of 1,500 feet and brushwood spurs were added to encourage silting. This rivetment needed specially careful maintanance from 23rd December 1927 right up to February 1928 as owing to the heavy winter rains the rever was abnormally high for much of that period. This might have been avoided by locating the outlet of the channel further west in the first instance.

## Construction of Left Guide Bund.

The earthwork in this bund was first started on 22nd November 1927, on a length of three chains at the north end which fortunately fell on high ground and presented no constructional difficulties. The earthwork in the remaining 9 chains, could not be started immediately, on account of the whole of this portion lying under water, especially the four chains at the south end where a deep scour of 35 feet existed across which the bank could not possibly be made until a stone toe wall had been made at both the ends of the aprons, to secure the earth against being washed away. The quantity of stone required to build there two toe walls was = 287,000 c.ft. and was placed in position by making a long bridge of boats at both the ends of apron. The construction of this bund also involved a very long lead varying from 12 to 18 chains. Arrangements therefore to put up the boat bridge import donkeys, labour, and lay lines for running tip wagons, had to be made and were completed by 23rd December 1927, when the actual filling work was started with a full force at the rate about 40,000 c.ft. a day, but unfortunately this progress could not be kept up on account of the river rising too high at times between 23rd December 1927 and beginning of February 1928 and flooding the borrow pits and the channel giving trouble as already explained. Notwithstanding these difficulties the earthwork was pushed through to such an extent that by 2nd February 1928 twenty-seven lacs c.ft. of earthwork was done. This completed 9 chains in bank and also filled the deep portion of 35 ft. scour up to a foot above water level.

As soon as the earthwork in the left guide bank was well in hand, arrangements had to be made to deliver the pitching stone from Delhi to the site. The total quantity to be dealt with was 35 lakhs cf.t. and delivery was made at the rate of 7 lakhs c.ft. a month. For this purpose temporary sidings were laid along each apron as shown in plate No. I. The portion in very deep water was filled by working night and day on it and was made ready for laying the siding on 10th January 1928. The rails were laid and siding completed on 15th January 1928, to receive stone trains direct over East Apron, which, not only facilitated the reception of stone trains for this bund, but also cheapened the laying of stone and proved to be a speeded means at the construction of the left guide bund.

On 4th February 1928 an unprecedented winter flood occurred. The river rose to 872·0 or 8 ft. above lowest water level. It washed away both the temporary dam and seven chains of earthwork already completed in left guide bund. In addition to this scour holes from 18 to 26 ft. deep were left in site of the left guide bund (Plate 3). The temporary channel was widened out to a section of 200′ × 14′ against 50×8 originally dug. The newly laid temporary siding was also washed out and several boats washed away. In fact, the situation at the time appeared so bad that hope of completing the bund that year, were alomost lost. The site was inspected by the Chief Engineer, Deputy Chief Engineer and Divisional Superintendent on 5th February but nothing could then be decided as to the further progress of the work as the river was still too high and flowing through the breach in the left guide bank at 10′ to 12′ per second. About 9th February the fall of the river gave a chance of selecting a site for the construction of another dam about 100 ft. below the old dam in the left bank stream. A site of a new central bund could not yet be selected. The work of redamming the upper left bank stream was started on 10th February 1928 and completed on 18th February 1928. This time the bund was designed much wider and its height kept 3 feet above the flood level of 4th February 1928. The plate No. 2 shows the details of the dam (2nd upper bund) which was this time covered on the top as well as slopes by sand bags, to safe guard it against scour, in case the river should again rise to its top level during the execution of the work. Several spurs were also provided to keep away the current from the bund and produce still water against it.

On completion of this dam the flow from the left bank upper Jumna stream at the site of the extension of left guide bund, was totally stopped butthatfrom the right bank stream still continued and did not allow work to be restarted on the left guide bund till another dam along the line of its West apron was put in (plate No. 2). This dam was completed on 25th February 1928, when the temporary siding in the East apron of the left guide bund was also made fit for receiving trains and was extended right through the whole length of the West apron, so as to bring trains straight on to this apron also by a back shunt, (plate No. 1).

The river was still persistently high with the result that it soon became impossible to do the earthwork by manual labour on account of long lead and the huge quantity of earthwork, *viz.* 27 lacs, still required to be done after the flood. Arrangements to carry out this earthwork by ballast train were therefore made by laying extra sidings in the river bed as shown in plate No. 1 which provided such shunting facilities, as to enable one to handle both the stone and earth trains at one and the same time, to keep the labour of two different contractors engaged who were working separately for each item. In addition to the above sidings it was also proposed to run an extra earth train from Jagadhri to push through the completion of earthwork earlier, and to do this the following additions

and alterations on the main line at Janeshnagar and Jagadhri were carried out at the same time.

(1) Laying a cross over at Janeshnagar which had previously been opened as a station for down trains only, to admit earth trains on up line from down line, when returning with empties to Jagadhri. It was anticipated that a great deal of time would be lost in running empties to Sarsawa and then back to Jagadhri if this cross over was not put in.

To admit this arrangement, Janeshnagar station had to be provided with interlocking gear as required by rules for this class of station and this cost the Railway Rs. 12,500.

(2) A similar cross over between Up and Down line at Jagadhri was put in to facilitate admission of the earth train direct into earth siding without any shunting. This saved detention to main line trains.

(3) Laying of an earth siding at Jagadhri with necessary signals and such interlocking gear as required by rules to safe guard the working of main line trains.

Notwithstanding all these extra precautions the earth train from Jagadhri could not make more than two trips a day and at times only one trip was made ; this was due to detentions caused by heavy traffic. In any case in the writer's opinion, it is always advantageous to arrange the working of such ballast trains in the river bed only, if possible, so as to keep them independent of main line trains. This had to be done at a later stage, when the working of earth trains from Jagadhri was cancelled and the stock utilized in river bed.

The earthwork in the river bed was started on 19th February 1928 with two rakes, each consisting of 25 trucks, and each rake was so arranged to work, as to leave no room for any of them to remain idle for any time, during the working hours, provided the labour continued their work regularly. Each of these rakes was allowed 2½ hours loading, and the same time for unloading and carrying the earth by baskets to site of bund. To keep this arrangement up, trials were made to arrive at a definite conclusion regarding the distribution of labour required separately for each operation and was found as follows :—

| | Men per truck. |
|---|---|
| Loading earth | .. 8 |
| Unloading earth | .. 4 |
| Carrying earth to site of bund | .. 8 |

The labour for the above operations was arranged in double shifts, and allowed to do the work on task system. The first batch of men worked from 7 to 17 hours and the 2nd from 17 to 24 hours after which the work stopped for the night. By this arrangement 7 trips = 70,000 c.ft. of earthwork were made each day from the river bed. More trips could have been easily arranged during this period if the earth train from Jagadhri

ad not been running. It was on this account that the earth train from agadhri was cancelled after having worked for 15 days, when three rakes nstead of two were provided in the river bed and did excellent work. The average earthwork thus done amounted to one lac c.ft. a day and the arthwork in left guide bund was completed on 25th March. If this rogramme had not been kept up for any reason the completion of the ank during that season would have been doubtful, not because of the hort time available but of the crop cutting season which set in soon fter, when the labour started deserting the work in large numbers. Great ifficulty was experienced in arranging even a couple of hundred men fter 1st April 1928. The working months therefore for this kind of work re from 1st October to 30th April during which time, the work must be ushed through and completed otherwise there is every likelihood of eaving the construction unfinished and thus wasting all the money spent n it by getting it washed away during the monsoon.

After getting the earthwork in left guide bank completed, the next oint of importance which required immediate attention, was to safe-guard the bank against a flood if one happened to some. To ensure this he slopes of the bank up to a height of 10 feet above top of apron, were itched by employing a large number of masons and coolies, and the pron round the bank made safe by filling up with stones. This took bout a week, and by about 2nd April the left guide bank stood quite afe in the river bed and beyond danger of being washed away.

### Right Guide Bund.

This bund for practically its whole length was on high and dry ground except the last 4 chains and therefore no difficulty was experienced n going ahead with the earthwork for the 1st 8 chains. The earthwork was started on 11th November 1927. The stone trains from Delhi start-ed to run with supply of stone on this bund on or about 13th December when it was completed for about six chains length. This enabled the stone to be unloaded direct over this bank and placed in the apron, which was also completed for this distance by that time. The remaining length was pushed through in the meantime by putting up a circular bund with sand bags, *vide* plate No. 2 round outside the apron at the Molehead to push the river out and produce still water at the site of bund, the last four chains of which were in water. This bank gave no trouble whatso-ever, the earthwork in it was completed by 31st January 1928 when im-mediate steps to protect it against a flood were taken by covering the slopes and the apron round about it with stone. The unprecedented flood of 4th February 1928 therefore, did not do any damage to this bund except a fairly deep scour which was made by the river in the apron in front of the Molehead where it had remained unfilled. This was not serious and was filled up with an extra quantity of 50,000 c.ft. of stone.

### Supply of pitching stone.

Total requirements of pitching stone amounted to 35 lacs for both the bunds. This supply was arranged from the quarries situated at Delhi

Sufdar Jung and Delhi Kishen Ganj at a rate of Rs 7 % c.ft. of stone delivered at the quarries loaded in trucks. To train this out to the site of work, four ballast trains, each consisting of 40 trucks were employed so as to deliver at least 25,000 c.ft. of stone every day at the site of work. To maintain this progress, the trains were provided with double crew and arranged to run to a time table, but unfortunately this could not be kept up on account of detentions on the road, due to the heavy traffic at that time. However the working of these trains on the whole was quite satisfactory, and the delivery of stone was not delayed by more than 15 days. It took 5½ months to train out 35 lacs of stone insteadof 5 months as originally anticipated.

### Delivery of stone at Site of Work.

In view of the fact, that 35 lacs c.ft. of pitching stone was required to be trained out for both the bunds, it was very necessary to start the working of stone trains in such a time as to ensure the completion of the bunds by 30th April 1928 as already stated. The stone trains, therefore, were started to carry the pitching stone from Delhi to site of work on and from 22nd November 1927, when the delivery had to be taken on the old bank of left guide bund, till a portion of bank on right guide bund was ready to receive the train.

The quantity unloaded on the old bank of left guide bund amounted to about 5 lacs and could not be taken into position, without spending an extra money on lead, but this was worth doing in view of the fact stated above.

Great care was taken in unloading so as to save as much detention to trains as possible. To do this, six men per truck were employed to unload the stone and clear if from the rails within a specified period of one hour. Whenever the stone was required to be unloaded in two or more shifts by shunting extra time at the rate of one hour per shift was allowed, and this worked without causing any unanticipated detention.

### Laying stones in aprons.

In laying the stone in apron, it is necessary to organise a system, by which the earthwork done in the actual construction of the bund is made secure, with a small quantity of stone and in as short a period as possible. The best method which proved of great use at the Jumna bridge was as follows :—

The stone in the apron was laid in sections 70′ × 50′ with the long walls 6′ to 8′ wide against the toe of the bank and at the ends of the aprons. These long walls were joined with cross walls at every 50 or 100 feet and the intervening space was then filled with stone with the result, that when these were completed the bank stood absolutely safe against a flood. This did not take long to do.

The other point of importance which improved progress is that the stone delivered by ballast train must be removed to the site where it is to be laid the same day that it is unloaded. This also ensures the regular

running of the trains, which are likely to stop running if site of unloading gets jammed up. To do this the following labour was kept employed for one stone train (15,000 c. ft. stone) per day :—

| | | |
|---|---|---|
| Masons for hand packing the surface | | 30 masons |
| Coolies with masons | .. | 30 coolies |
| Coolies for carrying stone | .. | 200 ,, |
| Coolies for laying the stone with dressed surface | .. | 50 ,, |

Care was also taken to lay each stone flat or with dressed surface on top so as to avoid any uneven settlement due to this. The top surface of the apron was laid hand packed, and so were the slopes of the bank.

The outer edge of the apron wherever it crossed a deep scour hole was provided with slopes of stone at 2 : 1. The portion in the dry was left vertical.

It may also be mentioned that the bottom of the apron at both the bunds, which was made level was scoured at places by the flood of 4th February 1928.

It was however not considered necessary to level it again and so the stone was laid on the uneven bed, keeping in view that the full designed thickness of stone, *i.e.*, $5\frac{1}{2}'$ was laid. Wherever the scour happened to be deeper than 5 feet below water level, the whole of it was filled in with stone.

## Labour.

To carry out the work the following labour was employed throughout the period of construction :—

| | | No. |
|---|---|---|
| Boats with 1 boatman each | .. | 12 |
| Masons | .. | 60 |
| Coolies skilled and unskilled for stone work | .. | 600 |
| Donkeys | .. | 300 |
| Donkeymen | .. | 300 |
| Coolies for earthwork | .. | 1,300 |

Out of the above labour 5/6 was imported from different parts of the country, the remaining 1/6 was local. The local labour in this part of the country was found to be very lazy and weak, the completion of work, therefore, mostly depended on the imported labour.

The bunds were completed in every respect on 25th April, after which the trains were employed to place about 2 lacs of stone as a reserve on both the newly constructed guide bunds.

The writer does not pretend to have evoloved any new thing but merely wishes to draw attention to the points mentioned here in which though known are some times lost sight of.

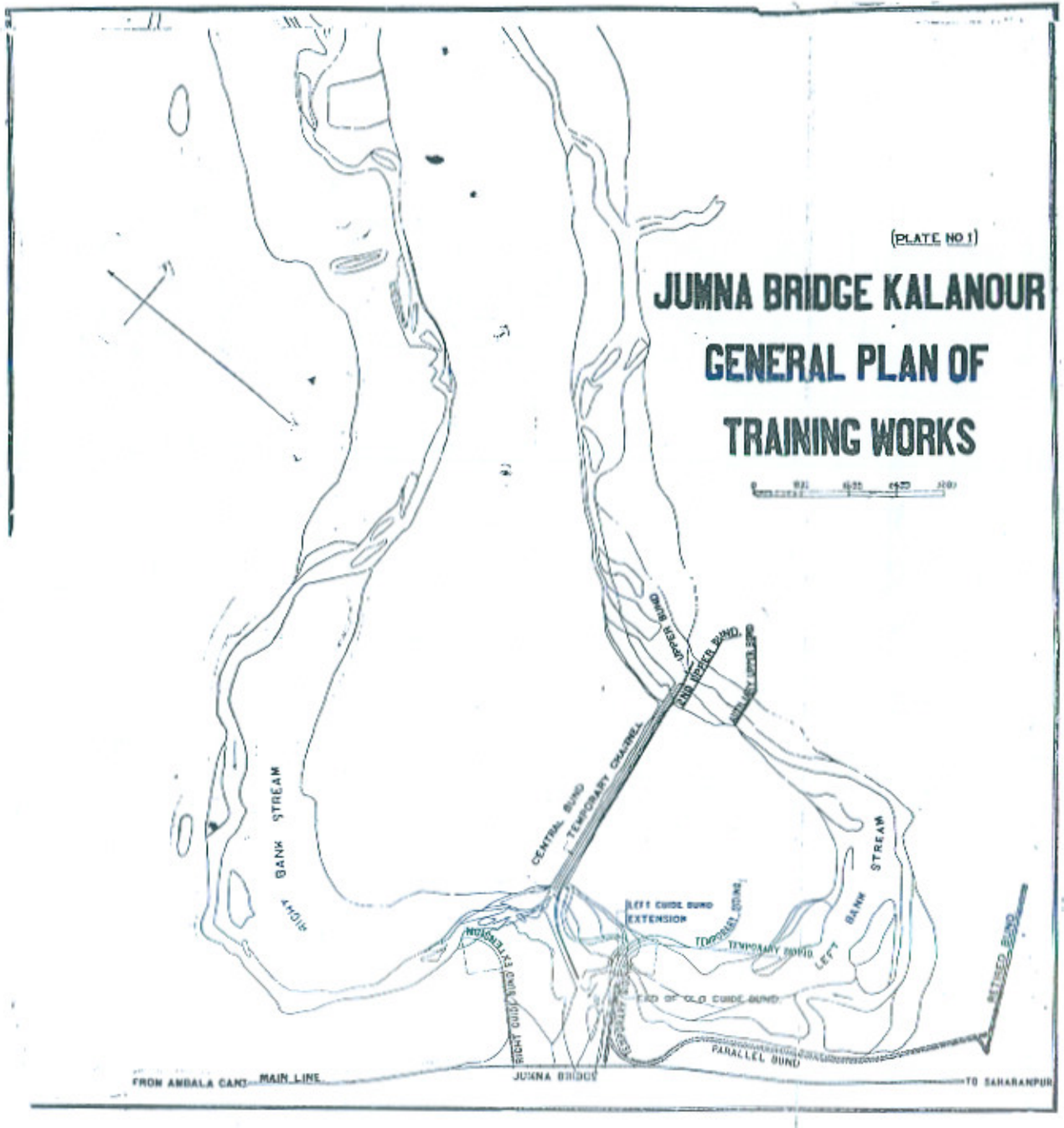
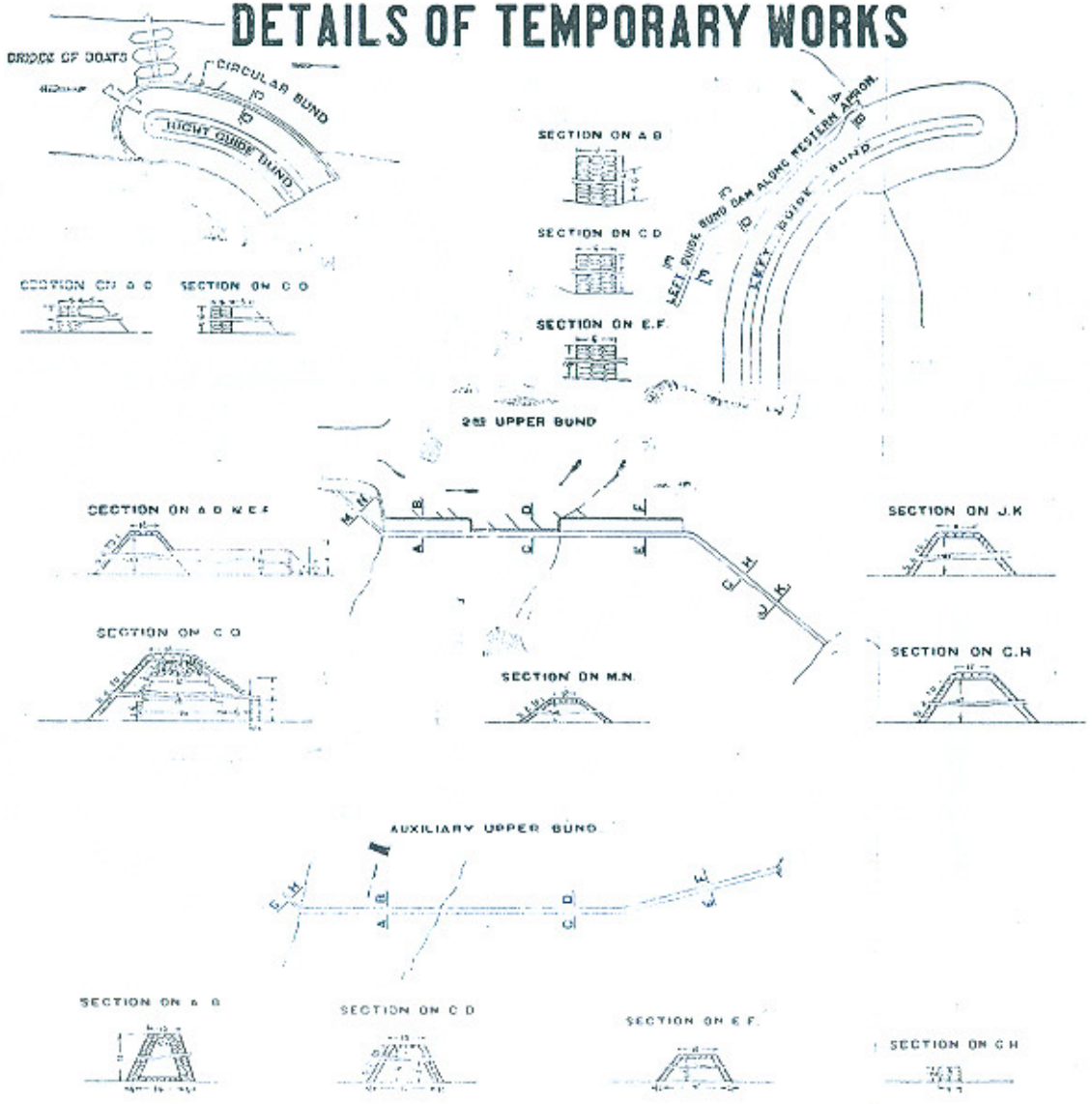

(PLATE NO 1)
JUMNA BRIDGE KALANOUR
GENERAL PLAN OF
TRAINING WORKS
UPPER BUND
TEMPORARY CHANNEL
CENTRAL BUND
RIGHT BANK STREAM
LEFT BANK STREAM
LEFT GUIDE BUND EXTENSION
TEMPORARY BUND
END OF OLD GUIDE BUND
PARALLEL BUND
RIGHT GUIDE BUND EXTENSION
FROM AMBALA CANT
MAIN LINE
JUMNA BRIDGE
TO SAHARANPUR

PLATE NO 2

# JUMNA BRIDGE KALANOUR

## DETAILS OF TEMPORARY WORKS



(PLATE NO 3)

# TYPICAL CROSS SECTIONS

SCALE

CROSS SECTION AT CH: 1700 AFTER FLOOD


CROSS SECTION AT CH: 1800 AFTER FLOOD


FINISHED CROSS SECTION AT CH: 1700.


FINISHED CROSS SECTION AT CH: 1800.

## DISCUSSION.

MR. DHAWAN in introducing the paper said that the author of this paper Mr. Varma was absent owing to unavoiadable circumstances. In doing so he offered a few explanatory notes for the facility of members. He referred to the first page of the paper on which it was stated that "the guide banks had acted successfully till the flood of 1924." He explained that as a matter of fact the river had been attacking the left guide bank off and on since the construction of the bridge in 1911 and in 1917, the left approach bank was protected by an armoured bank more or less parallel to the Railway bank and 400 to 500 feet away. This bund had gradually grown up in length and was now 5,400 feet long, and had cost over 2 lacs of rupees so far.

In 1926 the river started attacking the right guide bank and steps had to be taken to protect it by means of subsidiary works. It was considered that the method of building subsidiary bunds was unsound in principle and also uneconomical. It was therefore, decided to extend the main guide bunds up to a length which had been found to function satisfactorily on many of their other large bridges. He then referred to page 62, para. 4, and quoted the following passage :—

"The general design follows in fact pretty closely the rules given by Spring, the fall of the river being 2 feet per mile and the deepest scour 35 feet."

This he considered to be misleading and said that although the straight portion of the bund had been designed to take a scour of 30 to 35 feet, the curved ends have been designed to take a scour of 50 to 55 feet deep.

On the same page under the heading "Detail of temporary channel and Dam" it was stated that the lowest water level at the time the channel was dug was 872·24. On page 65 on the top it was stated that on 4th February 1928 an unprecedented flood occurred and the river rose to 872·0 feet, *i.e.* 8 feet above the lowest flood level. These he said appeared to be rather conflicting statements. The fact was that the first low water-level was taken about 3 miles upstream of the bridge and the 2nd at the site of the bridge, and as there was a fall of above 2 feet per mile the figures given on page 62 more or less agreed with the statement made on page 65.

He then pointed out that Mr. Varma had given in the paper the cost of the various operations; but had not given the total cost of the work. For the benefit of the Congress he stated that the total cost was 9 lacs of rupees.

MR. HADOW said that more information about the parallel bund would be interesting as it did not seem to be an ordinary form of river training work. River training works were often altered and extended and so ended up in a quite different form from what they were originally, and perhaps this was an example.

But, even if this were so, it did not dispose of his difficulty that, instead of a parallel bund, a T spur at right angles to the railway would have been more effective and cost less.

Turning to the question of the attack on two railway approach banks he asked whether it was ever considered desirable to put in T spurs to prevent attack on the railway embankments instead of prolonging the guide banks. From the plan it would seem that a T spur on the left side would have been little easier to do because the river would have had to be diverted in any case, on the right side it looked an easier proposition. On the right side he saw no signs of a marginal bund or retired bund as there were on the left side and this possibly had an influence in the decision. He said that he was not at all in favour of putting in T spurs unless there was something to tie them on to.

It was always interesting for engineers to see how some one else tackled a piece of work or set about it. At Panjnad there would be a very big diversion next year, so this paper was of considerable interest to him and he would ask for details, if available, of the relative levels of the bed at the upper end of the diversion, the level of the bed of the diversion itself and the actual discharge of the river when it was diverted. He would also like to ask if the apron laid at the site of the diversion bund which was made of gunny bags filled with sand, was a succesas. He said in the Irrigation Branch they used "pilchi" mattresses for such purposes. He thought that gunny bags were apt to loose sand and before using them in place of "pilchi" he wanted to be sure that this was not the case.

He noticed on page 62 that the width of the apron on the shank was designed to be 70 feet throughout, and he enquired what its thickness was. An apron width of 70 feet seemed to him to be very wide to put all the way down the shank of the guide bank. He had noticed at Adamwahan Bridge that he apron was a good deal more solid than was the practice in the Irrigation Branch where they favoured the principle of putting in a fairly light apron and then adding to it as required. He did not think they had put in more than 80 feet, for the aprons of the moleheads on the S. V. P., and not more than something like 40 feet, for the shanks of the guide banks. He gathered from the plan that the original guide bunds were straight and that the extensions only were curved. He would be grateful if a railway officer would say whether they favoured a straight guide bank or a curve guide bank.

In conclusion he expressed his admiration for the speed with which the work had been constructed. The officers had the usual unforeseen difficulties met within a river work, but they seemed to have got through the work in the end at a most extraordinarily rapid speed.

MR. BUTRA said an interesting point was that these bunds had been made at an angle of 97 degrees, he wanted to know what was the practice generally approved by the modern engineers. Referring to Spring he pointed out that Spring recommended two guide bunds at 90

degrees and the making of the straight portion of the bund equal to the length of the bridge. He said that it was a very great mistake to start work as late as October. He thought that the work ought to have been started somewhere about the beginning of September and thus about 6 weeks extra time would have made lot of difference. Referring to the temporary channel, he said it was difficult to get a proper idea of the actual state of affairs. He understood that a lot of money was spent on forcing the river through a small channel. In his opinion it would have been very much cheaper to put down the extension of the left guide bank by making a solid mattress of stone and then putting ordinary earth work on the top. In the end it would have been very much cheaper than the method adopted by Mr. Varma.

MR. TINSLEY asked what was the level and width of the top of the old bund which failed and how did it fail. Was it by erosion or was it actually overtopped?

If overtopped what was the previous maximum flood level and has the level of the repaired bund been raised in consequence.

MR. PAVRY said he would deal with the points raised by Mr. Hadow and the rest of the information, he hoped, would be given by Mr. Dhawan, in the absence of the author of the paper, as far as possible.

As regards the subsidiary T spur bund mentioned by Mr. Hadow, he pointed out that originally most of the bridge training works on the railway were scattered over several miles up and down-stream of the bridge; and that in such positions they were apt to be neglected or even lost sight of in time. This method of protection was gradually abandoned since Mr. J. R. Bell, while constructing the training works of a bridge, noticed that a short stretch of sand bank covered with some brick ballast remained in tact when the bank on either side was being washed away, and developed his idea of a permanent stone protected guide bank —an idea which he successfully applied to the bridge he was working on. Mr. Bell had laid down that the length of the guide bank should be approximately equal to the length of the bridge; but while both those lengths were functions of bed slope, nature of sand and volume of discharge and had, therefore, some connection,the crucial factors deciding the length of the guide bank were the extent to which the river could cut back behind the mole head and the depth of cushion which should be maintained between the main current and the approach bank. In connection with the depth of embayment behind the mole head, there had been a lot of talk about the minimum radius to which a river could scour; but if one examined the reaches of the Punjab rivers near the railway bridges one would find that usually the minimum curves had chords about 3 miles long and depths of about $1\frac{1}{2}$ miles. So that on the basis of minimum curvature the guide banks would have to be $1\frac{1}{2}$ miles long. The proper length of a guide bank was just as much a matter of experience and judgment now as it was in Mr. Bell's days; but guide-

banks 2,000 to 2,200 feet long were functioning reasonably well at many of the railway bridges and that is the length they were working to now. If and when guide banks of this length failed to function properly then was the time to consider whether they should be further extended or whether subsidiary works such as retired bunds, T spurs, etc., should be provided. They had not put in such subsidiary works anywhere on the Railway recently; but they were considering the use of Denehey's Groynes in connection with the Adamwahan Bridge on the Sutlej where the river had been hugging the approach banks down-stream and where they had a very complicated system of subsidiary works too far out from the approach bank. At the Jumna they had not resorted to such Groynes as the guide banks were obviously too short and the proper remedy was to extend them to the length which has been found to function satisfactorily elsewhere.

The second point raised by Mr. Hadow was as regards the section of apron which he thought was excessive. Their practice was to put in such a section as would cover the slope, after successive attacks, down to assumed maximum scour level with such a thickness of stone (usually about 3 feet) as would protect the slope from further scour. As they could not always have a natural gorge they thus provided for an artificial gorge. The cross-section of the apron having been worked out it was divided up between the width and thickness in proportions which gave the greatest promise of the stone falling gradually and covering the slopes unevenly.

The last point raised was whether a straight or curved guide bank would be better. The balance of argument and advantage was on the side of a curved guide bank. When heavily attacked the swirls causing deep scour are more likely to keep away from the main trunk of a curved guide bank than that of a straight one. The first straight guide bank on modern principles was put down by Sir William Johns on the Ganges at Garhmukhtesar. The only advantage claimed for it was that it would be more easily and economically lengthened if and when necessary. But when a length of bund has been arrived at which is found to work reasonably well in similar cases this argument loses most of its force. Only recently on the Sutlej at Phillaur their straight guide bank was heavily attacked and the unprotected back of the bund was so severely eroded that they had to throw in several lakhs of cubic feet of stone in a hurry to protect it. Their present practice was to make the ends of the guide banks curved to such a radius and for such length as to keep deep swirl scour as far away as practicable from the main trunk of the bund.

Mr. Robertson wished to make a few remarks with regard to the question of the advantages of having curved or straight heads to up-stream guide banks. He said, that if one was dealing with an irrigation head-works, it did not appear to be of so much importance if the upper ends of the guide banks were straight or curved—certainly not on

the modern head-works on the Sutlej. Such guide banks on the Sutlej Valley Scheme had been designed with straight ends, and many thought that they should have been curved.

At Sulemanke, in 1925, before the river was under control, there had been great difficulty in holding the right flank guide bank against river action; but in 1926, when the work was finished and the gates erected on the Weir, river action against the bund was checked by the regulation of the gates, which raised the up-stream water surface, and modified the scouring action against the noses of the guide banks. In the case of a Railway Bridge, the water surface cannot be controlled in this manner, and it is evident therefore that the railway and irrigation problems in such cases are quite distinct.

MR. NICHOLSON said that the question of the length of the bund up-stream of the bridge so far as the irrigation head-works were concerned was a thing which in his opinion was subject to modification from time to time.

He did not quite agree with what was laid down by Spring in his paper in regard to the length of bund in proportion to the bridge.

He said that last year he had an opportunity of being in camp with a junior officer of the Railway Department and discussed the question of training works with him after which he came to the conclusion that by knocking off a few spans with the economy effected one would be able to increase the length of the guide bank thus rendering it a more efficient bridge. The Chenab Bridge he said was started with 68 spans but was subsequently reduced to 17 by the Railway Department. In such cases he would always personally prefer to shorten the length of the bridge and increase the length of the guide banks, the question of afflux often raised was more of a bogey and did not hold in the case of a bridge in the alluvial plains.

MR. HADOW said, with reference to Mr. Batra's remark that the works should have been started some time in the beginning of September, he wished to point out that owing to unforeseen conditions it was in his opinion pure luck whether an early start was better than a late one. He started that on the Sutlej a record flood came down on the 24th of October one year, in which case it would have been of very little use to make an early start in September.

MR. DHAWAN in reply to the discussion said that as regards Mr. Batra's question regarding the angle of guide banks with the axis of the bridge being 97 instead of 90 degrees, he said that Mr. Varma had already touched upon this, and it was the present practice to build guide banks at 90.

With regard to Mr. Batra's questioning the utility of the temporary channel for diverting the river, and the statement that it would have been

cheaper to build the extension of the bund in the river itself using more pitching stone in it, he considered that Mr. Batra's system of construction would have been very much more expensive than the one adopted already.

Regarding a question raised about the reduced level of the top of the bund and as to how the breach occurred when the flood came, he said that the reduced level shown in plate 2 was the level of the old bund, and that it was breached by the water over topping it, and eroding the sand which was not protected by anything on the top.

Referring to Mr. Nicholson's statement that he could have solved the problem by shortening the bridge and increasing the length of the guide banks, he said that there was one drawback, *i. e.*, that the shortening of the bridge would result in a heavier afflux, thereby involving the Railway in possible claims for damage to villages and crops up-stream.