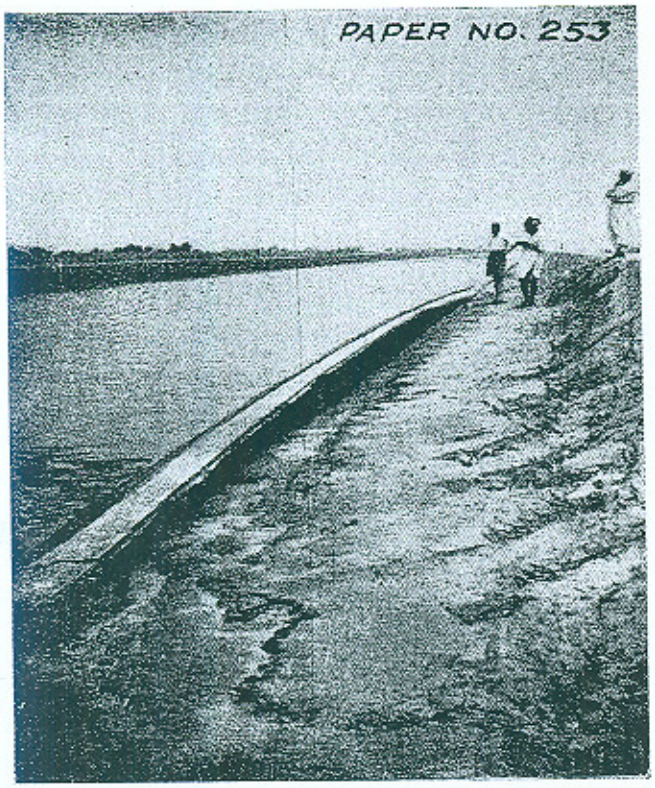
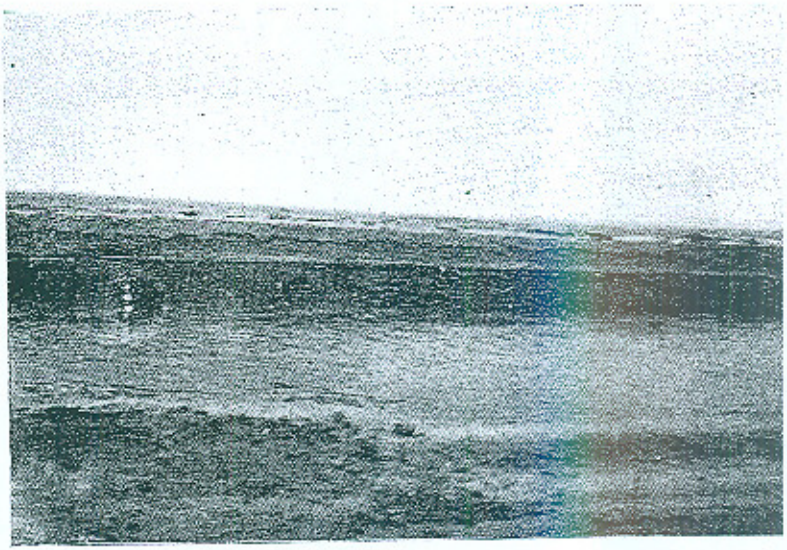
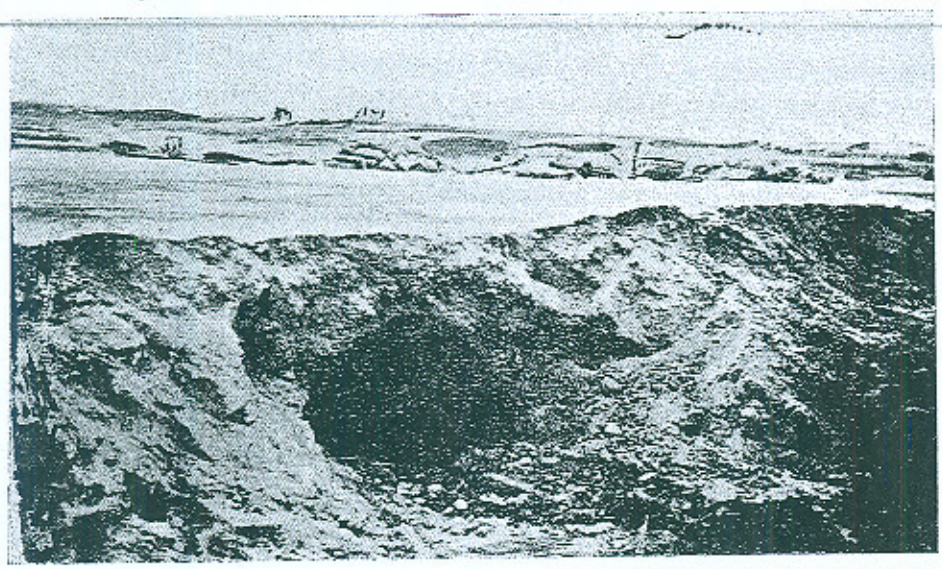


Good masonry standing inspite of cavity behind and a bulge.

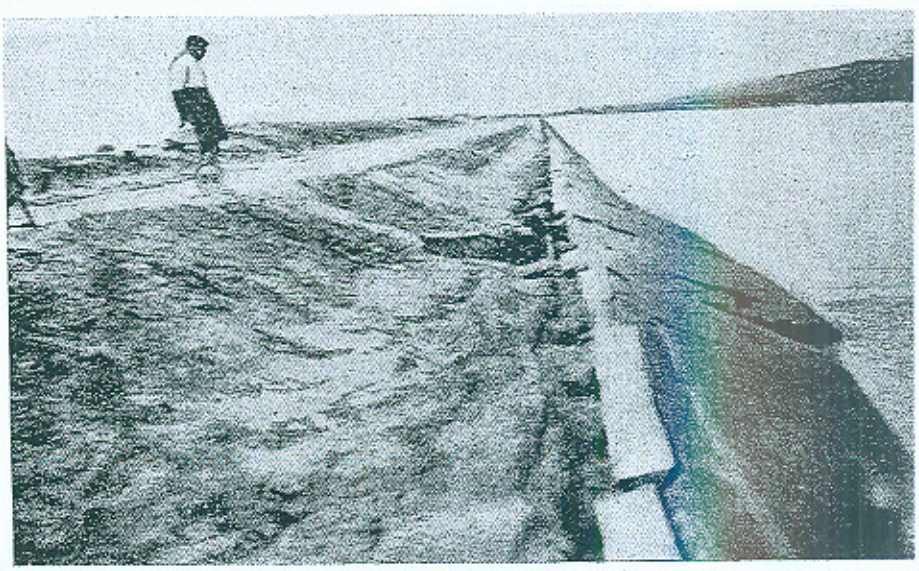


Note extent of marks of wave actio

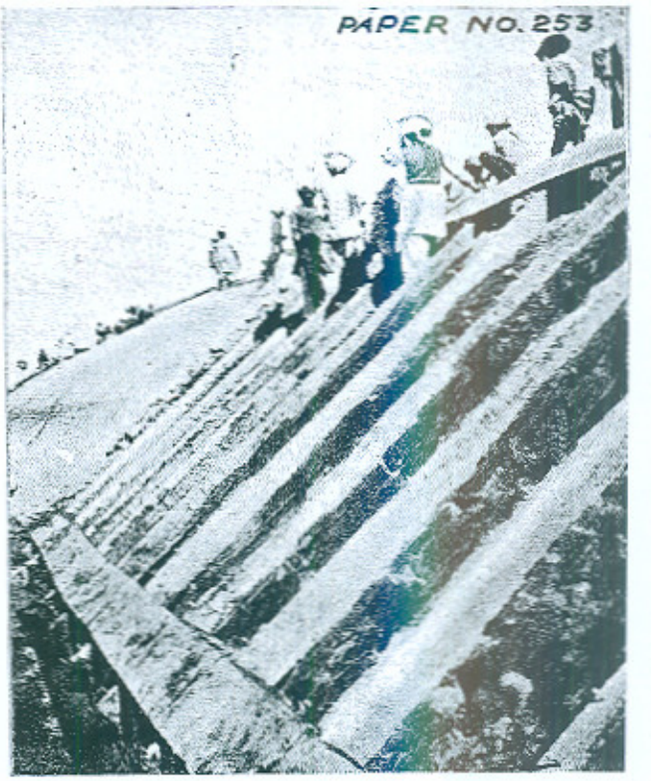


Top of bank arching a hollow at berm level.

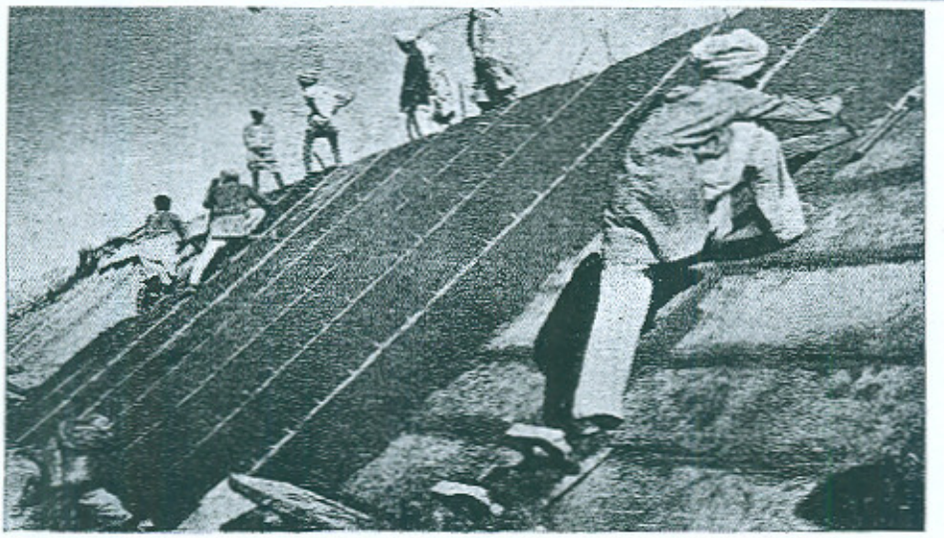
Damaged Lining. Note heavy slip in front of a ghara on berm.



DIFFERENT STAGES FOR SLAB AND BEAM TYPE

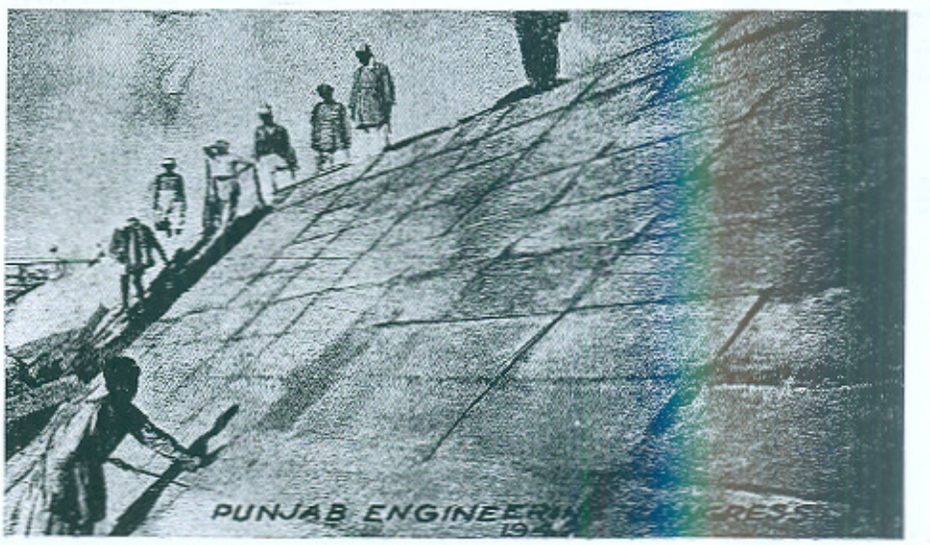


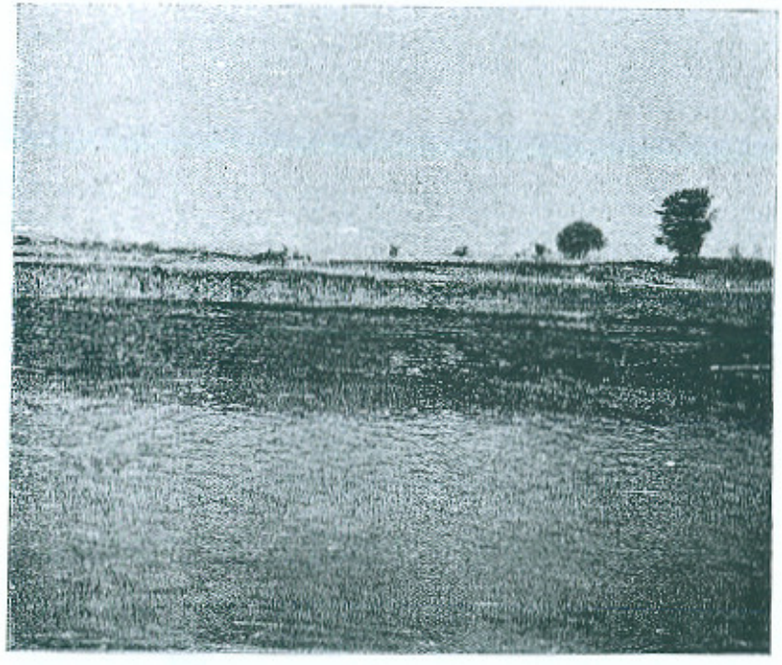
Laying, spacing and aligning beam.

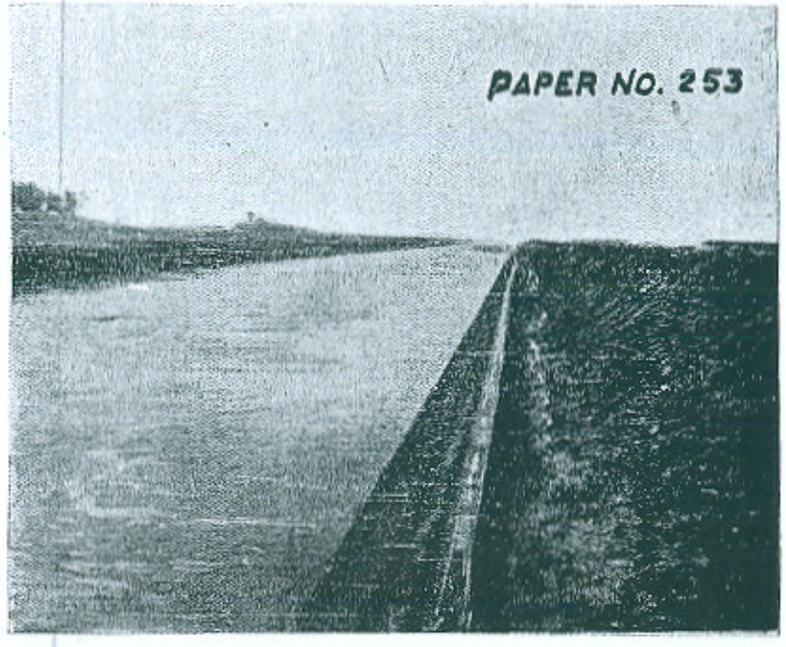


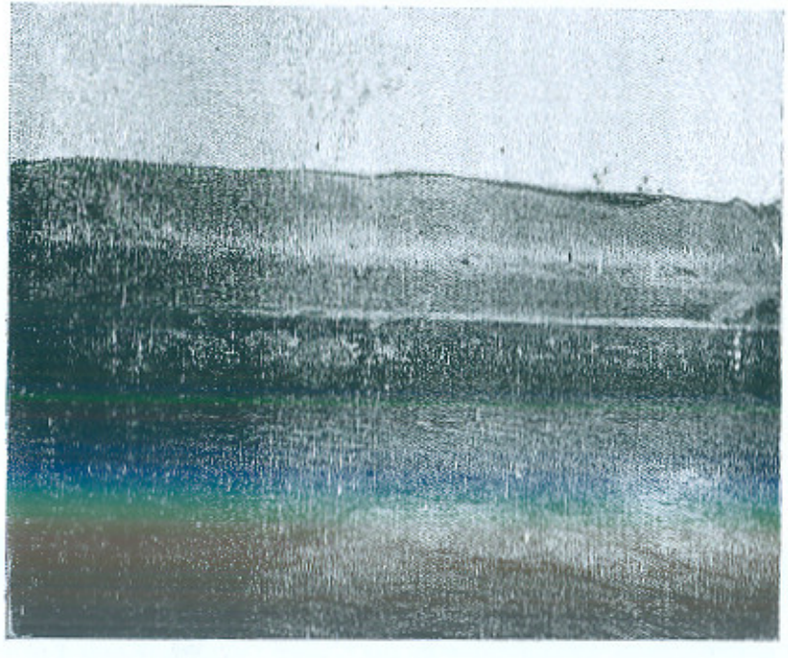
Space between beams puddled and slabs being bolted. Note bolts in beams and a precast block with perforated leg above.

The finished surface.



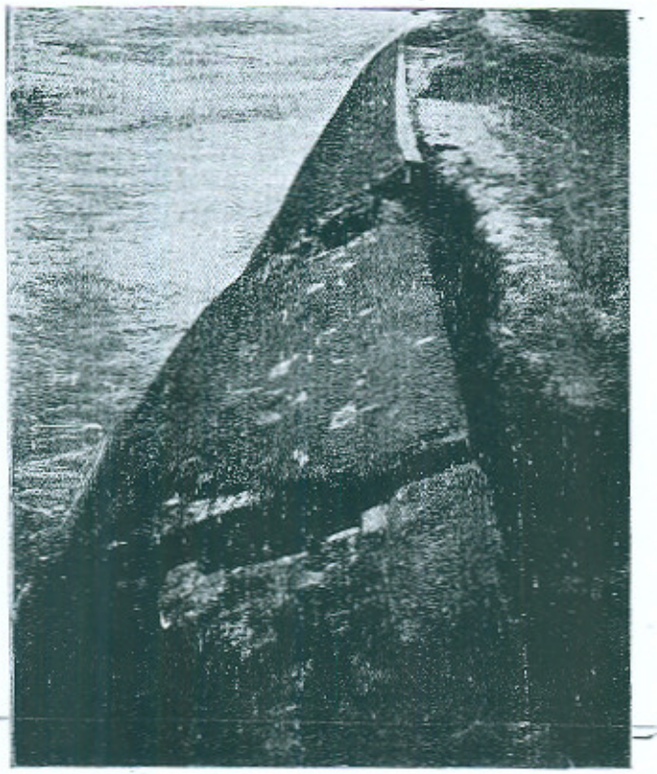


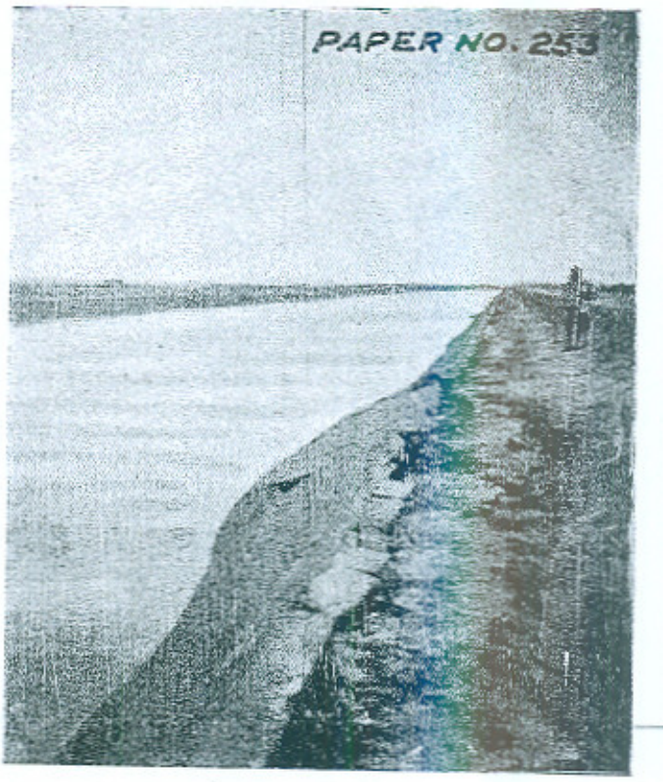




SHOWING EXTENT OF DAMAGE TO LINING

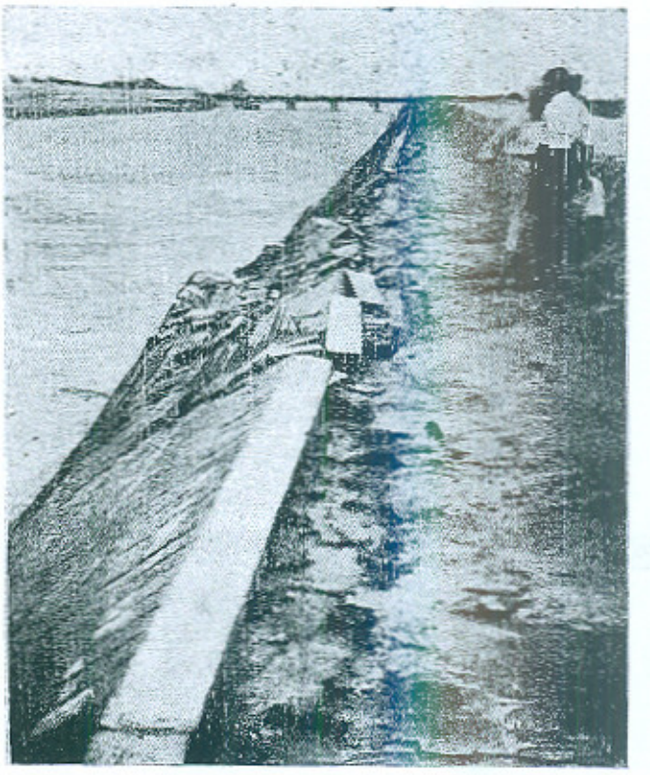
SHOWING NATURE OF DAMAGE TO LINING





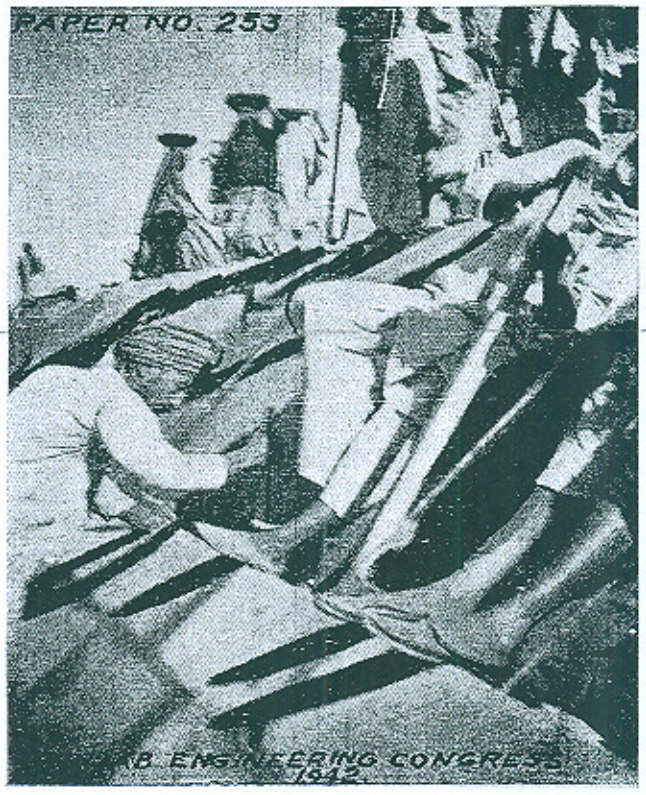
Note the drain cut behind the lining and marks of wave action.

Effect of profiles inspite of havoc by wave action.

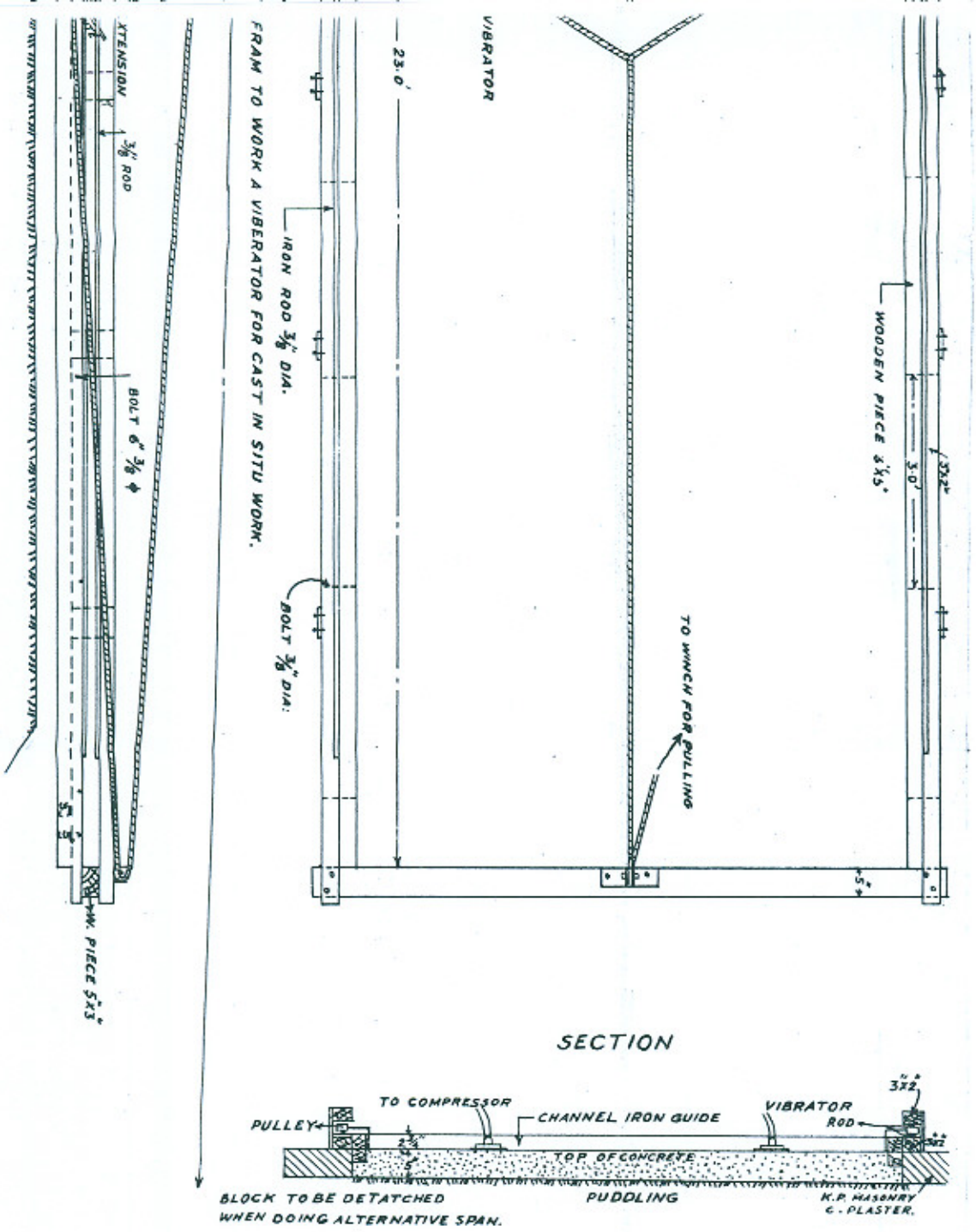


The lining crumbled and slipped.

FILLING CONCRETE BEHIND PRECAST BLOCKS

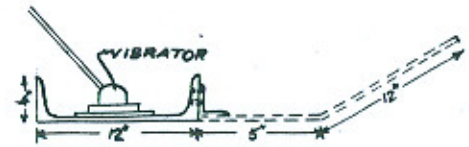


Note Coolies standing on blocks and resting on plastered slope, stuffing concrete behind.

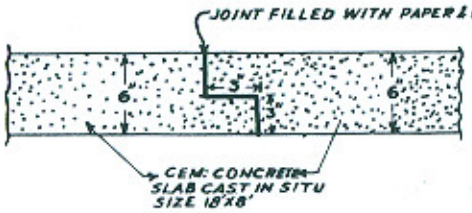

VIBRATOR
23.0'
XTENSION
3/8" ROD
IRON ROD 3/8" DIA.
BOLT 6" 3/8 ϕ
BOLT 3/8" DIA.
FRAM TO WORK A VIBERATOR FOR CAST IN SITU WORK.
WOODEN PIECE 5"x3"
3.0'
3"x2"
TO WINCH FOR PULLING
5"
W. PIECE 5"x3"

SECTION

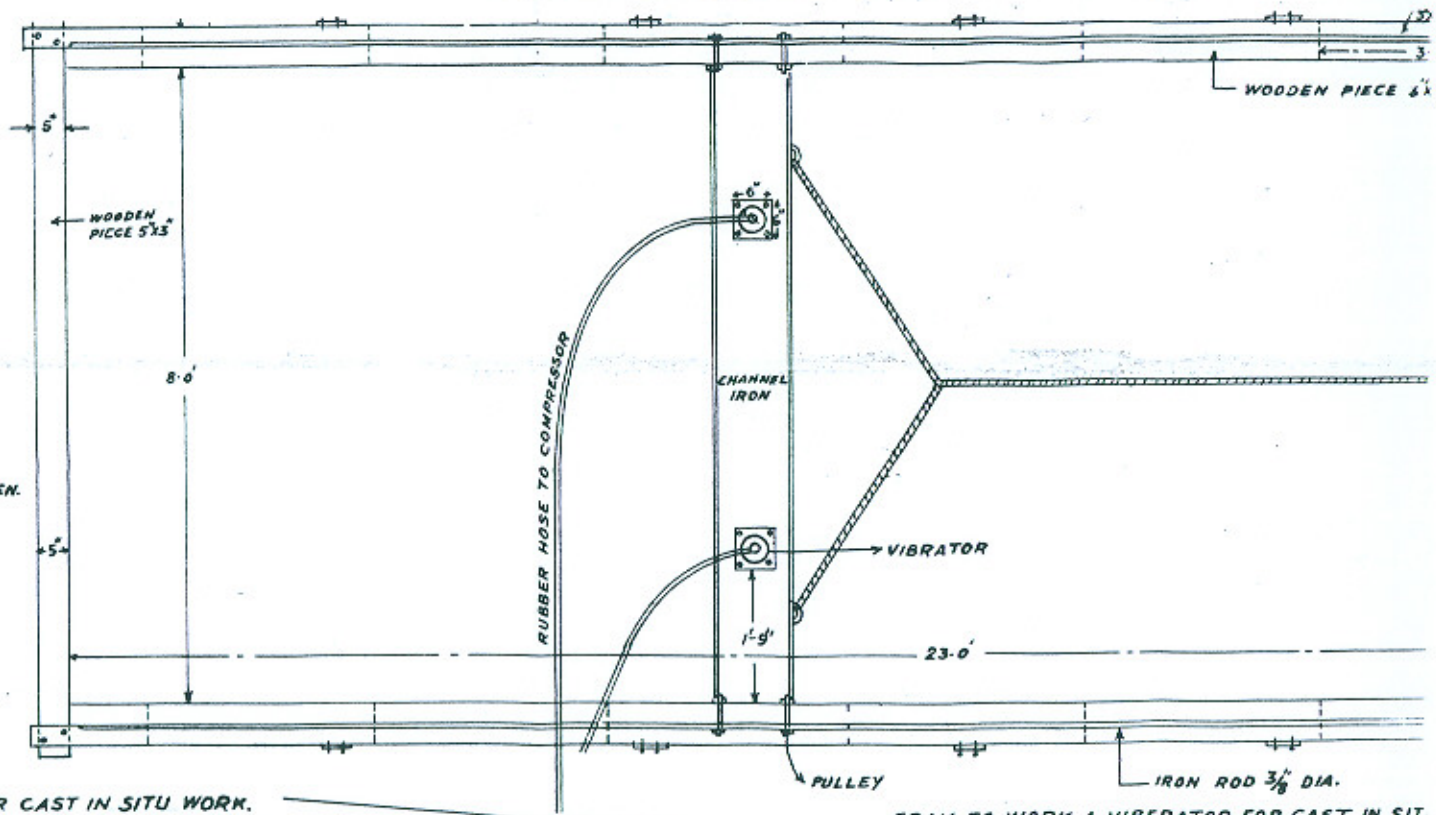
TO COMPRESSOR
CHANNEL IRON GUIDE
VIBRATOR
ROD
3"x2"
PULLEY
TOP OF CONCRETE
PUDDLING
K.P. MASONRY
C - PLASTER.
BLOCK TO BE DETATCHED
WHEN DOING ALTERNATIVE SPAN.



BOTTOMLESS CHUTE FIXED WITH CHANNEL IRON.
PROPOSED ADDITION IN DOTTED

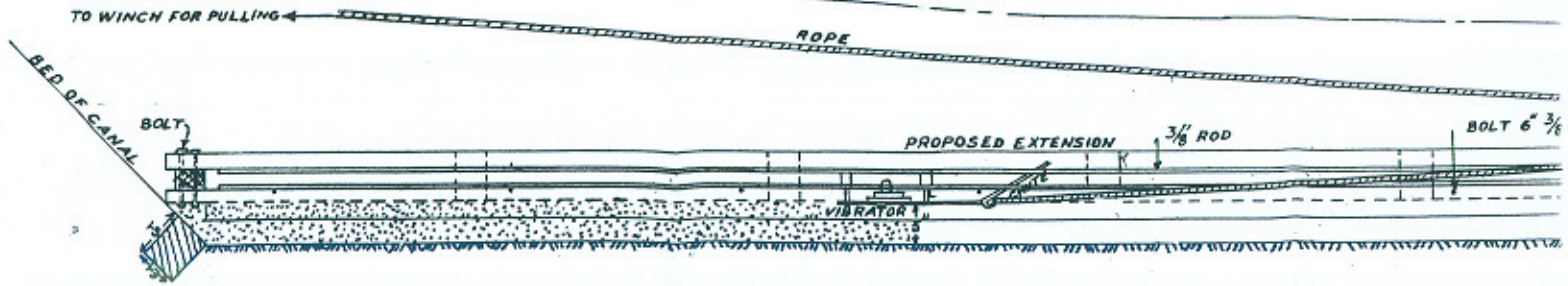


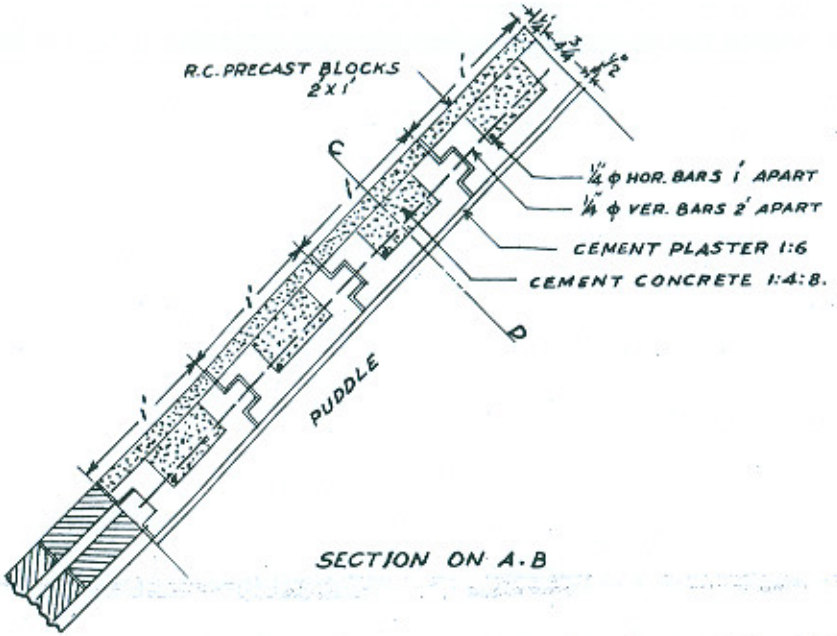
DETAIL OF JOINT



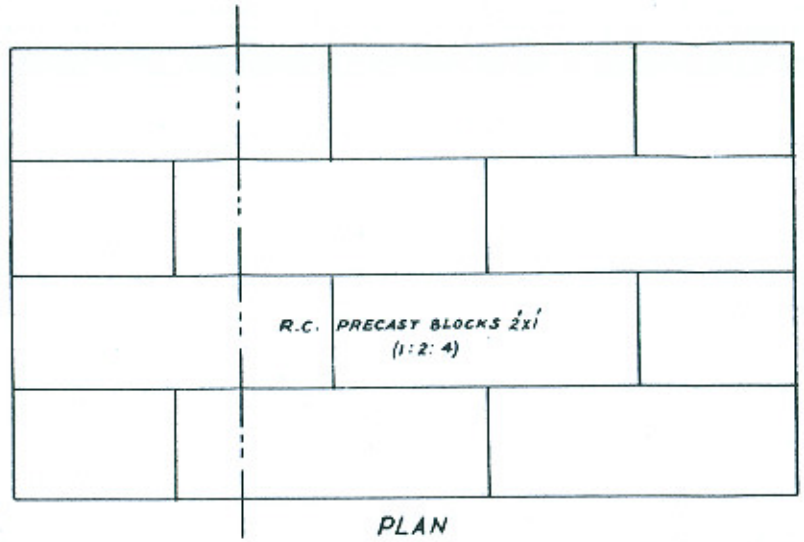
DETAILS FOR CAST IN SITU WORK.

FRAM TO WORK A VIBERATOR FOR CAST IN SIT

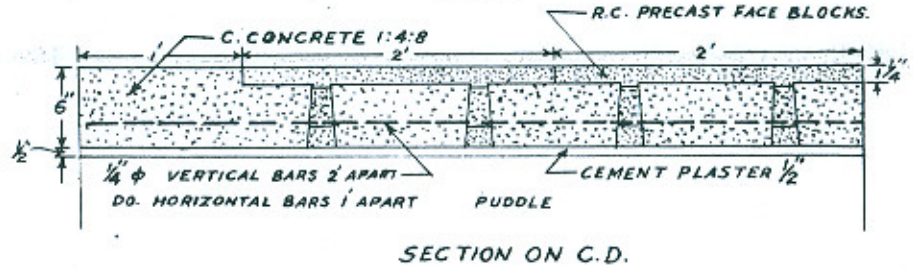




SECTION ON A.B



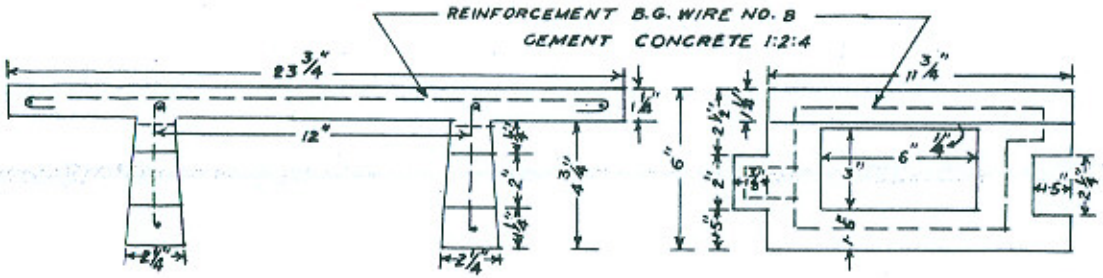
PLAN



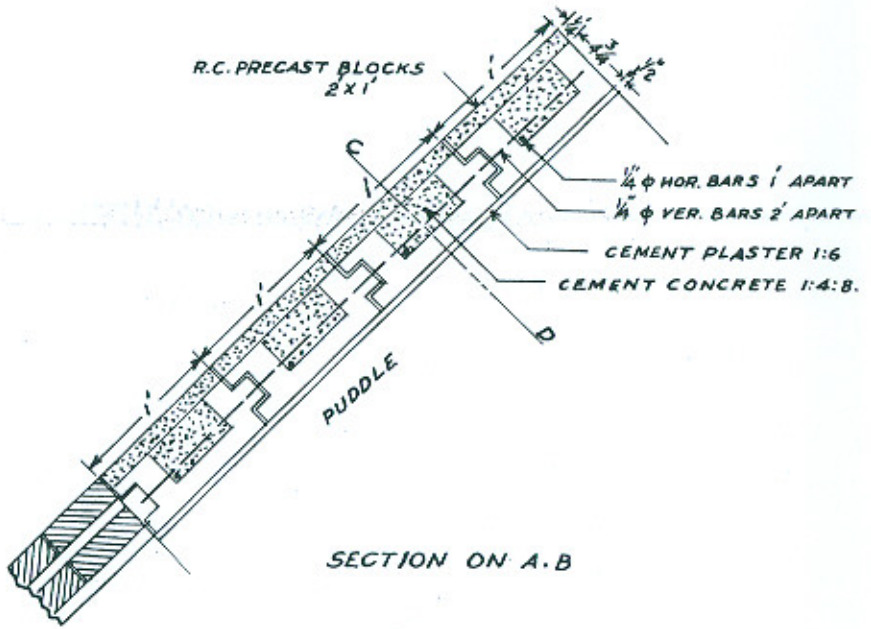
SECTION ON C.D.

REPAIRS TO DAMAGED LINING OF HAVELI CANAL IN PRECAST BLOCKS.

SCALE 1/10.



DETAIL OF PRECAST - BLOCK.
SCALE 1/5

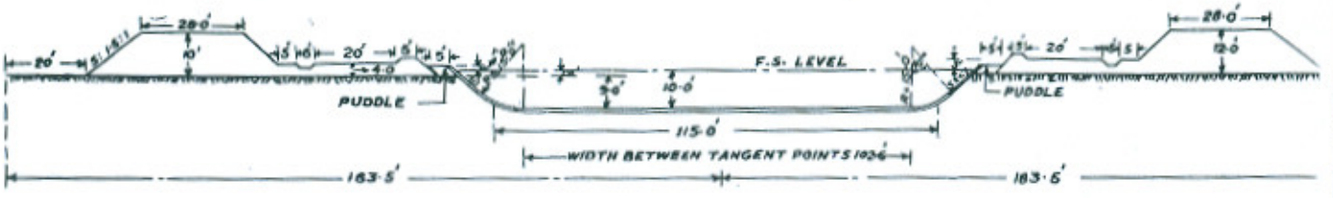


SECTION ON A.B

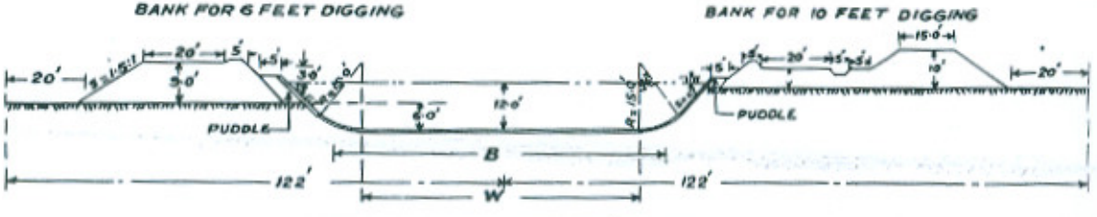
REPAIRS TO DAMAGED LINING OF HAVELI CANAL IN PRECAST BLOCKS.
SCALE 1/10.

SECTION FOR 10 FEET DEPTH WITH 9 FEET DIGGING

LINING A

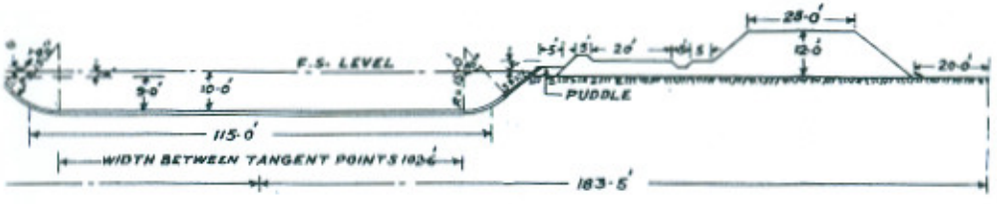


SECTION FOR 12 FEET DEPTH

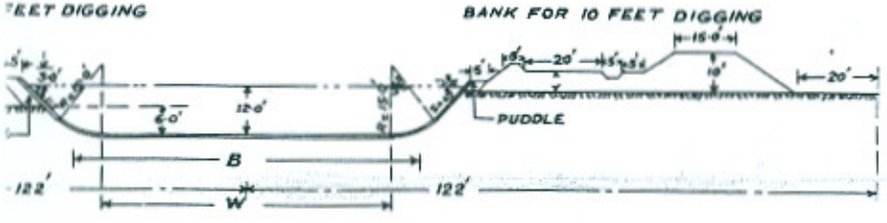


FROM R.D.	TO R.D	TRAPEZOIDAL BED WIDTH (B)	WIDTH BETWEEN T.P.s (W)	DEPTH
2000	20000	115 FEET	102·6 FEET	10'
20000	63000	84 -00-	71·6 FEET	
63000	130600	75 -00-	62·6 -00-	
130600	168313	72 -00-	59·6 -00-	12'
168313	227800	71 -00-	58·6 -00-	

TION FOR 10 FEET DEPTH WITH 9 FEET DIGGING



SECTION FOR 12 FEET DEPTH

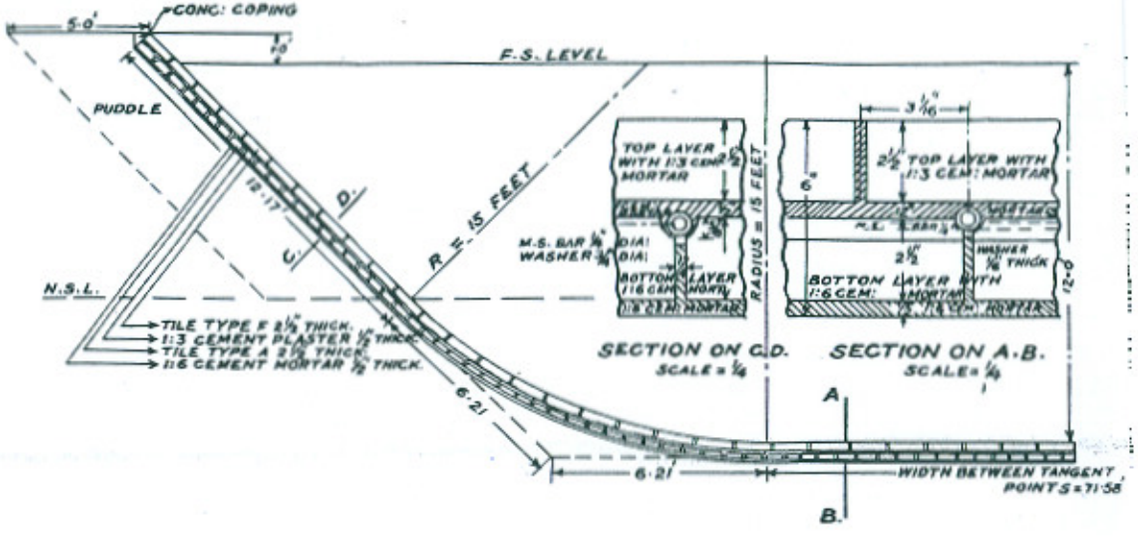


FROM R.D.	TO R.D	TRAPEZOIDAL BED WIDTH (B)	WIDTH BETWEEN TANGENT POINTS (W)	DEPTH
2000	20000	115 FEET	102-6 FEET	10'
20000	63000	84 -00-	71-6 FEET	
63000	130600	75 -00-	62-6 -00-	
130600	168313	72 -00-	59-6 -00-	12'
168313	227800	71 -00-	58-6 -00-	

LINING AS CONSTRUCTED

CROSS SECTION WITH 12 FEET DEPTH

SCALE = 1/50



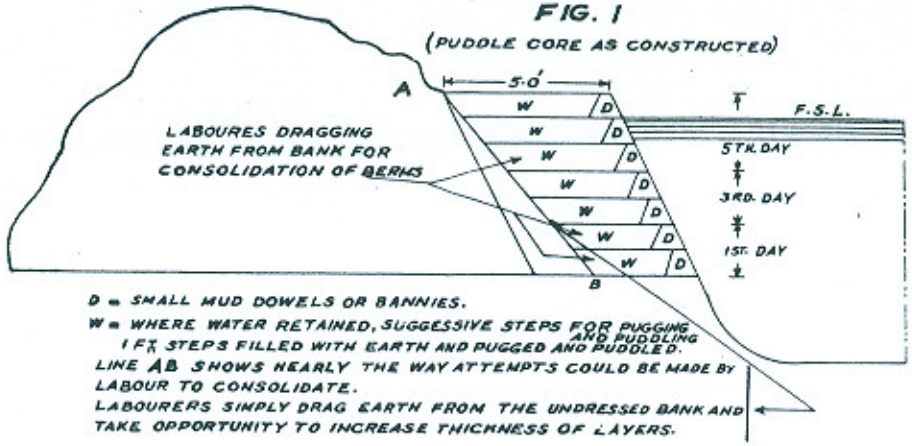
SECTION ON C.D. SCALE = 1/4

SECTION ON A.B. SCALE = 1/4

PUNJAB ENGINEERING CONGRESS
1942

FIG. 1

(PUDDLE CORE AS CONSTRUCTED)



D = SMALL MUD DOWELS OR BANNIES.
W = WHERE WATER RETAINED, SUGGESSIVE STEPS FOR PUGGING AND PUDDLING
1 FT STEPS FILLED WITH EARTH AND PUGGED AND PUDDLED.
LINE AB SHOWS NEARLY THE WAY ATTEMPTS COULD BE MADE BY LABOUR TO CONSOLIDATE.
LABOURERS SIMPLY DRAG EARTH FROM THE UNDRESSED BANK AND TAKE OPPORTUNITY TO INCREASE THICKNESS OF LAYERS.

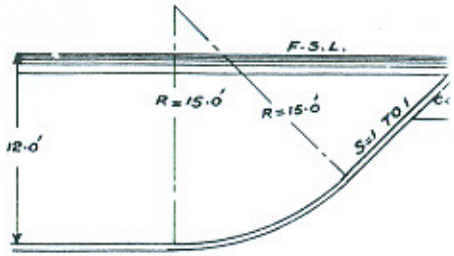
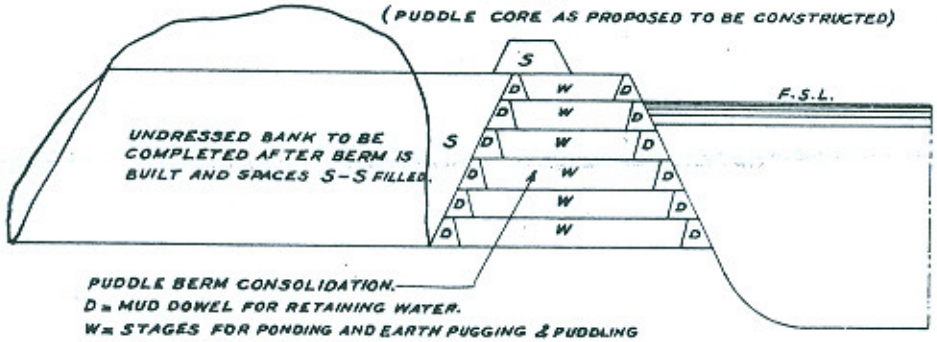


FIG. 2

(PUDDLE CORE AS PROPOSED TO BE CONSTRUCTED)



D = MUD DOWEL FOR RETAINING WATER.
W = STAGES FOR PONDING AND EARTH PUGGING & PUDDLING
S = SPACE TO BE FILLED AFTER PUDDLE PROFILES ARE READY.
INTO A COMPLETED CONSOLIDATION.

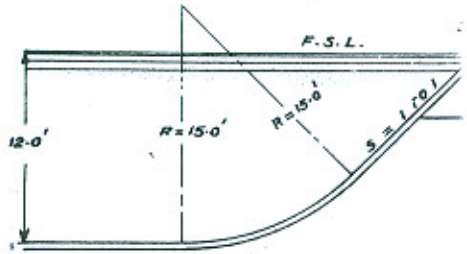
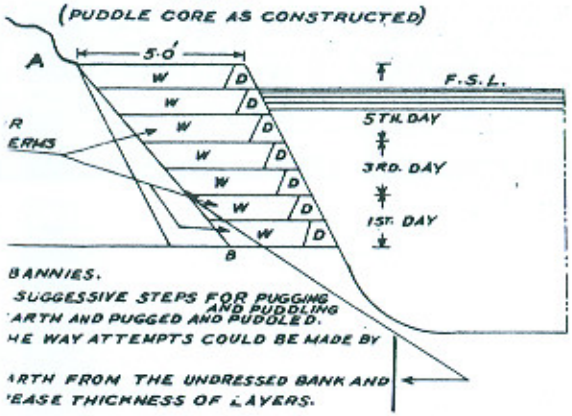


FIG. 1

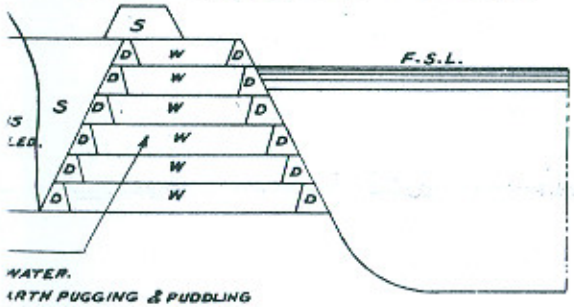
(PUDDLE CORE AS CONSTRUCTED)



BANNIES.
SUGGESSIVE STEPS FOR PUGGING AND PUDDLING
ARTH AND PUGGED AND PUDDLED.
HE WAY ATTEMPTS COULD BE MADE BY
ARTH FROM THE UNDRESSED BANK AND
EASE THICKNESS OF LAYERS.

FIG. 2

PUDDLE CORE AS PROPOSED TO BE CONSTRUCTED)

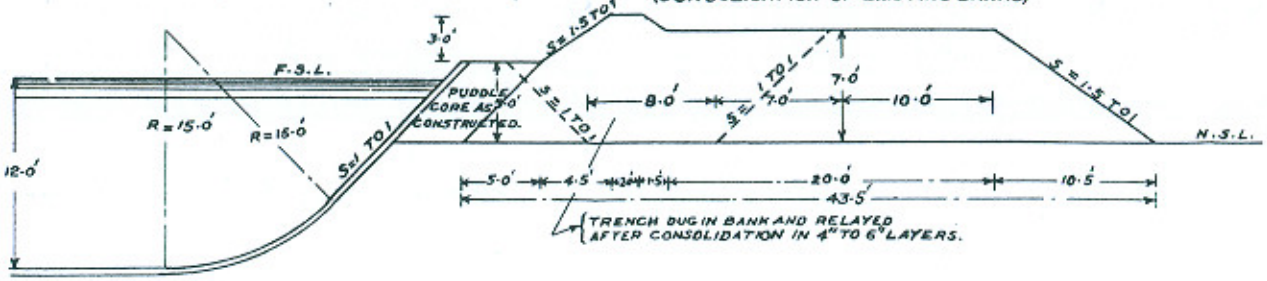


WATER.
ARTH PUGGING & PUDDLING
ER PUDDLE PROFILES ARE READY.
OLIDATION.

FIG. 3

SCALE 1/100

(CONSOLIDATION OF EXISTING BANKS)

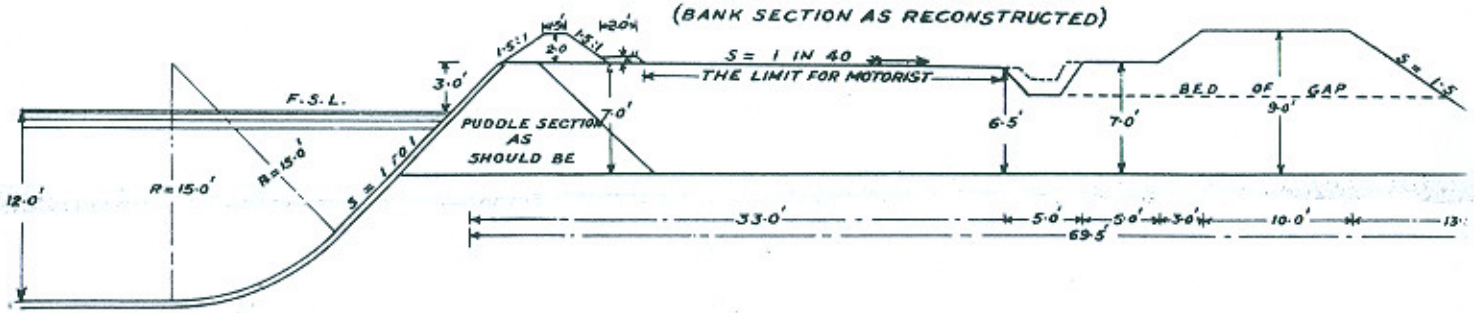


TRENCH DUG IN BANK AND RELAYED AFTER CONSOLIDATION IN 4" TO 6" LAYERS.

FIG. 4

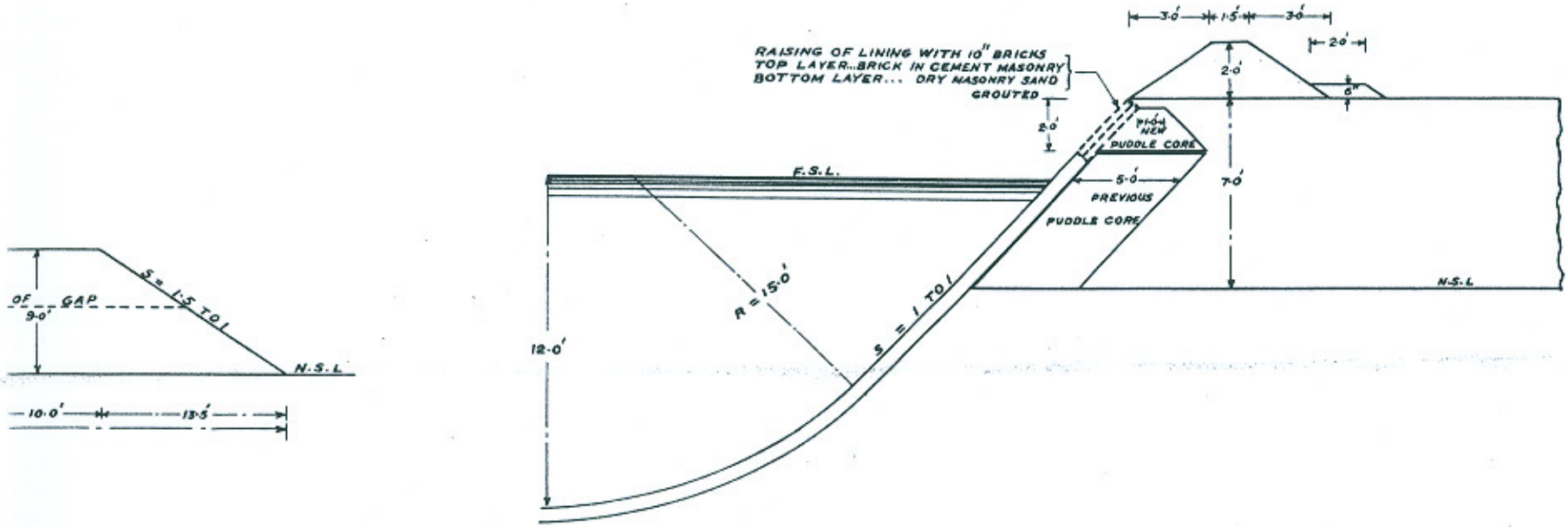
SCALE 1/100

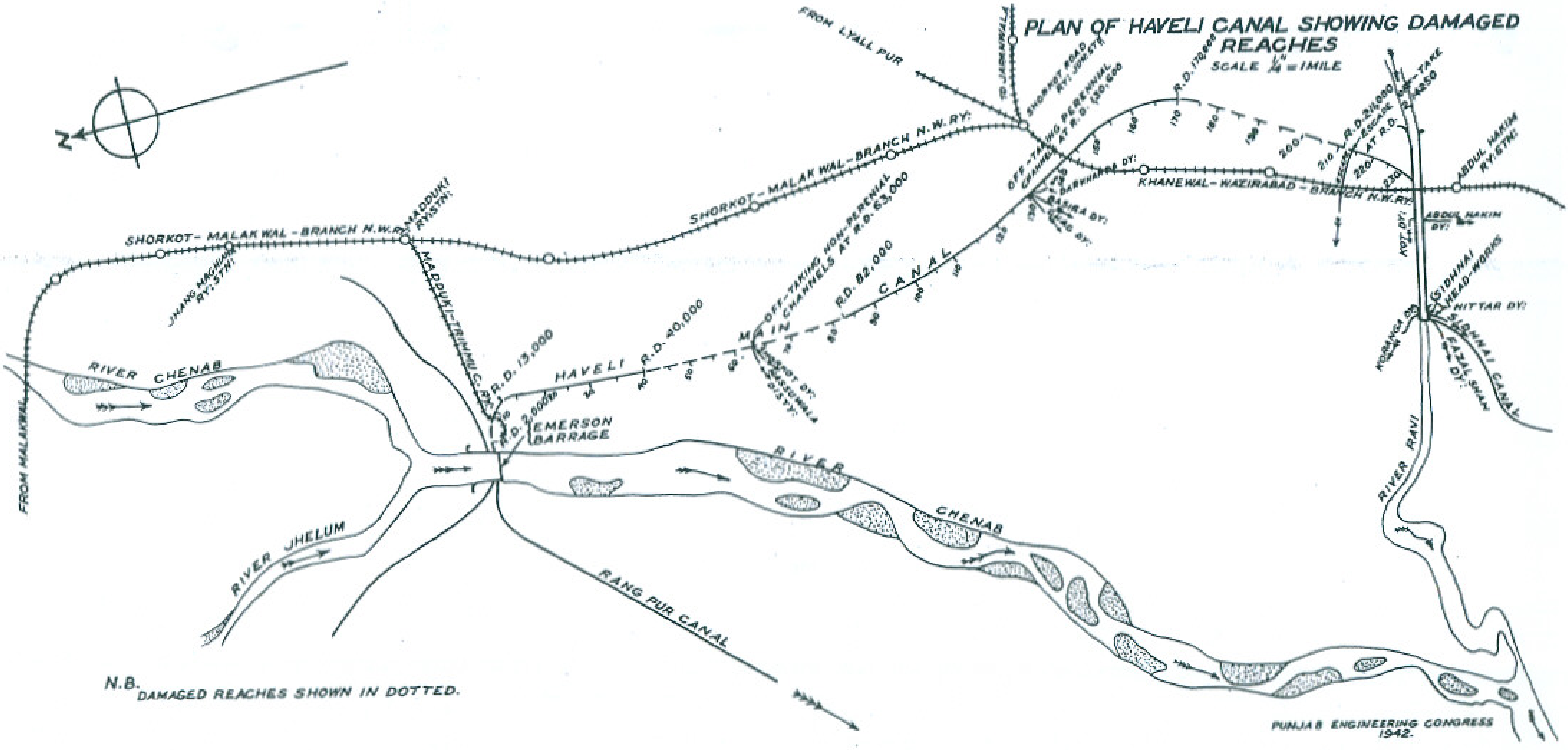
(BANK SECTION AS RECONSTRUCTED)



L.

FIG. 5
SCALE 1/50

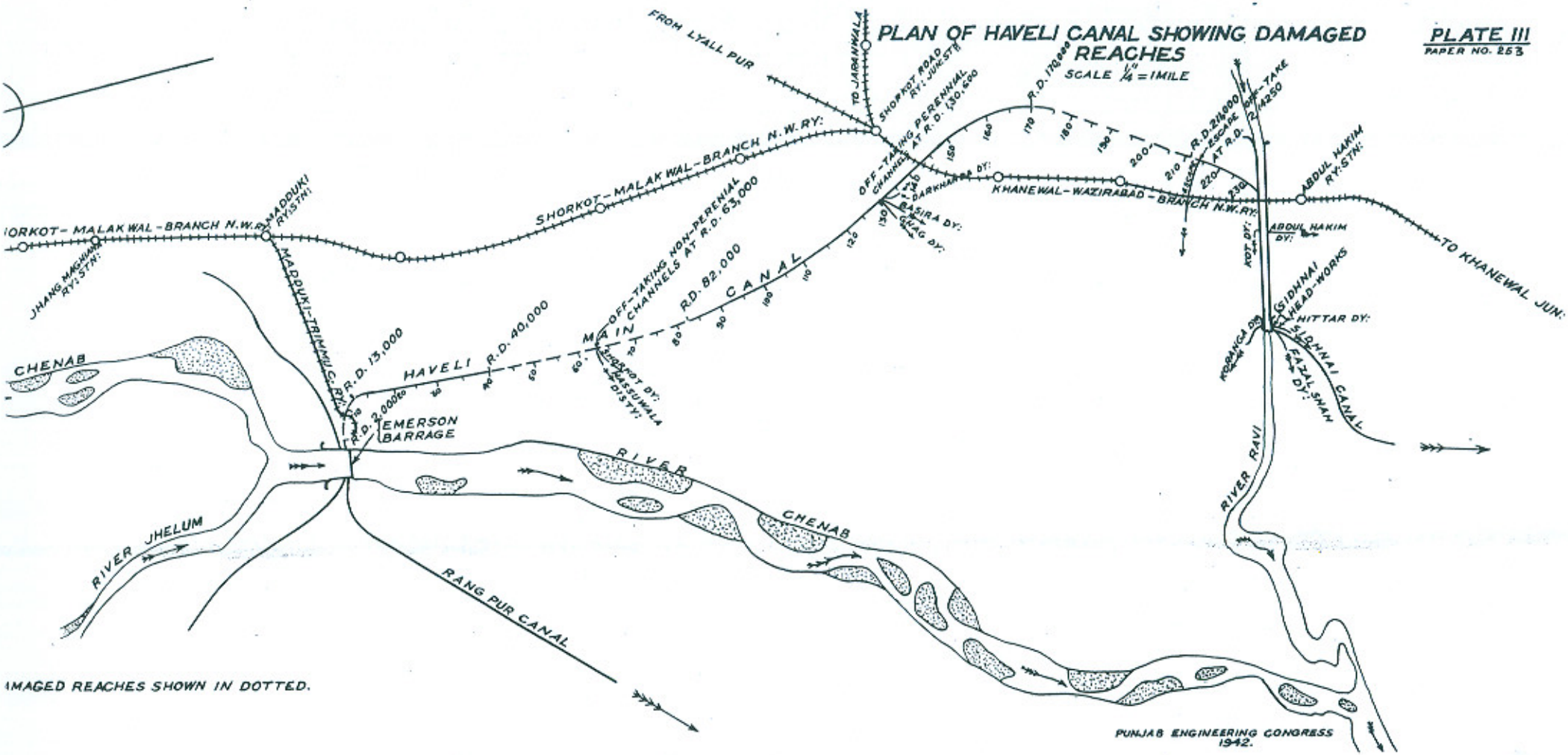



PLAN OF HAVELI CANAL SHOWING DAMAGED REACHES
SCALE 1/4" = 1 MILE
N
FROM MALAKWAL
SHORKOT-MALAKWAL-BRANCH N.W.RY.
JHANG MAGHIANA RY: STN:
MADDUKI RY: STN:
MADDUKI-TRIMMU C. RY.
FROM LYALL PUR
TO JARANWALA
SHORKOT ROAD RY: JUN: STN:
KHANEWAL-WAZIRABAD-BRANCH N.W.RY.
ABDUL HAKIM RY: STN:
RIVER CHENAB
RIVER JHELUM
EMERSON BARRAGE
R.D. 2,000
R.D. 13,000
HAVELI
R.D. 40,000
MAIN
OFF-TAKING NON-PERENNIAL CHANNELS AT R.D. 63,000
R.D. 82,000
CANAL
OFF-TAKING PERENNIAL CHANNELS AT R.D. 130,600
R.D. 170,000
R.D. 211,000
R.D. 2,4250
KOT DY:
ABDUL HAKIM DY:
SIDHNAI HEAD-WORKS
HITTAR DY:
SIDHNAI CANAL
FAZAL SHAH DY:
KORANGA DY:
RIVER RAVI
RIVER CHENAB
RANG PUR CANAL
N.B. DAMAGED REACHES SHOWN IN DOTTED.
PUNJAB ENGINEERING CONGRESS 1942.

PLAN OF HAVELI CANAL SHOWING DAMAGED REACHES

PLATE III
PAPER NO. 253

SCALE 1/4 = 1 MILE



IMAGED REACHES SHOWN IN DOTTED.

PUNJAB ENGINEERING CONGRESS
1942.

MODIFIED SECTIONS TO ELIMINATE DISADVANTAGES OF CURVED SECTIONS.

FIG. 1

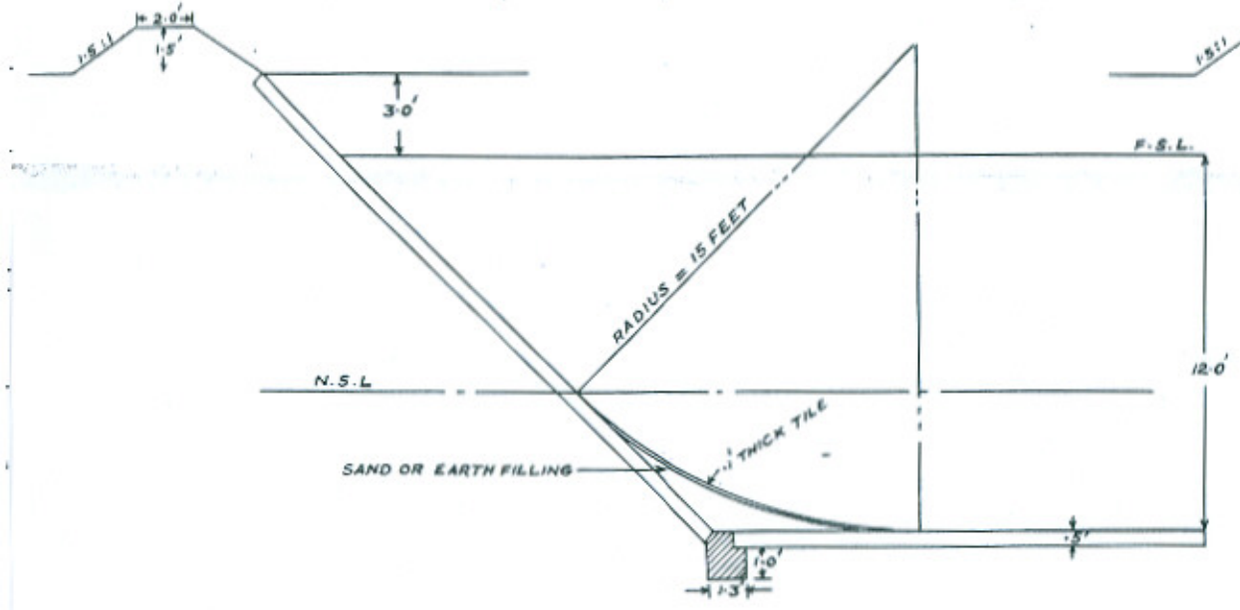
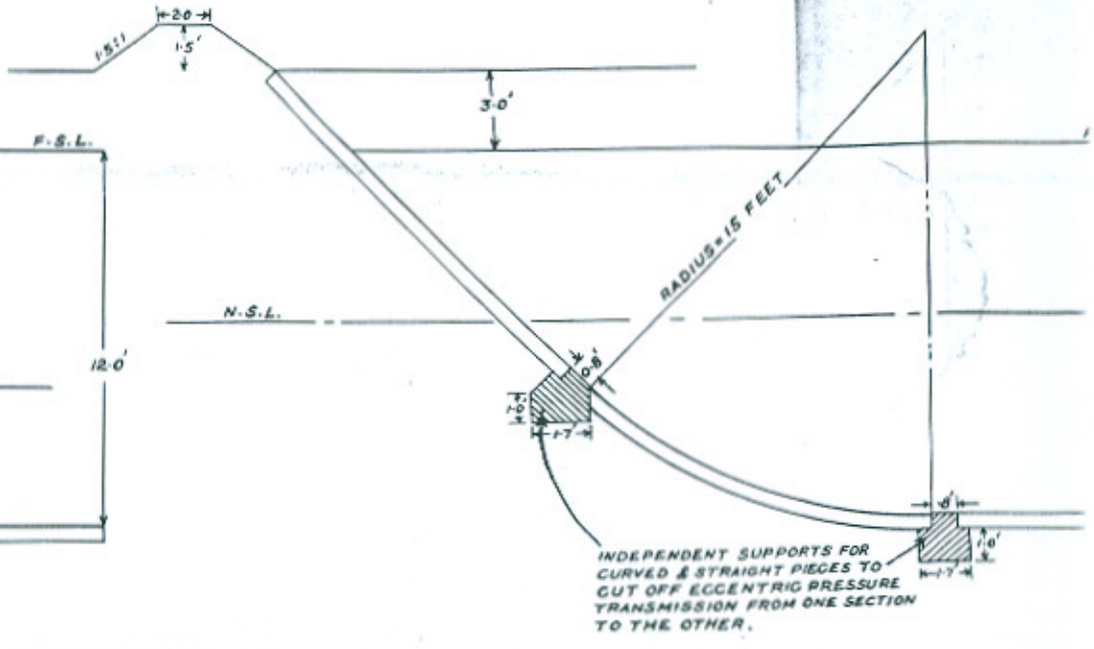


FIG. 2



MODIFIED SECTIONS TO ELIMINATE DISADVANTAGES OF CURVED SECTIONS.

FIG. 1

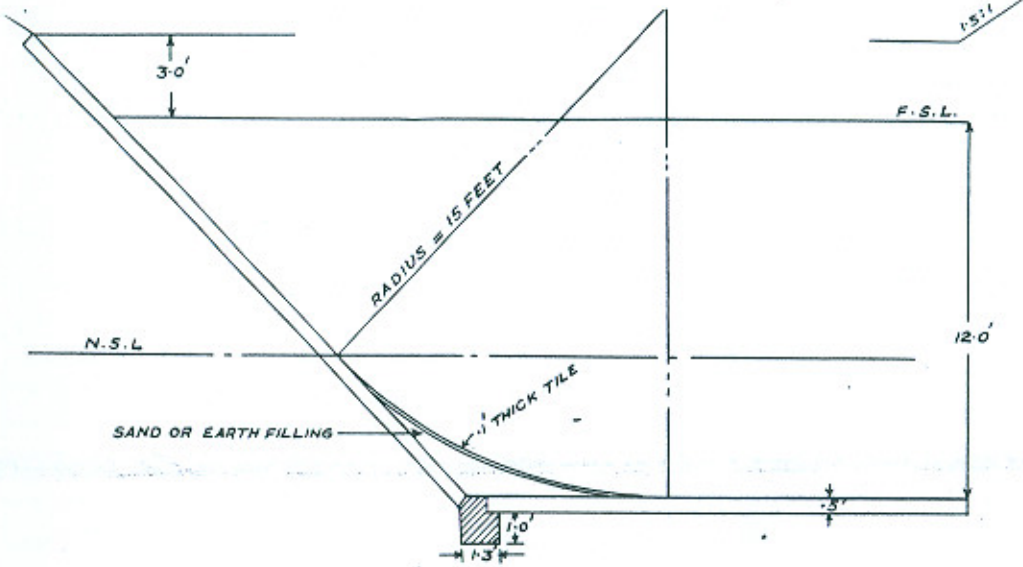


FIG. 2

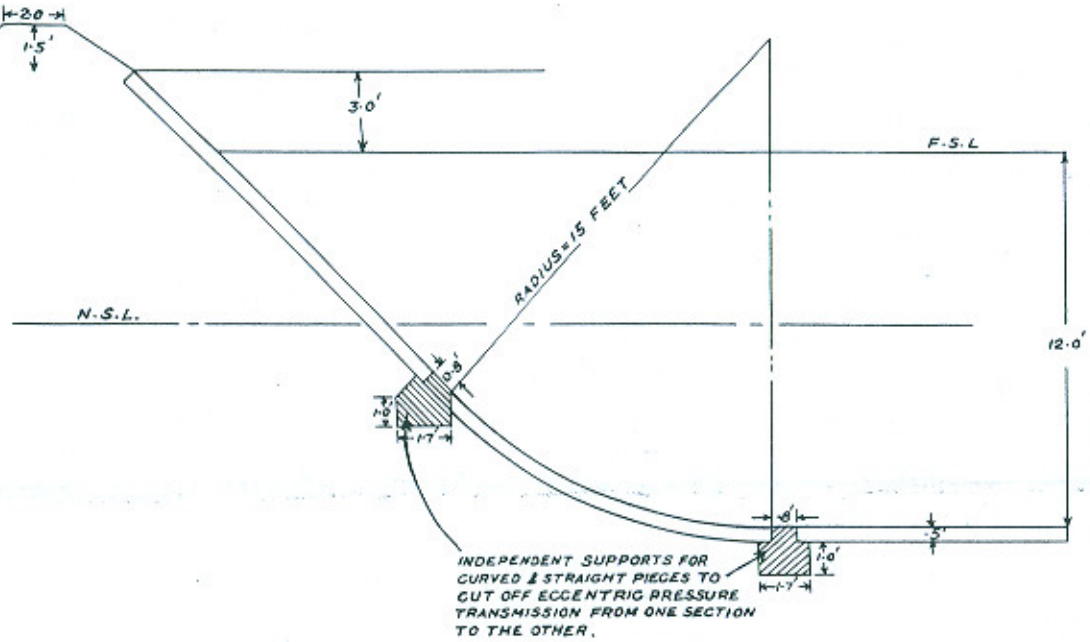
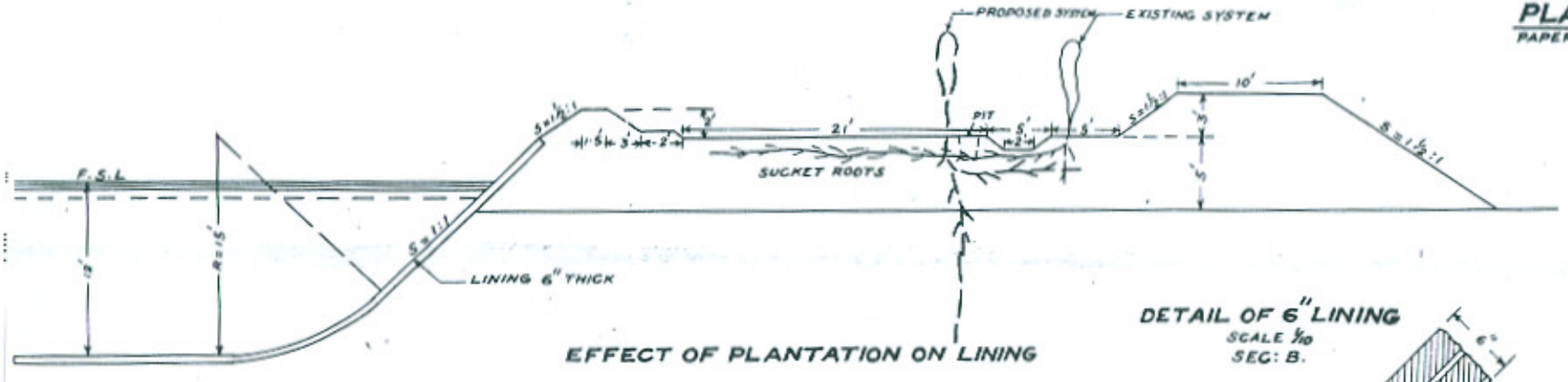
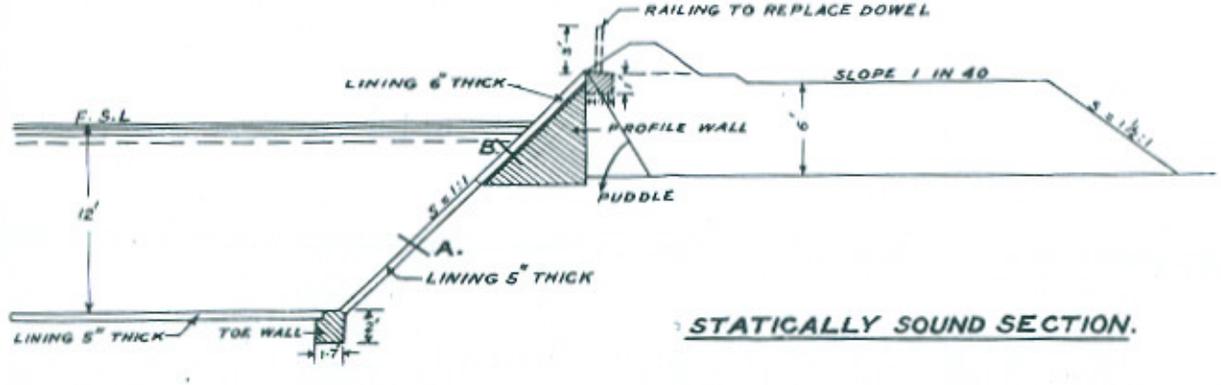


PLATE VI

PAPER NO. 253

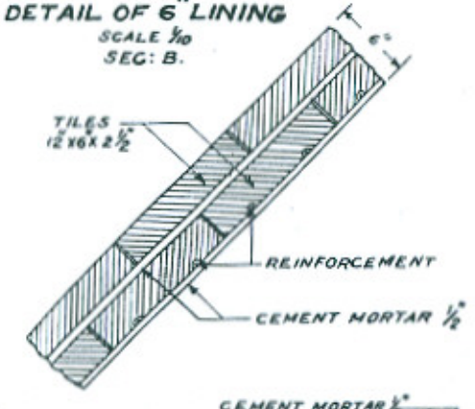


EFFECT OF PLANTATION ON LINING

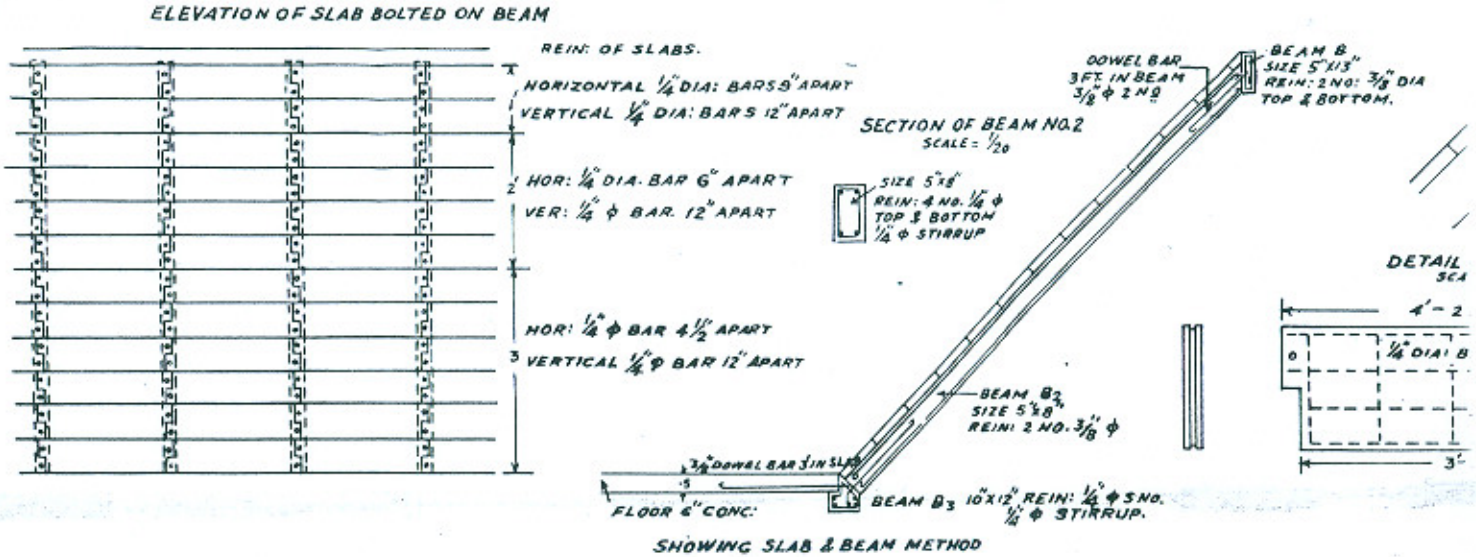


STATICALLY SOUND SECTION.

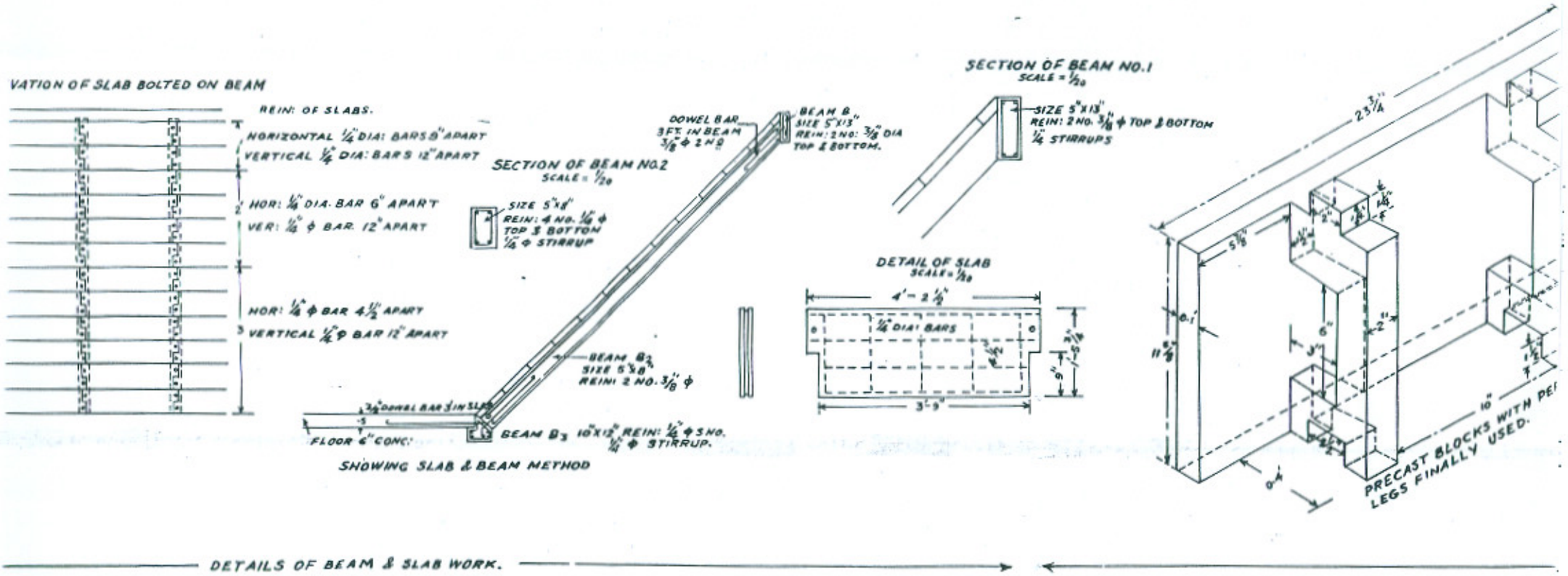
DETAIL OF 6" LINING
SCALE 1/10
SEC: B.



DETAIL OF 5" LINING.
SCALE 1/10
SEC. A.



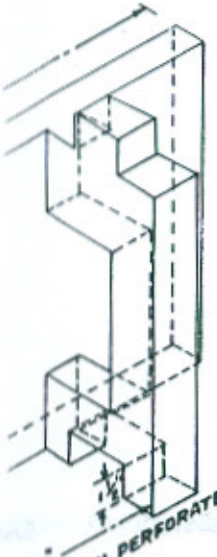
DETAILS OF BEAM & SLAB WORK.



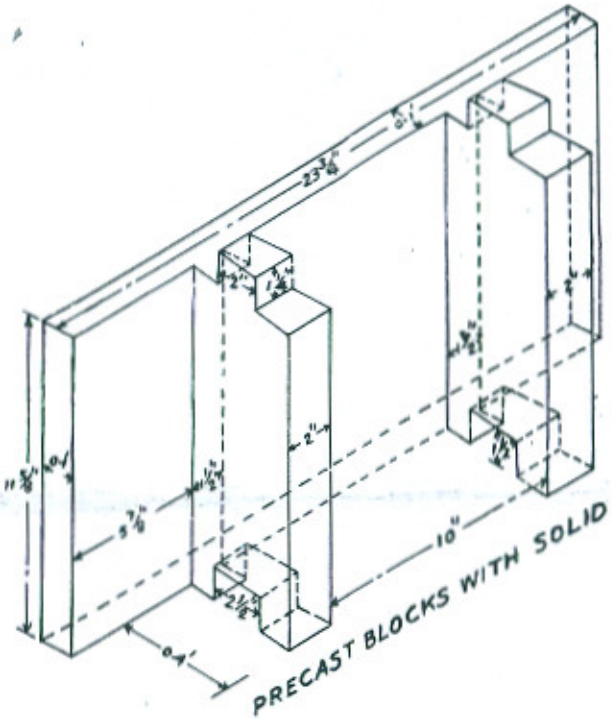
DETAILS OF BEAM & SLAB WORK.

PLATE V

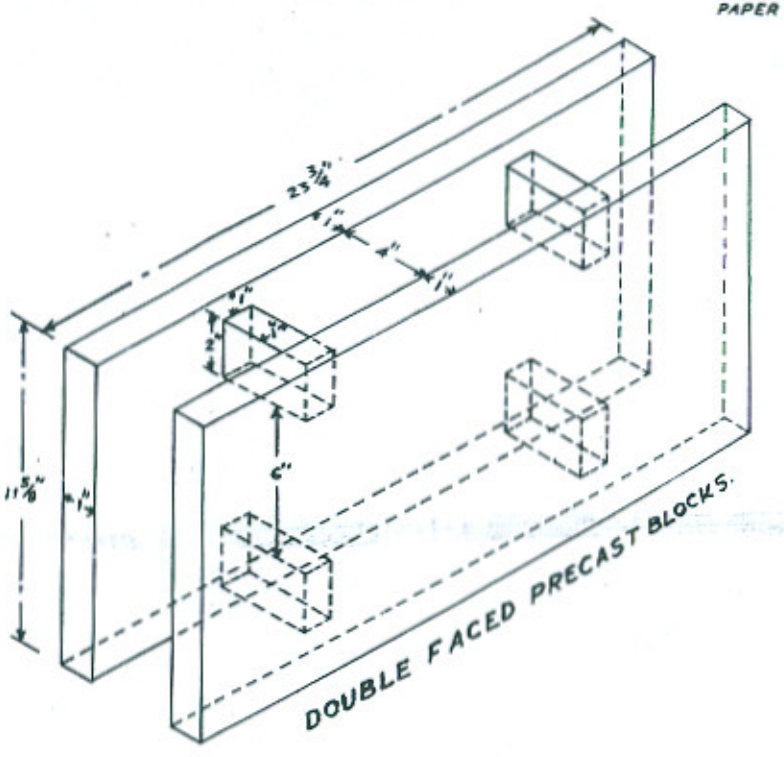
PAPER NO. 253.



CKS WITH PERFORATED
LY USED.



PRECAST BLOCKS WITH SOLID LEGS.



DOUBLE FACED PRECAST BLOCKS.

TYPES OF PRECAST BLOCKS.

PUNJAB ENGINEERING CONGRESS
1942.

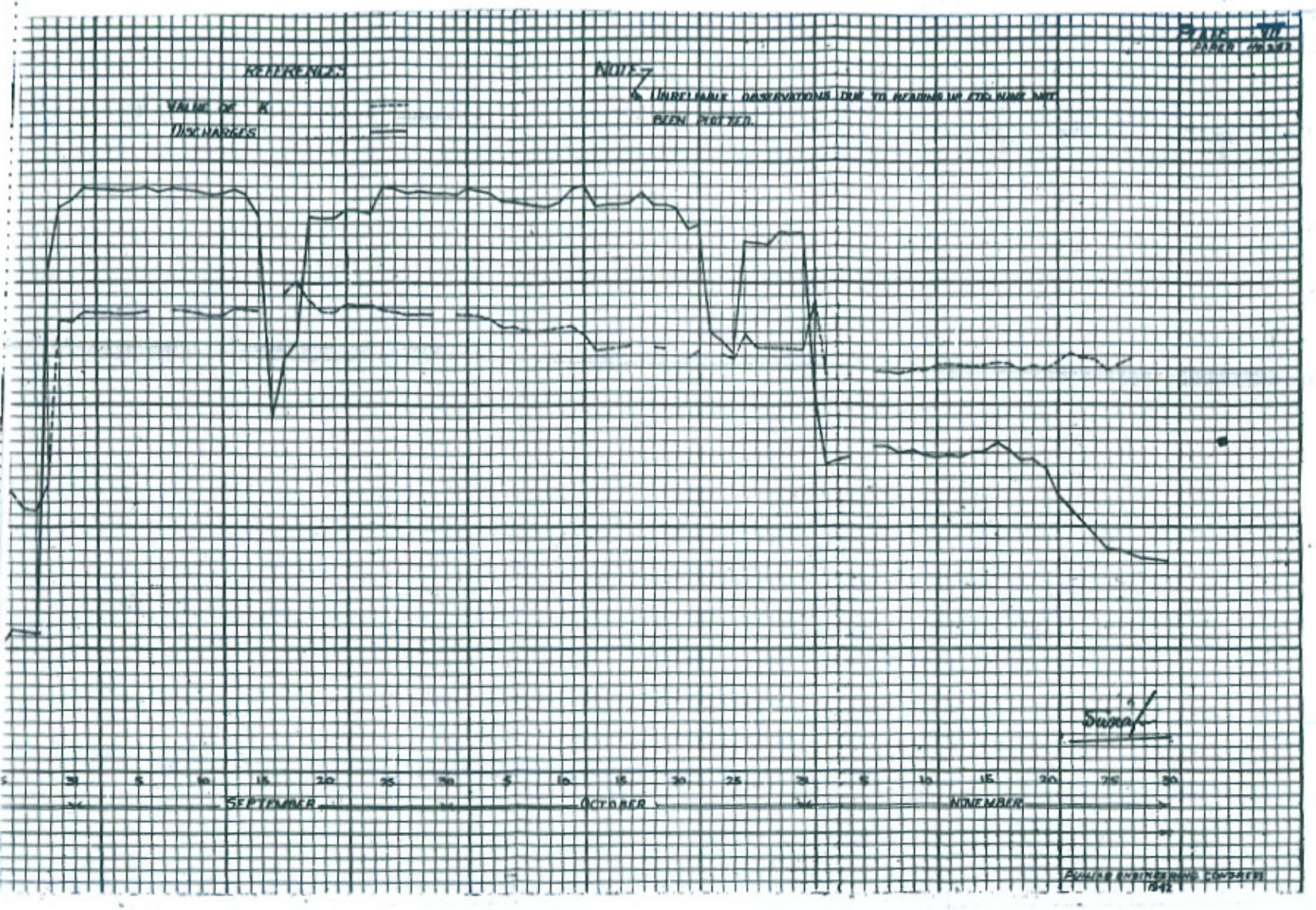
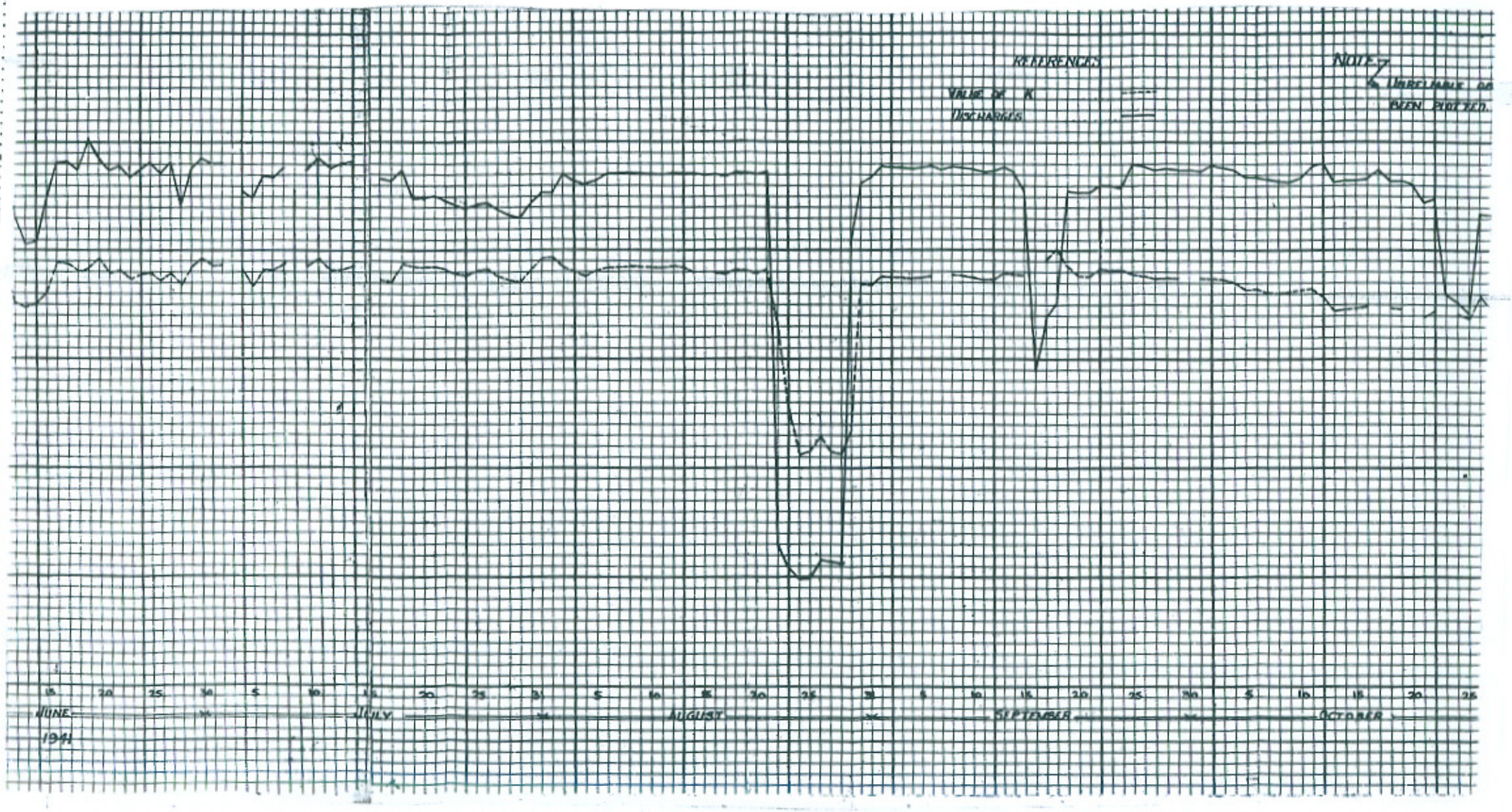
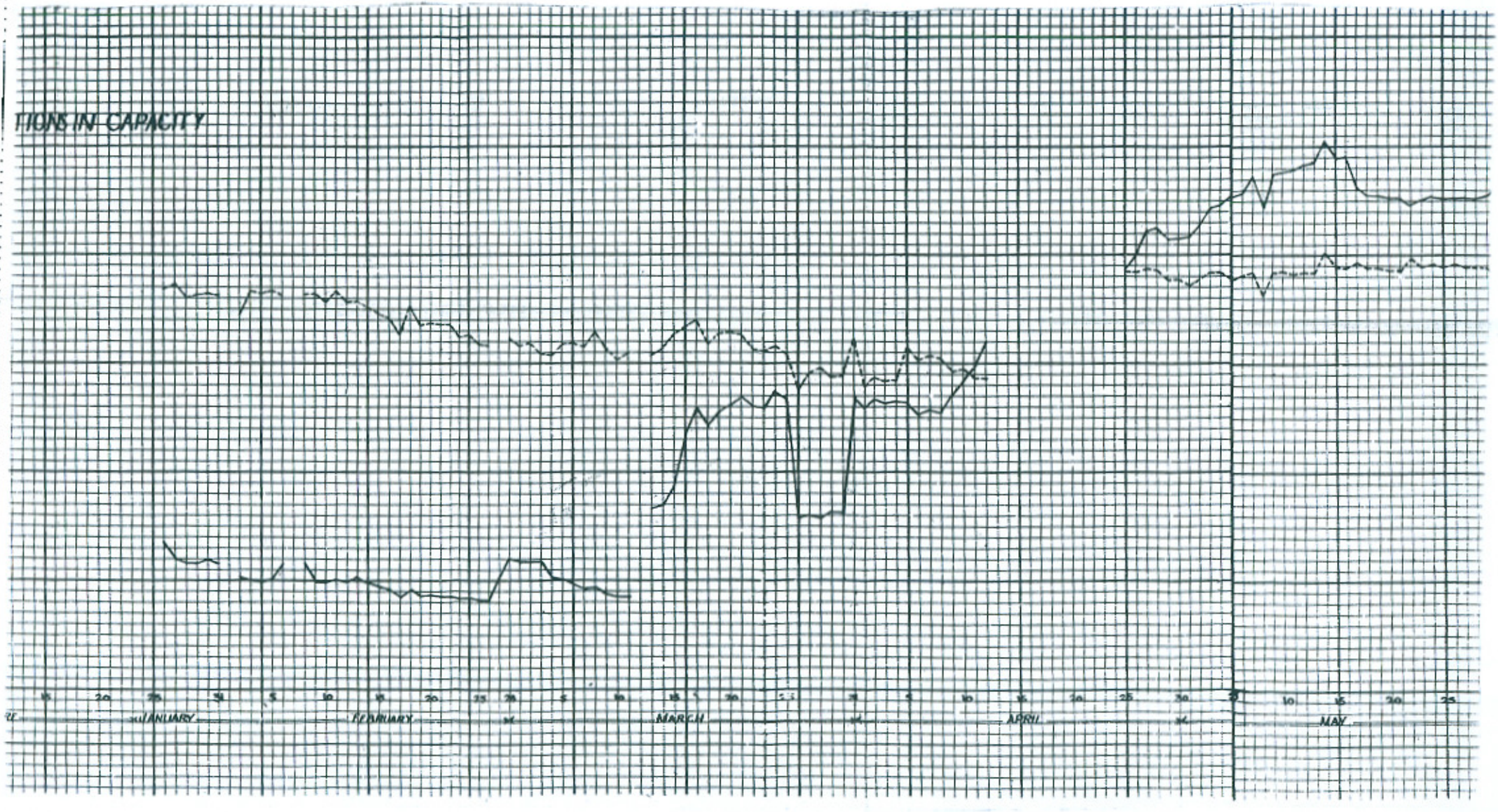
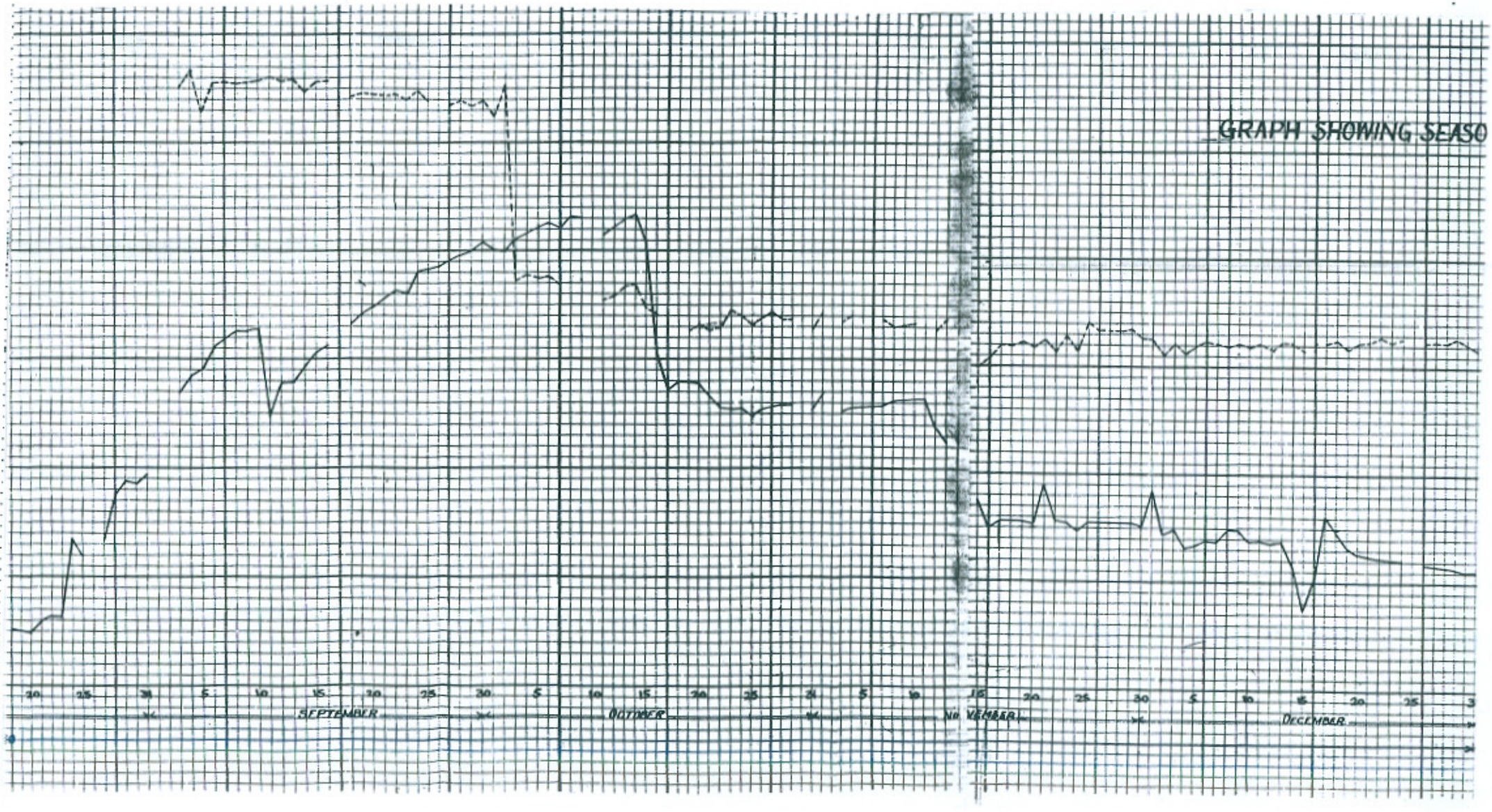
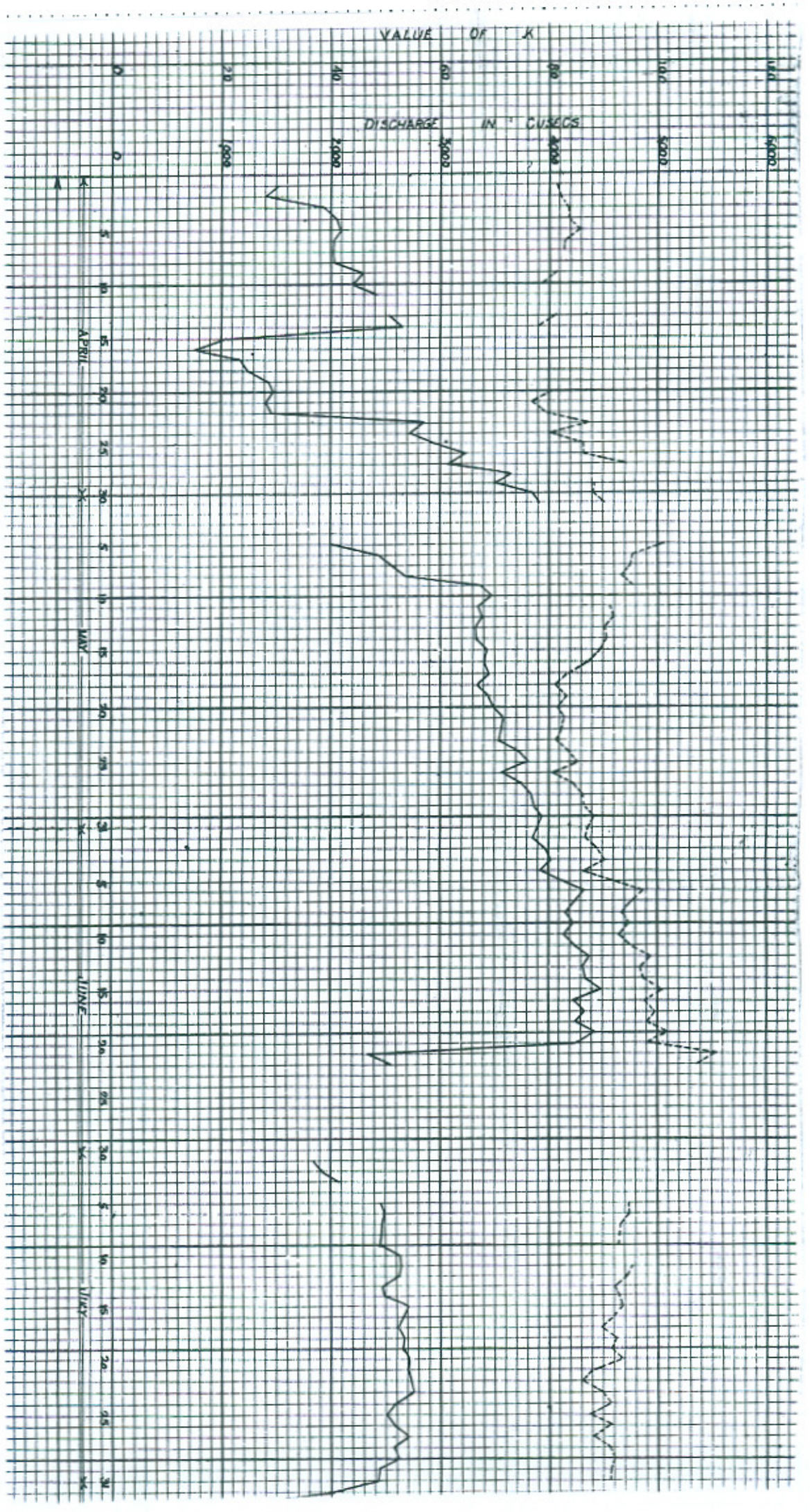


PLATE VII
REFERENCES
VALUE OF K
DISCHARGES
NOTE:-
K UNRELIABLE OBSERVATIONS DUE TO READINGS NOT ETC. NOT HAVE BEEN PLOTTED.
SEPTEMBER
OCTOBER
NOVEMBER
BULLOCK ENGINEERING COMPANY


REFERENCES
VALUE OF K
DISCHARGES
NOTE
UNREPLIABLE OR
BEEN PLOTTED.
JUNE
1941
JULY
AUGUST
SEPTEMBER
OCTOBER


TIONS IN CAPACITY
JANUARY
FEBRUARY
MARCH
APRIL
MAY


GRAPH SHOWING SEASO
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER


VALUE OF K
DISCHARGE IN CUSECS
APRIL
MAY
JUNE
JULY

DISCUSSIONS

In introducing the paper the AUTHOR stated that lining of canals was a subject likely to assume greater and greater importance and favour with the lapse of time both as an anti-waterlogging and water conservation measure and therefore he decided to acquaint the profession as to how the Haveli Canal on which this measure had been last tried was behaving and what lessons could be learnt therefrom.

The author regretted that the drawings attached to the paper had not been supplied to the members without which a connected study could not be made.

After the submission of the paper the canal had its annual closure in January. Insect growth which had been a source of great anxiety in the past was not found to be as intensive as it was during the previous years and was only 80 per cent. although it extended as before to almost the same length of the canal. It was probably due to the fact that the canal had much better supplies and therefore very low velocities had not prevailed and also because the water had been silt laden before the closure. The two combined gave lesser sunlight and lesser period of low velocities which seemed an essential factor for insect growth. The problem however remained unsolved.

Referring to absorption losses mentioned on page 83, the author stressed the importance of watching the same and expressed that those dealing with it might have to say something about it in detail. From the results so far analysed however it appeared that the exact loss was too small to permit accurate gauging with the means at disposal and this he believed was true of Gang Canal as well. As a result of analysis of the data for Haveli Canal made by Mr. Goodman the absorption loss seemed to be of the order of 36 cusecs for a discharge of 4,250 cusecs.

Regarding the value for Kutter's 'N' analysing it over a long reach it had been found that for reach R. D. 2,000 to 20,000 this varied during September 1939 to May 1940 from ·016 to ·025 and for the reach R. D. 130,000 to 220,000 for the same period it varied from ·0112 to ·0153. Thereafter the canal got damaged and it did not seem advisable to draw any conclusions from the data of that period.

The canal remained in a more or less damaged condition from May 1940 to May 1941. For the subsequent period the values were found to vary between ·015 and ·019 for the reach 35,000 to 60,000 and almost the same for the tail reach. As the capacity of the canal was determined by the tightest section and at a time when its condition was worst, the author considered it desirable to adopt the figure of ·018 to ·020 for purpose of design. This he thought would not only be safe but would also avoid later anxiety. This value was all the more justified where variations in discharge were great, and coarse sand got blown into the canal by storms.

The author considered that main achievement of lining was the saving in absorption and therefore consistent with the materials locally available, different types would suit different localities. He thought that the value of 'N' would be more of a theoretical consideration and in the absence of a full-scale experiment with different materials in different reaches, the value of 'N' assigned to each material would be problematic. In any case with low supplies and subsequent silt deposition or sticking of clay to the surface and with sand getting blown into the canal reaches could get a silt coating and would irrespective of lining behave like earthen channels and therefore a value lesser than ·020 would not be operative under all circumstances. As such it appeared that exact value of 'N' was more of a theoretical interest than practical utility and for that object consistent with cheapness any material with value up to ·02 would suit.

The necessity of the section being a self-supporting structure had been stressed on pp. 91 and 103 by the author. This might at first sight appear as an expensive design but considering the damage to sides that had occurred both on Gang and Haveli, he was convinced that this was an important matter. Unevenness on sides could not be permitted as it would disturb the flow and increase friction. No earthen banks could ever stand likerock and even if they did, wave action and rain would disturb the backing. It was therefore essential that the sides of lining should stand intact under all circumstances and as such to be independent of earthen banks should be self-supporting. In Mr. Kapur's opinion the additional cost of profile walls above N. S. would not exceed Rs. 8,000 per mile against a lakh per mile for lining.

MR. HAIGH was glad that Mr. Kapur had produced an able paper about the Haveli Canal as there was a good deal of misapprehension among engineers interested in canal linings as to the cause of the troubles which had been experienced there. Mr. Kapur's paper in making public for the first time the facts in connection with the failure of certain portions of the lining would go a long way in removing such misunderstandings.

The direct cause of the failures of the lining was, in every case, water getting behind the lining, and creating a hydrostatic pressure on it which no lining of economical thickness could possibly have stood. This water came from two sources, the canal and rainfall.

As regards the canal water, it is now obvious that the free board provided in the design was insufficient to take care of the wave action which was set up by the local storms, the intensity and effect of which was not known to the designers. As regards rainfall, the design of the banks was distinctly defective in that the provision for drainage was inadequate and permitted the accumulation of water on the berms at the back of the lining whence it found its way behind it in large quantities.

The bank design was in Mr. Haigh's opinion the principal defect. It provided for wide berms at the level of the top of the lining with the object of reducing the earth pressure behind it as much as possible. On these berms, after slight settlement, large quantities of water could accumulate and thence found their way behind the lining. In the reaches in cutting, also, no adequate arrangements had been made for the drainage of the areas between the high spoil banks and the canal and much of the rain water found its way on to the berms. In the design of bank for the lined channels of the Thal Project there would be a steep slope from the road dowel directly to the top of the lining, on which water would not be able to accumulate. Also, all rain falling outside the dowels would be drained away from the canal. Mr. Haigh opined that if the Haveli design had these features, there would have been probably no serious trouble on the canal, even from wave action, in spite of the various other defects.

The free board provided was of course inadequate and would be increased in future designs. The under-estimation of the rugosity coefficient could hardly be considered contributory to the failures of the lining, since the designed full supply level was very little if at all exceeded in running the canal. From the point of view of the capacity of the canal, the low rugosity assumed was of course a mistake. The effect of this was enhanced by the fact that a value of 'n' suitable for use in Manning's formula, was applied to Lacey's formula without realizing that the use of Lacey, for the high values of hydraulic mean radii involved, automatically reduced the capacity by about 8 per cent. As Mr. Kapur had said, the reason for the high rugosity coefficients prevailing in the canal had not yet been determined, and until this was done it would be advisable to use a value of at least 0·018 in Manning's formula for the design of the canal section.

Mr. Haigh did not regard the bank settlement as a very serious defect. A settlement of about 10 per cent. in new canal banks is normally expected and the main banks of the Haveli Canal were no exception to this rule. An endeavour was made to reduce this settlement as far as possible in the vicinity of the lining by puddling the earth there but this was not very effective. In the light of the knowledge at that time, the speaker thought this was all that could be expected. It was no use either trying to blame the contractors or the officers in charge for defective puddling. The puddling was done as conscientiously as usual in accordance with the specification. It was the specification which was wrong. In the light of our present knowledge this puddling would be described as light compaction with excessive moisture content and could not be expected to produce dense earthwork which would not subsequently settle. Bank settlement was anticipated and expected to produce horizontal cracks at natural surface which could be prevented at low cost. The effect of settlement on drainage, too, would not have been serious if the

bank had had a margin above the top of the lining to provide for the contingency.

However, a bank which did not settle would undoubtedly give a far better job and relieve the engineers in charge of much anxiety while the canal was new. It was to develop the specification of such a bank, could it be made at reasonable cost, that the Mianwali experiments described in Mr. Mahbub's paper on compaction were initiated and there was little doubt that we were now in a much better position to produce such a bank.

As regards other minor changes in the lining specification, it was proposed in future to omit the reinforcement from the lining. Although the steel in the Haveli lining had undoubtedly rusted in places due to defective cover the effect of this rusting on the lining was negligible. However, the reinforcement seemed to have no advantage commensurate with its cost and consequently it would be omitted in the future.

A point on which Mr. Haigh definitely disagreed with Mr. Kapur was as regards the shape of the section. A section with rounded corners was better hydraulically and stronger structurally than a trapezoidal section with a toe wall. It was also cheaper. On the Haveli Canal, there was only one case where pressure developed under the bed and with the improved specification it was very unlikely that this would occur in the future.

It might be observed that of the various causes that contributed to the failures of the Haveli Canal lining, the type of lining had not been mentioned, the reason being that the type of lining had practically nothing to do with the trouble. There were various minor defects in this lining, particularly in the quality of the bricks and the workmanship, but Mr. Haigh apprehended that it would never be possible to carry out any work of that size spread over such a long length, without some such defects appearing. Various other types of lining had been used experimentally in the repair work, but they were all much more expensive than the Haveli type. The latter had such great advantages in simplicity and speed of construction, general adaptability and economy, that it was in Mr. Haigh's opinion bound to be very largely used in the future.

Rai Bahadur A. N. Khosla said that Mr. Kapur had presented a most useful paper on a subject which was going to be of the utmost importance in Irrigation Projects of the future, which of necessity had to depend on the extensive supplies from storage reservoirs, as the Punjab was practically at the end of its resources of water for flow irrigation direct from the rivers. Lining of channels had a two-fold function. Firstly, it prevented waterlogging and, secondly, it conserved valuable supplies of water which would otherwise be lost by absorption. A very considerable length of channels was proposed to be lined on the Thal Project, involving a very heavy outlay in expenditure. The subject of lining was, therefore, of the foremost

importance. Mr. Kapur had very ably brought out certain features of design and maintenance. The presentation of the subject would have been more complete, if he had appended a statement of the coefficients of rugosity obtained as a result of observations by the Discharge Division for a period of about three months on the Haveli and the Gang Canals. The Gang Canal lining consisted of a 6-inch slab of Kankar lime concrete. The coefficients of rugosity on this canal—as far as was known—were lower than those on the Haveli Canal, which was of brick lining. It was felt that where the costs between the two were not very different, Kankar lining would be preferable because of a smoother surface and lesser friction. For Kankar lime concrete lining it was, however, very necessary to get uniformity in strength and other properties of the Kankar lime in use in the various reaches. A chemical analysis was made of a very large number of Kankars along the Bhakra Canals and it was found that the constituents in most cases approached the ideal constituents for low heat and weather-resisting cements. Compression tests gave very favourable results. If the technique of Kankar lime burning could be developed and standardised, it would be quite possible to obtain Kankar limes with strengths not very much below those of cements with the great additional advantage that because of the slow setting Kankar limes concretes were comparatively free from cracks.

Mr. Kapur had rightly drawn attention to the supreme necessity for proper consolidation of the backfills behind the lining. His suggestion that the channels to be lined should be run as unlined channels for a year or two, was first considered in 1939 for the first stage of the Bhakra Canals and was one deserving of serious consideration.

DR. J. K. MALHOTRA remarked that in the first para on page 81 it was stated by the author that the Haveli Canal was decided to be lined, in order to avoid the possibility of waterlogging. On page 102 in the third paragraph from the bottom, the author had stated that the objectives of a lined canal were (*a*) saving of excessive absorption, (*b*) lesser sectional area for same discharge, and (*c*) flatter slopes. Again on page 81 in para 3 it was stated that the limited drop of levels between Sidhnai and Trimmu determined the slope of the canal.

He asked the author to kindly state if the main reason for lining was the limited drop of levels, or the necessity of avoiding waterlogging.

The author had referred to the growth of insects on the Haveli lining. References to this were given on page 84 (para 4), page 86 (para 3) and page 93 (paras 3 and 4.)

The speaker was in a position to supplement the information given by the author, as the investigation referred to on page 86 was referred to Dr. George Mathai through the Irrigation Research Institute.

It was known that after the growth of insects had reached formidable proportions, a sample was collected from the site, and sent for examination to the Zoological Laboratory, Government College, Lahore. The report was that the insects were of the genus Trichoptera. The non-scientific name was given as Caddis-fly. It was suggested that the life history of this pest may be studied over a period of years.

Mr. A. St. G. Lyster, I.S.E., Chief Engineer, looked up this word in the dictionary, and found that Caddis-fly was defined as "Larvæ of mayfly, generally used as bait for fish." As these insects form the natural food of fish, it was considered that their abnormal growth on the Haveli lining was due to disturbance in the natural regime of the fish due to construction of the Trimmu Barrage. It was expected that in a few years' time the balance between fish and insect life would re-establish itself.

The extent to which the presence of headworks on a river, interfered with the frequency of fishes in the river, and with their entry into the canal, had not been studied very thoroughly in the Punjab. The speaker, however, drew the author's attention to a paper on "Fish Ladders in the Punjab Weirs" by Dr. Hamid Khan Bhatty, Fisheries Research Officer, Punjab, who had discussed the shortcomings of the Punjab fish ladders, and the extent to which they affected the movements of the fishes.

3. On page 91 the author had referred to the value of Kutter's 'N' taken for purposes of design and on page 92 had given the range of its actual value for different reaches. In the last para on page 92, the author appeared to suggest that the value should be increased to ·020. On page 108 in para 5 the author recommends that the designed value 'N' should not be less than ·020.

In 1939, a few months after the Haveli Canal was opened, the discharge data for the various reaches were sent to the speaker, for analysis by Mr. C. L. Handa, Executive Engineer, Main Line Division. His own opinion was that the value of 'N,' then obtaining, ranged between ·012 and ·016, with a bias towards the lower value. On analysis he found that while Mr. Handa's conclusions were not entirely correct, the value of 'N' was well within the designed value. The average value for all the reaches was ·0148, and the speaker informed Mr. Handa that a value of ·015 would be adequate, for similar works elsewhere.

This was also the conclusion arrived at by Mr. Crump, who was at the time engaged on the L. C. C. Lining Project, by an independent analysis of the Haveli Canal data.

Mr. T. Blench, who was also engaged on the L. C. C. Project, has studied the data from Bikaner Main Line, and arrived at a value of N=·015.

Dr. Malhotra stated that he had been asked later to comment on the value obtained by Mr. Blench, and in a note which he submitted to the Chief Engineer in March 1940, a value of ·016 was suggested as ample for the L. C. C. Lining Project. In this note he also discussed the values obtained for Haveli by the Central Designs Office. These values, however, were generally for low water months, and while it appeared that the value of 'N' was higher at lower discharges, the speaker did not consider it worthwhile recommending a higher value, for at lower discharges the depth also was small and some increase in it would not matter. It is only at full supply discharge, that the value of 'N' really ought to be considered.

Dr. Malhotra asked the author to kindly state if the values of 'N' in different reaches, given by him on page 92 were higher at the lower discharges. If so it should be possible to adopt a low value of 'N' without any risk of the channel not being able to carry the full supply discharge.

The speaker entirely agreed with Mr. Kapur in the suggestion made by him in the last para on page 102, that lined channels should be constructed for perennial capacity only.

In the end, the speaker congratulated Mr. Kapur on producing a very detailed and interesting paper, which would enable others to avoid some of the difficulties encountered with the Haveli Lining.

Dr. N. K. Bose remarked that the only point in the paper which he would like to bring out was given on the first page under "Sections of lining." Here the author said that according to Lacey silt factor 'f' for a discharge of 5,000 cusecs and a slope of 1 in 10,500 would be ·82. The speaker did not know whether Mr. Lacey would agree to this application of his theory to a lined channel. In any case if the theory still held corresponding to this value of 'f' the mean diameter of the silt which the channel could carry would be ·27 mm., whereas the silt samples taken from the river and in the head reach of the canal showed that the average diameter of the silt was ·25mm. Under these circumstances it was not understood why the authors of the Haveli Project went to the extent of providing a very elaborate system of silt excluder at the head and two silt ejectors in the canal. It appeared that the authors of the Project had not very much faith in Lacey's theory, otherwise it was not necessary to have such a formidable series of silt excluders and silt ejectors for this particular channel.

Mr. N. Gopal welcomed the paper as giving some of the results of a large-scale experiment on Lining Canals. It appeared to describe constructional defects and remedies adopted, which could be useful for future Projects of the same kind. Lining of Existing Canals appeared to be the problem of the near future in the Punjab. It might seriously come to the forefront before long as not only an additional or perhaps the only possible source of more canal water

supply, but as a very effective and economical remedy of water-logging, when the value of water saved from absorption losses in earthen channels was given full credit towards the cost of such projects. This would be governed by the type of materials used for lining. From the title of the paper, one had a right to expect as the foremost, some observations and results of absorption losses on the lined and unlined portions of Haveli Canals. One read the paper in vain to find any help in this respect. The speaker would be grateful if the author of this valuable paper gave results of actual absorption losses for—

(*i*) The type of lining used in the first instance,
(*ii*) Lining as Repaired, and
(*iii*) Unlined portion of canal.

MR. GERALD LACEY remarked that it had not been his intention to take part in the discussion but as Dr. Bose had referred to the employment, by those who designed the Haveli Canal, of the Lacey silt theory, and had suggested that their use of it associated with a margin of safety implied that they had not entire confidence in it, it was necessary for him to say something on the subject.

In the first place the theory was intended to apply to regime channels in alluvium and flowing within a boundary of deposited silt of the same character as that transported. In the second place it was clear that if the Haveli silt factor was to be applied as a measure of the necessary turbulence to ensure that the silt was swept forward in turbulent suspension and the cement bed swept clean, that was a very different thing from a silt factor associated with a moving bed of silt, and which bed silt grade determined the rugosity. It was clear that the turbulence necessary and postulated by the first set of conditions would need to be greater than that required by the second. The average grade of the silt admitted to the canal might be the same but the mode of transport very different and also associated with a very different velocity distribution. The application of the Lacey theory therefore required caution and the guarded use of it was no condemnation of the theory.

In the design of the canal the Lacey equation $d=f^2/_{64}$ had been employed. This equation was suggested in 1930 by the speaker and had been intended merely as a rough guide to the diameter in inches of the predominant type of silt transported by channels ranging from fine silt to boulders. The speaker described it in 1930 as "a very rough qualitative formula" and remarked that had it been possible to collect information as to the size of particles corresponding to lower silt factors a more reliable rule could have been obtained. Written in terms of the average diameter in millimeters the equation was $f=1{\cdot}59\ m^{\frac{1}{2}}$. A recent and more accurate expression based largely on observations in the Punjab was $f=1{\cdot}76\ m^{\frac{1}{2}}$. It was clear

that the use of the lower coefficient of 1·59 would lead to underestimating the required value of 'f' and that there would therefore be some risk of silting. The silt factor, however, was applied to the average diameter of the bed silt particle. It would appear that in the design of the Haveli Canal the silt factor was determined by employing the maximum size of silt grade which it was proposed to admit to the canal. This was a very sound procedure since an attempt was being made to compute the degree of turbulence necessary to keep all the particles including the coarsest in suspension, or at least in saltation and this was very different from sweeping them forward on the bed.

On the Haveli Canal project the slope available was the control and therefore, to be strictly accurate, it should be stated that from the available turbulence (or silt factor) the corresponding average bed silt grade for an ordinary regime channel had been computed, and, since it was necessary to maintain the silt in suspension, and not transport it on the bed, it was intended to restrict the *maximum* size of silt admitted to the same numerical value as the computed average. This left a margin to cover the increased turbulence necessary but that margin was somewhat reduced by the employment of the 1930 coefficient which was somewhat too low. The subject was of great importance in the design of silt extractors.

Mr. C. L. Handa drew the attention of the house to a possible wrong impression resulting from the form of presentation of the paper. He said, that "the damage to the lining and its failure" were rather loose terms, and the members of the profession could easily form an erroneous notion regarding the soundness of the idea of brick lining on canals. In fact the Haveli lining had been a great success. Analysing the cost of repairs as given by the author, it would be seen that the total expenditure of about 5 lakhs contained only one lakh for repairs and the balance of the amount was spent in increasing the free board by raising of the lining, and in improving the drainage of the banks. Hence the repairs amounted to less than 2 per cent. of the cost, which was by no means high and did not impair the soundness of the Project. The speaker next remarked that the Haveli Canal lining did not suffer so much from the soundness of the quality or mode of construction, as from defective design, which in the very nature of engineering undertakings, always improved when more experience was gained. In the design of this lining, a free board of only 1 ft. above Full Supply Level was provided, and it was imagined, that the water, in its behaviour would be pet and tame and not go beyond or above the line drawn by the master. The speaker was in charge of the Haveli Main Line Division in April 1939, and experienced all the misgivings of the first flow of supply in the biggest lined channel of the Punjab. Nothing went wrong to start with, except a little segregation of the puddle, which was promptly staunched with mud-slurry. But as the summer advanced and storms put in their appearance, the danger line came nearer. In the

progress report for June or July 1939, the speaker reported to Mr. Haigh, then Superintending Engineer, Haveli Circle, that waves 3 ft. to 4 ft. high were witnessed in a storm, and that the free board of the lining appeared to be inadequate specially in the tail reach. But luckily nothing untoward happened in the year 1939 and the failure came in 1940 due mainly to insufficient free board.

The speaker then narrated how he had carried out an experiment in order to test whether the banks were compact. He along with his Sub-Divisional Officer, Mr. B. S. Talwani, had arranged to install a $1\frac{1}{2}$ cusecs pump near the dowel with an idea of pumping water on to the top of the bank, so that it may fill and staunch the voids in the bank. Accordingly this pump was started and both the officers got a rude shock when the pumped out water started disappearing into the bank and a huge pit resulted even making the officers slip into it. The experiment was, therefore, abandoned and the conclusion arrived at that the banks had any amount of large hollows in them. This again was a matter of design, because in spite of the rigid specification about breaking of clods, artificial banks must have hollows and voids and clods. To get over this, the banks must be solidly compacted in a scientific manner by having 6 ins. layer of earth and rolling them with toothed rollers. But this was a comparatively recent thought and would be incorporated in future works. The engineers, who made the Haveli Canal, could not be blamed for this omission, as science was always advancing.

The next point raised by the speaker, was, that the effective slope provided in a lined section was most important. On the Haveli Canal, the slope was 1/10,000 and could not be made steeper, as the drop from the Pond at Trimmu to the Pond at Sidhnai was uncontrollably limited. But steeper slopes were bound to be more helpful. In the Project just sanctioned for lining an experimental reach of 1 mile of the Jhang and Rakh Branches, the slope adopted was about 1/3,300, which would give a mean velocity of 6 ft. per second. With this velocity, there was no chance of silt depositing at the bed and it would be quite possible, that the growth of the insect pest mentioned by the Author, may also be prevented. Again it was the feeling of the speaker, that with a slope of 1/3,300, there might be a favourable modification in the rugosity coefficient and a smaller value than 0·018 might be possible, thus leading to economy in cost. This, however, was a matter still needing confirmation by field observations.

The speaker concluded by saying that the subject of lining of canals was a most important one, as it had great potentiality in respect of the old canals, where we could save absorption and seepage by lining the canal.

Dr. George Mathai stated that on the 17th February 1941, the Director of Irrigation Research, Punjab, wrote to say that considerable roughening of the brick lining of the Haveli Main Line Canal had taken place owing to the accumulation of some kind of animal

cocoons formed of straw, sand and mud, resulting in reduced velocities and discharges. Samples of the material, when examined, appeared to contain Trichopterous (Caddis-fly) larvæ.

The speaker continued that he was given an opportunity of visiting Trimmu on 14th and 15th March, 1941, when these larvæ were observed at the Head Works and Caddis-flies over the canal. On a subsequent visit on 15th and 16th April, as the canal was being emptied, tubes of these larvæ could be seen along the bed and sides of the canal from Trimmu to Sidhnai, although less abundant towards the Ravi end. Winged adults were also seen over the canal.

On visiting the cement lined Bikaner Canal at Ferozepur on 21st and 22nd March 1941, neither Caddis-fly larvæ nor larval tubes were noticed, although the surface of the bed and sides of that canal were sufficiently rough for the accumulation of larval tubes. On the 4th and 5th April, 1941, while at Khanki and Rasul, no larvæ were seen in the upper reaches of the Chenab and Jhelum. Nor according to information available was there any larval problem in the 'kacha' irrigation canals in the Punjab. It seemed, therefore, that the presence of Trichopterous larvæ was a unique feature of the Haveli Main Line Canal.

If this problem were to be tackled effectively, it would be necessary to obtain reliable facts regarding the life-history of this Caddis-fly and to determine ways and means of controlling the larvæ by the introduction of larvicidal fish into the canal. Biological control of this kind would be advisable in the case of irrigation canals rather than any chemical method of control.

The speaker, however, said that in June, 1941, he was given to understand that, without incurring expenditure on such investigations, it would be possible to run the Haveli Main Line Canal full supply.

MR. B. S. TALWANI remarked that the author had contributed a very useful paper on the working of lined canals, which were yet in their early stages. He had narrated very lucidly and at some length the history of the canal from the very day of its opening. Very minute details were given, which would be useful both in designing and running the lined canals in future. Mr. Talwani said he would add a few remarks from his own experience, as one who had both constructed the canal and run it.

1. As the author had written, there were 3 objects of a lined canal :

(*a*) To save excessive absorption ;
(*b*) To permit lesser sectional area for same discharge ; and
(*c*) To permit flatter slopes.

Now how far had these objects been achieved. Regarding (*a*) there was no shadow of doubt that any lined canal whether of tile masonry, or of concrete blocks or of slab, etc., would prevent absorption losses.

There were pressure pipes fixed all along Haveli Canal in the berm. Strainers of these pipes went to local spring level. The water level in these pipes was read thrice a month. From their study for the last three years it was quite clear that there was no rise in the spring level. Moreover the rise or fall of water level in the canal had absolutely imperceptible effects on the spring level although the pipes are fixed in the berm. The everyday discharge observations too showed that actual absorption in the canal was very little.

Regarding (*b*) that lesser sectional area was permitted, experience had shown that section originally designed was not sufficient to run the full supply discharge. Whatever material might be used, for lining of the canal, after some time, the surface was smeared with something like fine silt or some insects growth, which increased the roughness of the surface, and the channel behaved somewhat midway between an earthen channel and a lined channel. The section with value of 'N' not less than ·02 would prove more accurate, and such a section should take full supply discharge.

Regarding (*c*) that flatter slope can be permitted, Haveli Canal had been given too flat a slope due to exceptional circumstances. It was more or less a feeder canal, and the drop in its full supply from head to tail was controlled by the maximum pond levels at Trimmu and Sidhnai. But in designing lined canals at other places steeper slope could be permitted and should be more useful.

The major damage which occurred to the lining in 1940 was due to an exceptionally abnormal and severe cyclone. In the opinion of the speaker this cyclone would have similarly damaged the lining made of any other stuff. Otherwise in normal cases the damage done every year was not much at all. The damage always occurred whenever water found its way to behind the lining, and this took place only because the free board was small. The minimum free board of 3·0 ft. in such dry lands through which the Punjab canals ran and where duststorms were too frequent was the best guard against any normal damage. The water waves had actually been seen rising 3·0 ft. and even more.

The main defects in the original design were that, firstly, the puddled earth behind the lining did not stand on its own foundation, and secondly, the free board was not sufficient.

Further too many cracks appeared in the joints of tile masonry. These cracks were grouted during closures every year. But there was no end to them as yet. More cracks appeared again. This was probably due to settlement of the earth and consequently of the puddle behind. This process would go on till all settlement took place once. Although these cracks appeared everywhere, the leakages took place only in certain specific reaches. In those reaches it had been found that the earth of which the bank was made of was the hardest, and full of kankar particles. This leakage would stop

only after a lapse of time when all the fill behind the lining was fully soaked and saturated. An experiment was tried to saturate and soak the bank by means of a pump. A drain about 2·0 ft. deep was dug in the centre of the bank. Water was pumped out from the canal by means of a 2-inch pump and put in the drain. A gang of *beldars* was employed to repair the hollows in the bed or sides of the drain where they occurred when water was let into it. After two days' hard trial, the water could not go beyond 200 ft. length. All the water was soaked into the bank. So much saturation of bank was still required.

The author had suggested that the section of the lining should be statically sound and suitable to withstand the pressure that might come on it, so that there might be no damage. But when it was considered that the main object of the lining was to save absorption losses, which had been achieved even by the existing design, and that the damage to lining and its bulging, etc., could be overcome by other means like giving more free board, consolidation of banks at the time of construction, and making puddle section to stand on its own foundation. It is worthwhile to find out whether there still remained the necessity of designing the section statically sound.

Regarding constructional details experience had shown that the sandwich of 1 : 3 cement plaster between the two layers of tiles had proved very very useful against leakage. Unfortunately, this sandwich of plaster was laid only in the bed of the canal at the time of construction but no such plaster was laid on sides. This plaster invariably must be used for sides as well. Moreover it must be stressed that actually ratio of 1 : 3 was used. It had been found while dismantling lining for repairs, that at some places the dismantling was done with great ease and at other places with great difficulty. This showed that 1 : 3 ratio was overlooked at many places and a leaner mixture was used.

The comparative costs of different kinds of lining had been worked out by the author. There was no doubt that brick lining was the cheapest, though defects had come to light now during this period of three years of running. But most of these defects were not due to the brick masonry alone but due to other things as well such as settlement of banks, defective puddle section, less free board, bad soil, etc. The other experiments of concrete blocks, etc., had been tried after knowing the constructional defects and then overcoming them and avoiding them. Had we constructed lining of other materials in the very beginning, not knowing the defect as we knew now, perhaps the latter too would have behaved in the same way as the tile masonry lining. All the repairs whether done in tile masonry, brick masonry or concrete blocks, or slab and beams, etc., were standing intact. So it was not a fair comparison between the tile masonry of construction time and other types of repair at a later stage. We could still rely on tile masonry as the cheapest material for lining, of course making all sorts of improvements as the defects come to light.

MR. R. R. HANDA while congratulating Mr. Kapur on his ably-written paper remarked that as he was in charge of the work shortly after construction was over, it was incumbent on him to make some remarks as a result of his experience of this work.

He felt that the value of Kutter's 'N' accepted in the design was too low. During the canal closure of winter 1939, he found small worms sticking on the joints of tiles. When the canal rose in May, it could not carry more than 3,800 cusecs with F. S. L. at head and also from R. D. 35,000 to R. D. 1,10,000. He left the place in May, 1940, and he was told that gradually the discharge rose to 4,200 cusecs in about a month. In the previous August also, the canal had run to 4,200 cusecs with a lower gauge. The conclusion from this was that in winter, when less discharge entered the canal and the water was clear, these insects got collected and added to its roughness. With the increase of velocity, when the canal ran full, these gradually washed away. The demand was, however, very keen during May, which was the sowing season. As the coefficient was high in those days, the canal would not run full supply and irrigation would suffer. The remedy, therefore, was to adopt that coefficient which applied in April or May. Very likely this was 0·020. This would no doubt make the canal more costly, but the real cost of using a low coefficient was the cost of the work and the salaries of staff engaged later to discover the causes of the canal not running full. Or, as an alternative the free board could be increased.

Another reason for the increase of coefficient was the rough surface presented by kallar eaten tiles. While selecting sites for kilns the time-honoured practice of burning bricks or tiles from earth was given up and laboratory tests were considered sufficient to decide whether a particular site was feasible or not.

The lesson to be learnt from this was that laboratory tests were not sufficient guides.

After a storm in late April, 1940, he found that as a result of water-lash deep trenches had been formed behind the lining, which indicated that puddle behind the lining was not so compact. Similarly, one speaker had already said that while he was trying to pump water on the bank, the latter settled. This indicated that earthwork of the banks had not fully settled. The cause of this was that the work was finished in a very short time, and settlement which time and one or two rainfalls allowed, were denied to it.

The storms in the area through which the Bikaner Canal passed must be of the same ferocity as those in the Shorkot area. Yet no disaster of the magnitude of that on the Haveli Canal occurred on the Bikaner Canal. The reason was that earthwork extended over more than one or two years which allowed the banks to settle down.

Hence the other conclusion was that where lining was desired to be done earthwork should be completed in one or two years, by

ng funds and lining should start at least one year after the start thwork, so that it might be done over settled earthwork.

. ISHAR DASS said that the Haveli Canal to all intents and ses was a lined canal and a feeder canal. It poured water from: River into the River Ravi. Only a fraction of a mile was and that also was designed for 7,452 cusecs against 5,249 authorised fully supply discharge. Difference in slope in this each of 2,000 feet would result in very small fall. Suppose it lesigned with 1/6,666 against 1/10,500.

ifference would be ·11.

Only a *hissa, i.e.* 1/10th of a foot. This would have mattered . Then why any talk of limiting value of Lacey's f to ·82 to ermine mm. as ·27.

The speaker agreed that it was a good thing not to allow coarser aan ·27 mm. In fact he advocated it very strongly in his paper No. 249 last year.

But if the implication was a designed lined canal with f=·82, that was incorrect, because the designed lined canal had a value of f=1·18 in reach 2,000 to 35,000 and f=1·6 further down up to 90,000 as shown in the attached statement.

So the determining factor of silt grade was not the available slope between Chenab and Ravi as 1/10,500 but the consideration that coarser sand should be excluded in the head reaches to as much fine as possibly could be and that was done by Silt Excluders in the design of Head Regulators and Silt Ejectors downstream.

The other consideration could be that of Sidhnai Canal which has been running with very flat slopes and very fine silt and it was not desirable to introduce coarser silt in that system of canal which work so well.

This talk of Lacey's f and calculation of mm. therefrom was all irrelevant in case of Main Haveli Canal and displayed confused thinking of the designer or writer responsible for the statement made in this paper.

Taking actual value of f 1·08, 1·6 and 1·43 as arrived at in the attached statement by $V=\sqrt{\frac{4}{3} f R}$

$$d=\frac{1{\cdot}6^2}{64}=\frac{2{\cdot}56}{64}={\cdot}04 \text{ in.}$$

$$d=\frac{1{\cdot}08^2}{64}=\frac{1{\cdot}666}{64}={\cdot}026 \text{ in.}$$

$$d=\frac{1{\cdot}43^2}{64}=\frac{2{\cdot}0489}{64}={\cdot}032 \text{ in.}$$

This would have been, of course, by Lacey's formula, correctness of which the speaker did not vouchsafe. He simply analysed it.

The second point the speaker would take was that value of adopted as ·016 and now advocated to be used as ·02 which w the way more than what we get in case of some earthen chann the Sidhnai Canal system and in Sind as well. In the Punjab tion Nomogram on page 1 value of Kutter's 'N' was giv different conditions, 'N' for concrete lined channel was giv and the value ·013 assigned in the design of Bikaner Main Line was working well. Its CVR is 1·43 and f=1·54. The design o channels was assuming great importance. It would be inte if the author or the designer came forward and stated proc actual design. To the speaker this unscientifically assigning or that value of 'N' ·013 to ·016 or ·02 was a jump in dark. might come out with good design as was the case in Bikaner M Line and one might fall badly as had been proved in case of desi of Haveli Main Line. Sometimes the canal was said to be full t about F. S. L. but only with 2/3rd discharge and sometimes with 3/4th and even with most valued observed data in best of times the FSL exceeded with less than designed discharges. Nature had been blamed for being ungenerous and not behaving itself just with expectation of the designer.

Mr. G. R. Sawhny said that the members should be grateful to the author for writing the paper and thus keeping the Congress alive to the importance and urgency of this rather intricate subject. He had given us an interesting history of what should not have been done in the first place, and what good things had since been thought out to meet the serious troubles, which had to be faced.

While speaking on the paper No. 221 by Mr. Duncan before this Congress the speaker pointed out the probability of the tiles getting affected by kallar, and enquired what steps had been thought out or taken to guard against it, and was told, that the question would be dealt with when it arose. He also apprehended trouble when rain water soaked in behind the pitching, but was replied that the probability of rain water finding its way between the puddle and the lining was not dangerous, as any such rain would help to compact the backing. In reply to the speaker's question, about the position of reinforcement and the joints he was told that the author carried out just whatever orders he was given. The speaker was, then, looked down upon for offering honest criticism, which has since proved was not only honest but very correct.

It was not a convincing argument that as the cost of land per mile is only a small fraction of the cost of lining, so we should have wider and deeper lined canals than it was necessary. Then why line them at all; also designing with N=0·02 or allowing a bigger factor of safety merely because we might do bad work or follow wrong designs was not good engineering. We should experiment further and find more appropriate solutions.

Data Tabulated.

Reach.	Q	B	D	Side Slope	A	P	R	N	$V=\frac{Q}{A}$	$C_1=\frac{V^1}{R^{\frac{1}{2}}}$	$C_2=\frac{P^1}{Q^{\frac{1}{2}}}$	$f=\frac{\cdot 75V^2}{R}$	CVR or $\sqrt{f}$
					Haveli Main Line—Lined Channel.								
					Designed Data.								
2,000 to 35,000	5,249	115	10	1 : 1	1,250	148·94	8·39	·016	4·2	1·26	2·256	1·18	1·086
35,000 to 63,000	5,244	84	12	1 : 1	1,152	117·94	9 767	·016	4·55	1·46	1·63	1·6	1·264
63,000 to 90,000	4,747	75	12	1 : 1	1,044	108·94	9·58	·016	4·547	1·47	1·58	1·6	1·264
					Observed Data.								
20 to 63,000	5,038	84	12·53	1 : 1	1,212·8	1,19·5	9·01	..	4·154	1·38	1·68	1·43	1·196 say 1·2
					Bikaneri Main Line Gang Canal Lined Channel.								
					Designed Data.								
	2,144	52	8·0	1 : 1	480	76·66	6·43	·013	4·51	1·78	1·61	2·37	CVR 1·43 $\sqrt{f}$ 1·54

Author had noted down a rather useful set of precautions, but the substitution of plain iron sheet in place of mortar pan seemed rather overdoing it; why not see that proper quantity of water was mixed and the mason was not allowed to keep the mortor pan hanging about for any length of time.

The speaker continued that the paper was an interim report, as besides other information which was not yet available, we had to await diagnoses of chemists and biologists, and then know if any suitable cures would be forthcomig, to permanently solve the troubles connected with that kind of lining.

"If" was the most unsatisfactory word, in the English language and author's too frequent use of it in his paper, tended to minimise its value.

As the lining was to be done mainly to save excessive absorption, the speaker suggested that tiles laid over bed and slopes up to N. S. plastered with Bhusa Carbonate of soda and mud plaster should be tried.

In life or in play it was the skilful guy who did the right discard. The author went a step further and left the discarding to others.

Major T. Blench, I.E., commented that two essential points appeared to have been overlooked: (*a*) that a very good lining could not be justified economically, and (*b*) that there were simple principles from which the scouring ability of a lined canal could be obtained.

Point (*a*) was illustrated by the fact that a lining reduced the perimeter to 50 per cent. so saved that much water even if so leaky as to be quite ineffective. Actually it was a very poor lining that could not reduce from the usual 8 cusecs/million to 2 cusecs/million and thereby save, allowing for the halfed perimeter, 87·5 per cent. of seepage from an unlined channel. Obviously, with only 12·5 per cent. more water left to be saved by a perfect lining, the cost of lining per cusec saved must be high for very superior linings.

For point (*b*) all that was needed was to assume a roughness as for the sand likely to be deposited and calculate V^2/R for the canal running absolutely full*. If this turbulence criterion exceeded that corresponding to the f of the sand the canal could sluice itself out. The Haveli head reach did not pass this test; but the Bikaner Canal did. The tighter the section relative to its depth the better its scouring properties. It was obviously futile to save 10 per cent. seepage by lining, and then lose 15 per cent. capacity by forgetting to test for self-sluicing. Incidentally the author's conclusion that a large value of N should be used for safety would, on borderline cases, give a larger section than necessary and make all the difference between a channel being self-sluicing or not; so the conclusion was a very dangerous one.

*Use formula $V = (60/f^{1/4}) R^{3/4} S^{1/2}$.

Major Blench said that he was using ½″ plaster between bricks as a damp-proof course for very temporary mud huts—in fact he was using a Haveli lining—and that was all he thought it fit for. Such a design seemed absurd for a lining. The bricks were pervious. The sandwich was flimsy. The slope joints could not be adequately filled. The laminar structure was bound to result in disintegration. The use of reinforcement in circumstances that experience showed would result in corrosion was amazing. A few months after the opening of the canal he motored along it at 20 m.p.h. and could see the open joints on the opposite side-slope.

He stated that he was making concrete roads of 1 : 2 : 4 mix, 4″ thick, under 25 Rs. % sq. ft., and a 1 : 2½ : 5 lining would cost 20 Rs. % with cement at 2/2 per bag at site. Such a lining would not have the defects of the Haveli one.

He considered the author's figures for concrete were based on unpractical designs. For example the cost of the beams for the beam cum slab lining came to more per hundred sq. ft. of perimeter than a solid 1: 2½ : 5 lining, and the contribution of the beams to impermeability, or even to strength, was negligible. All that was wanted was a straightforward lining of weak concrete (weak to avoid temperature cracks) laid on pre-settled banks. The Bikaner Canal was an example worth of study.

He mentioned that he had found the original 'N' calculations for the Haveli lining had been based on part supply conditions with slope over several miles 100 per cent. off bed slope and the sections chosen at one end of the reaches. The calculations were obviously wrong; and he hoped the same error was not still being made.

Mr. T. A. W. Foy, I.S.E., rose to correct R. B. A. N. Khosla's statement that evidence of unevenness in certain sections showed settlement of the lining of the Bikaner Main Line. The position was firstly that the side slopes had been constructed on a 1 to 1 slope in cut and a 1½ in fill; during the pneumatic ramming operations the sharp line dividing the two slopes would be obliterated. Secondly, the ramming operations transmitted pressure through the concrete to the earth fill behind. This earth fill would naturally be of varying degrees of compactness before ramming, which would find out the weaker spots of the fill and compact them. Thus the concrete originally laid to a more or less smooth slope after ramming took on a wavy aspect in the upper portion of the side slopes.

In replying to criticism the author thanked the various members for taking part in the discussions. Referring to Mr. Haigh's remarks regarding the rugosity factor the author considered that for purpose of designs so far as capacity was concerned the value of ·018 would fit the worst conditions and therefore he had advocated its use. Regarding his remarks about the consolidation of banks under the lining, the author reiterated his opinion that a self-supporting section just behind the lining was all that was required and the remaining

portion of the bank would take care of itself and therefore it would not be worthwhile spending a huge amount on the entire consolidation of earthwork which should be left to time. Regarding his remarks on the shape of the section the author's main assertion was that whatever section was adopted should be statically sound and in case of curved section the various portion should be split up into self-contained compartments by introduction of toe walls so that no undue stresses were to be transmitted to the adjoining section thereby reducing their strength. As regards the cost it was a matter for consideration whether initial cost in providing extra toe walls was preferable to the cost of setting right the distortions later on.

Regarding Dr. Malhotra's remarks about the points which determined necessity of lining the Haveli Canal, the author stated that all the three factors individually and collectively were responsible for the decision. The limited drop undoubtedly determined the slope and silt factors and the necessity of saving on land and to avoid waterlogging it was found necessary to line the canal. Regarding his remarks on the fish regime having been upset due to the construction of barrage, the author stated that the fact could not be ignored but the same also had happened in case of Ferozepore weir where no such trouble had been noticed on the Bikaner Canal. It was, therefore, obvious that some factor other than mere disturbance of the fish regime was also responsible for the insect coating over lining. The author also pointed out that the fish ladders at Trimmu had not started functioning as efficiently as they should because the entry of the same was not sufficiently self-advertising, but it could not be said that they were not functioning or that the fish got locked up anywhere because water continued standing both upstream and downstream throughout the year. Referring to Dr. Malhotra's remarks about the values of 'N' as determined in 1939, the author stated that the values then obtained were correct theoretically for masonry because the lining had not got the insect coating or the fine silt coating which it later got, therefore the values obtained in 1939 were bound to be low. The same remarks applied to the results obtained by Messrs. Crump and Blench.

The author further remarked that Dr. Malhotra had considered that the value of 'N' was high for low discharges and low for high discharges. To a certain extent on the Haveli Canal this could be taken as correct because there was a certain amount of ponding always existing at the tail of Haveli Main Line due to the heading up at Sidhnai and this vitiated the results for low discharges. However, it was pointed out that the high values had been obtained even when the canal was running up to full supply levels in the beginning of the hot weather. Gradually, however, the value dropped and it again started increasing during the months of October and November when also the Canal was running to full supply levels. In view of this Dr. Malhotra's assumptions that the high values should be ignored altogether because they would probably relate to low discharges was

incorrect. In view of these facts the author considered that the value which should be given to 'N' should be for the worst period and therefore considered it safe to be reckoned at ·018 minimum.

Regarding Dr. Bose's remarks the author stated that Mr. Lacey had more than replied to the criticism offered by Dr. Bose and had shown that it was definitely advisable to work on the safe side.

Referring to Mr. Nand Gopal's remarks the author said that he had already stated that the total absorption losses varied from 20 to 80 cusecs. The permissible percentage error in a discharge observation by current meter, was so great compared with actual absorption losses that a very accurate and definite figure could not be given. The fact however remained that the absorption loss was very small. No observations could be carried out to determine the absorption losses on the different kinds of linings because during the repairs no separate reaches had been done with one or the other type of lining. In this connection the author also referred to his remarks in the main paper. For the exact determination of absorption losses for different types of lining it would be necessary to line entire reaches of channels between the various control points with different materials as that alone could give a definite figure for absorption and the value of 'N.' Regarding Mr. Nand Gopal's remarks on the determination of absorption losses in the unlined reach of the Haveli Canal the author stated that the total length being only 2,000 ft. obviously no observation could be carried out to that effect.

Referring to Mr. C. L. Handa's remarks the author agreed with him that if high velocities were obtained in a lined canal the possibilities of silt and insect sticking to the lining would be obviated. From that point of view a lined canal with steep slopes definitely stood on a different footing In the case of Haveli Canal, however, the slope was so flat that possibilities of high velocities were not many.

The author thanked Dr. George Mathai for his remarks in connection with his investigations. Although the question of running a canal to full supply was being solved in a different way the insect insect problem had not yet been solved.

The author thanked Mr. Talwani for giving further information on the subject. The author had qualified his remarks about the use of the lesser sectional areas on lined canals by stating that the value of 'N' should be taken ·018 minimum. This would also cover the defects due to deposit of silt, etc., during low supplies. Regarding Mr. Talwani's remarks about the advisability of adopting a statically sound section the calculations made showed that by addition of the profile walls mentioned on page 103 the increase in cost was very small and therefore this improvement was justified.

The author thanked Mr. R. R. Handa for his remarks and in connection with the laboratory results on brick burning agreed with

him that practical observations were more reliable than mere laboratory tests. The author stated that some of the kilns burnt in connection with the raising and repairs of the lining definitely gave bad bricks in spite of the fact that these had been declared suitable in the laboratory tests. This point could therefore not be overlooked.

Referring to Mr. Sawhney's remarks in general the author stated that the facts had to be faced. The advisability of lining canal was definitely a point which admitted of no further discussions and regarding the practical details it was best to adopt as fool-proof methods as possible keeping in view the various loop-holes that might arise during construction and afterwards.

Referring to Mr. Blench's remarks the author stated that the canal could only be designed as self-sluicing for a definite discharge figure but this would not hold for all cases as the discharges varied between the minimum and the maximum. With this object the author had already recommended not to line canal for the non-perennial supplies. The author had recommended the larger value of 'N' so as to meet the worst cases because it would be more harmful to see the canal not taking full discharge when the demand was keen than see a canal's capacity for taking greater discharges at times. In case a canal could take greater discharge and water was available use for the extra water could be found. Regarding his remarks about the cost of concrete at Rs. 25 % s.ft., the author referred to the various costs given by him which definitely proved that a brick lining was not only the cheapest but also quicker from constructional point of view.

Referring to Mr. Foy's remarks the author considered that such constructional difficulties and defects consequent thereto were bound to upset the smooth flow and therefore it was all the more necessary to have a liberal value for 'N'.

Referring to Mr. Ishar Dass's remarks the author thanked him for a frank expression of his views. Mr. Ishar Dass had, however, criticised the design part of it to which the author had made no contribution and tested it according to his own theory. The author considered it indiscreet to make any comments in view of Mr. Ishar Dass's theory which had yet to be tested in the field.

The author further thanked Messrs. Khosla and Lacey for their remarks.