DISCUSSION.

In introducing his paper, the author remarked that, in February last year he had the privilege of taking the members of the Congress round the works described in the paper. That afforded the opportunity of discussing at site, the various aspects of the scheme. The informed criticism, received at the time, proved to be of very great value. This paper was an attempt to put forward, in connected form, the broad outlines of the scheme, the various details of design and execution and the difficulties and pit-falls, inevitable on a construction of this nature and magnitude. He expressed the hope, that the engineers who had had the experience of the various problems dealt in the paper, would give the congress the benefit of their views and would thus add to that wealth of knowledge which made for improved efficiency and economy.

The author took over charge in January 1934 from Mr. Fletcher. The late Mr. H. W. Nicholson who, alas, was no more in their midst, was the Superintending Engineer at the time.

As stated in the text, the Khanki Weir was the first of its kind to be constructed on the alluvial bed of a river. The life history of this Weir was, in reality, the history of evolution in hydraulic engineering. The early failures on the weir led to the classic experiments of Col. Clibborn. Each subsequent failure or damage called into action fresh effort and fresh ideas and made fresh landmarks in that evolution.

The problems at this weir were so many and so varied that a complete presentation of these within the scope of one paper was impossible. The method of river control and regulation of supplies as between the approach to the pocket and the far arm of the river, was one such problem. The other was to determine as to which of the three systems of regulation would keep the maximum amount of silt out of the canal. These were, the still pond system as followed at Rupar for many, many years and as introduced lately with such success at Marala and Rasul, the partial still pond system as then current at Khanki and the open flow system in vogue on the other Head-works.

Silt exclusion from canals by means of silt tunnels was another such problem. Similar tunnels had been constructed on the Upper Jhelum Canal and on the Upper Bari Doab Canal. A major scheme of this nature was shortly to be executed on the latter canal. The author requested the Engineers connected with these works to give the benefit of their views.

Pressure pipes and model work had played a prominent part on this construction. The results of pressure pipe observations had given the first real warning of the unsatisfactory condition of the weir floor. The tests on models predicted damage and the damage did occur. Further laboratory tests made it possible to effect large economies in the loose protection in Bay 8.

It was also made possible to study on models, with fair degree of confidence, the behaviour of the various energy dissipating devices, namely arrows, raised blocks, stepped compartments, etc.

The laying of concrete in layers instead of *en masse* would call for a good deal of instructive criticism. The correct method of determining the right mix and consistency for concrete and the extent of control to be exercised by the water cement ratio needed discussion.

All steel work on this construction was manufactured and erected by the Superintendent, Central Workshops. It was exceedingly well done. The erection was remarkably quick and in spite of the various alterations that had to be made during the course of manufacture as a result of alterations in design, this steel work was fabricated and carried to Khanki at approximately Rs. 450 per ton or Rs. 50 cheaper than works of similar nature supplied by firms elsewhere. The cost per square foot of gated area worked out to Rs. 45. Kuplus steel, claimed to have considerable rust resisting property, had been largely used on this work. Messrs. Wheatley and Benson would perhaps comment on the use of this steel.

The painting of steel work was a problem of immense interest to the profession. Within the author's experience, no paint stood on the underwater work so well as the one, known as the Khanki mixture. It was hoped engineers who were faced with difficulties of a similar nature would give their views on the subject.

On this construction, the officers were required to be on the work all through the working hours. This was to ensure efficient supervision which was so essential particularly in under-water work and cement concrete. The office work had consequently to be cut down to the absolute minimum. The Sub-Divisional Officers had no more than an hour's office work per day. This system worked well and there was nothing much for the Accountant General to find fault with.

A special feature of this construction was the liberal use of precast units, more particularly, of the precast R. C. troughs on road bridges. In connection with the design of this type it was pointed out by Mr. Kanwar Sain that it was doubtful if good bond could be established between the precast concrete and the concrete laid at site. He felt that the stirrups would not be able to secure satisfactory bond and that the beam would fail in direct shear. To make sure on this point, test troughs were placed side by side and made up to the full section exactly as done in the bridges across bays 4 and 8. The results of these tests indicated that the design was sound beyond doubt. The twin troughs were designed for a working load of 22 tons, that is, 11 tons at each quarter span, the clear span being 20 feet. They stood a load of 110 tons without breaking—a most unusual phenomenon. The first hair cracks appeared at no less than 50 tons with a deflection in the centre of 5/16 inch. The first shear cracks occurred at 81·5 tons. The

elastic limit was reached at 93 tons. All the available steel of the Division was piled up on the composite beam, but the latter refused to break. A description of the tests was attached.

The explanation for this abnormally high factor of safety, apparently, lay in the large number of vertical stirrups, and in the wedge-shaped hollow for the insitu concrete. The present trough having been cured before the insitu concrete was laid, the internal heat generated by the latter as well as its moisture content caused expansion which forced an intimate bond under high compression with the precast work.

The calculations for the bridge troughs were done with the following assumptions:—

Clear span	=	20 ft.
Effective span	=	21·5 ft.
Roadway	=	10 ft. clear between wheel-gaurds.
Loading	=	15-ton Road Roller
Impact	=	+25%

fc=650 lb. sq. inch.

fs=16000 lb. sq. inch.

The bottom level, (739) of the road way was fixed by the free board required above maximum flood level and the top (741·0) level to suit the superstructure.

For the road roller the over-all depth required was no more than 20" or an effective depth of 17." The balance of depth was considered as a wearing coat but it was laid monolithic with the roadway slab in 1 : 2 : 4 concrete.

The precast troughs were calculated as forms to withstand the entire superimposed load of insitu concrete and workmen and also to stand their own weight if suspended from the middle for haulage.

The shear at the contact plane of the precast and insitu concretes was to be entirely taken up by vertical stirrups, no allowance being made for the mechanical bond afforded by the wedge shaped hollow of the trough or by the neat layer of cement grout between the two concretes.

Otherwise the calculations were done on standard lines.

These bridges, although calculated only for a 15-ton road roller were actually strong enough to take almost a B. G. railway train.

Taking the section at maximum depth, the slab thickness is 26" with the C. G. of tension steel 3" above bottom, the effective depth is 23".

The equivalent area of steel is :—

8 bars 5/8" $\phi = 8 \times 0{\cdot}31 = 2{\cdot}48$ Sq. inches.

2 bars 3/8" $\phi = 2 \times 0{\cdot}11 \times 8{\cdot}9 = \frac{0{\cdot}15}{2{\cdot}63}$,,

With fs=16000 lb. and J=7/8,

Safe B.M. $= 1600 \times 2{\cdot}63 \times 7/8 \times 23$ } Per trough of
$= 8,46,900$ in lb. } 17·5" width.

B. M. per foot width $= \frac{8,46,900 \times 12}{17.5}$

$= 5,80,000$ in lb.

$= \frac{WL^2}{8} = \frac{W \times 21.5 \times 21.5 \times 12}{8}$

$= W \times 693.$

W=Load per sq. ft. uniformly distributed $= \frac{580000}{693} = 837$ lb. sq. ft.

Dead load of trough for 26" depth=390 lb. per foot,

or $\frac{390 \times 12}{17.5} = 267$ lb. sq. ft.

Hence equivalent live load=570 lb. sq. ft.

From B.E.S.A. specification No. 153 appendix No. 1 table 4 (Highway bridges) using 10×B.E.S.A. units.

Equivalent load for 21 ft. span $= \frac{2.106 \times 2240}{21}$

$= 225$ lb. sq. ft.

Ditto for 22 ft. span $= \frac{2.148 \times 2240}{22}$

$= 214$ lb. sq. ft.

Thus for a 21·5 ft. span the equivalent load assuming 10×B.E.S.A. units would be 220 lb. sq. ft. against a safe equivalent load of 570 lb. sq. ft. which these bridges can stand.

Tests.—

For purposes of test, two troughs were cast of exactly the same size. composition and reinforcement as the ones for the road bridges across bays 4 and 8. In order to reproduce the exact field conditions the consistency of the mix was controlled by eye judgment and not by water cement ratio or slump tests. One was cast on 10th December 1935 and the other on 22nd December. They were cured as usual.

They were then brought to the supports (Plate VII Figure 4) and placed evenly on the steel bed plates over a thin layer of cement mortar.

The inside of the troughs was carefully cleaned of all laitance, the additional stirrups and top reinforcement were tied in position and the " insitu "concrete laid on 5th January 1936. A thin layer of neat cement grout was applied to the precast work immediately before the insitu concrete was laid.

This composite beam of two troughs was cured with wet gunnies till the 26th January for 21 days. Three days later, *i.e.*, on the 29th January, the loading was started.

The materials used in the manufacture were :—

	Precast work.	*Insitu work.*
Cement.	Rapid hardening Swasticrete cement stored at Khanki since 3rd April 1935 or for about six months before use.	Punjab Portland cement stored at Khanki since 20th May or for 6½ months before use.
Sand	Khanki River sand	
Ballast	Jammu machine crushed ballast.	
Reinforcement	Tata Untested mild steel.	

Swasticrete cement is slow setting but rapid hardening. The comparative strengths of this and Punjab Portland cement are given in Plate VII Figure 3.

The supports were made of 1 : 4 : 8 concrete and were placed exactly 20 feet clear.

The load was applied at points 5' from either end. 7" × 3" channels were laid evenly over a thin layer of cement at these points and 60 lb. flat-footed rails placed in these channels (see Plate VII Figure 5).

The loading was started with 30 feet universal piles each weighing (with clutch) ¾ ton. Subsequently all other available steel was collected and used for loading (see photograph).

Figure 2 Plate VII shows the rate of loading and the resulting deflections at mid span and quarter points.

Figure 4 shows cracks as they stood with a load of 100 tons of which the composite beam accounted for 8 tons and the superimposed load for the remaining 102 tons.

ABSTRACT OF LOADING MATERIAL.

Weight of trough	=8·0 tons.
Universal piles 30' long	=18·0 ,,
Universal piles pieces	=17·7 ,,
Ransomes piles ,,	=17·4 ,,
Mill stones 6 No.	= 8·52 ,,
N. G. Rails	=11·05 ,,
B. G. Rails	= 1·13 ,,
Shutters	=12·65 ,,
Old angle iron	= 5·0 ,,
R. S. Beams	= 5·25 ,,
Channel iron	= 1·69 ,,
Pile driver hammer	= 1·29 ,,
Gate rollers	= 2·48 ,,
Total	=110·16 tons.

The concrete at crack 14 (elevation B)—one of the widest—was cut open and the reinforcement exposed. The junction between the precast and insitu work could not be traced except by a slight difference in the colour of the two concretes. The bond was found to be absolutely perfect. The steel directly at the crack showed a very minute reduction in section. The caliper could not measure the exact diminution.

The beam had extended at the bottom by $1\frac{3}{4}$". The maximum stresses developed in concrete and steel at 110 tons load as worked out by the Author are given below.

" *Calculation of stresses in steel and concrete with* 110 *tons load on the composite twin trough beam.*

The effective span which for calculations was taken as 21·5 feet is now reduced to 20 feet as the beam was resting almost at the edges of supports.

For 110 tons, maximum B. M. $= \frac{110}{2} \times 2240 \times 5' \times 12 = 7{,}402{,}000$ in. lb.

B. M. for each trough $= \frac{7402000}{2} = 37{,}01{,}000$ in. lb.

The safe resisting moment has already been worked out as 8,46,900 in. lb.

The composite trough had thus stood a B. M. $\frac{3701000}{846900}$ =4.4 times the safe resisting moment, without failure. The safe load concentrated at two points 5 feet either side of the centre would be—

$$W=\frac{2\times 846900}{\frac{(21.5-5)}{2}\times 12\times 2240}=22 \text{ tons, nearly.}$$

On application of load, the stresses developed in steel and concrete, do not rise in the same proportion, as with the development of cracks above the neutral axis, the latter rises thus decreasing the lever arm.

As shown in figure 4 Plate VII with the exception of one crack which extended to within 2" of top all the others extended to within 3" of top at 110 tons load. The top 3" of concrete may thus be considered as effective in compression.

Total depth of beam from top to C. G. of tensile reinforcement— .. .. .. 23"

Neutral axis from top .. 3"

Lever arm (C. G. of steel to C. G. of compression) =23– 1=22"

Area of steel as per calculations =2·63 sq. inches.

Equivalent area due to compression bars 2 No. 3/8" ϕ and 2 No. $\frac{1}{2}$" ϕ area=0·612 sq. inches.

At 10" from top or 7" below N.A. (These act in tension due to N.A. having gone up)= $\frac{7}{20}\times 0{\cdot}612$=0.21 sq. inch. Equivalent area due to distribution bars.

3 No. 1/4" ϕ are = 0·15 sq. inch 4" below.

N.A. = 4/20 × ·15= 0·03 sq. inch.

Total tensile area = 2·63 + 0·21 + 0·03 = 2·87 sq. inch.

Mean tensile stress at C.G.=$\frac{37,01,000}{2{\cdot}87\times 22}$ = 58,700 lb.

Tensile stress in the lowest layer = $\frac{58,700\times\left(20-\frac{13}{16}\right)}{20}$

= 61,200 lb.

If f_c be the extreme fibre stress in concrete, then mean compression stress will be $\frac{f_c}{2}$.

$$\text{Hence } \frac{f_c}{2} = \frac{3701000}{(17{\cdot}5'' \times 3'')} \times 22$$
$$\text{or } f_c = 2 \times 3701000/52{\cdot}5 \times 22$$
$$= 6{,}400 \text{ lb.}$$

The distribution bars at top are about 3" below surface and therefore ineffective so far as compression is concerned. But assume that they are placed by mistake only $1\frac{1}{2}$" from top. There are two bars $\frac{1}{4}$" on top of each trough area = 0·1 sq. inch.

Assuming the compressive stress developed in the steel =15 times that developed in concrete at that point this stress comes to $\frac{f_c}{2} \times 15 = 48000$ lb.

Moment of resistance due to compression steel
$= 48000 \times 0{\cdot}1 \times 21{\cdot}5 = 1{,}03{,}000$ in. lb.

If allowance is made for this

$$f_c = \frac{2 \times (37{,}01{,}000 - 1{,}03{,}000)}{17{\cdot}5 \times 3 \times 22} = 6300 \text{ lb.}$$

From the deflection curve Fig. 1 Plate VII, it would be noticed that the deflection varied directly as the load upto about 93 tons, so that the beam as a whole appeared to be maintaining its elastic properties upto that load. At 93 tons the tensile stress in tension steel would be somewhat more than $\frac{93}{100} \times 60000$ or over 50,000 lb. per sq. inch.

The recorded deflection at this load was 0·72" and the calculated deflection assuming n=15 and E=200,000 works out to 1·1". If n=10 which is the value recommended by Turner and Mauer for computing deflections of R. C. beams, then this deflection works out to 0·73" which is exactly equal to the observed.

Conclusions.—

From these tests, the Author derived the following conclusions :—

(*a*) The final failure, if it occurred, would presumably be a tension and compression failure and not a shear failure.

(*b*) Beams of this composite type, part precast and part insitu can be made definitely secure against shear by means of suitable stirrups, aided, as in this case, by the wedge shaped

hollow of the precast work, clearing of laitance and the laying of a layer of neat cement slurry between the two concretes. It was note-worthy, that, while the shear cracks in the end quarter spans did not develop at all, the horizontal crack ($\times\times$) between precast and insitu work appeared for the first time at hundred ton load.

(*c*) The liberal use of stirrups necessitated by the composite form of construction appears to add to the strength of beam both in tension and compression and eliminates danger of failure by shear. It also reduces deflection.

(*d*) A composite beam so designed is actually stronger than one of monolithic construction, owing to the comparatively larger amount of stirrup steel in the former.

(*e*) The Untested Tata steel, used in this test, developed a maximum tensile stress of 61,200 lb. without final failure. The yield point of this steel works out to over 50,000 lb. per sq. inch.

(*f*) The concrete developed a maximum fibre stress of 6,300 lb. to the sq. inch and had not failed. In this connection it should be noted that the cements used had been stored for over six months in which time they are supposed to lose some strength. Also the test was started 24 days after the insitu concrete was laid—the latter being in Punjab Portland Cement. The stress developed is almost 10 times the safe stress assumed for calculations,

(*g*) The test indicated that the Tata steel and the Punjab portland cement could be depended upon to give higher working stresses than the usual 16000 and 650 lb. per square inch respectively, as were then assumed for design of 1 : 2 : 4 concrete. The British standard specifications allowed a fibre stress of 750 lb. per sq. inch. This should be accepted for designs in the Punjab as the Punjab cement, as indicated from the above tests, appeared to be stronger than the standard Portland cement.

Mr. **R. K. Khanna** said that the scheme of reconstruction of Khanki Weir, with which this paper dealt, in Mr. Khosla's own words, aimed at securing firstly, the safety of the weir, and secondly the exclusion of harmful silt from the canal. The bill of cost of actual repairs to damage, to portions of the Khanki Weir, and protection of the weir against future possibility of damage, appeared to be about one third of the total expenditure of fully forty lacs of rupees incurred on the reconstruction of the Khanki Weir. The remaining two thirds, or at any rate, considerably more than one half of the expenditure was incurred on measures for the exclusion of harmful silt from the canal. And, whereas,

quite an imposing description of the measures adopted for sending all but filtered water into the canal had been given, no mention was made of the actual achievement in this direction, unless the following brief sentences were intended to convey an idea of the sum total of the success of these measures.

Page 111.—

"These tunnels have proved to be quite effective in silt exclusions. Their efficiency is being carefully tested since 1934."

Page 114.—

"With the construction of the above works, and the partial still pond system of regulation, it has been possible to effect a considerable improvement in the silt conditions of the canal ; and if the anticipations are fulfilled, the silt trouble on this canal may disappear, and the stable conditions obtaining on the Sirhind Canal may be obtained in this case as well."

These few extremely vague words about the efficacy of the measures for silt exclusion from the Lower Chenab Canal, which have cost the province a treasure, hardly offer any justification for the expenditure of a sum of money for which a new weir could have been built. Mr. Khanna wondered whether the careful tests of the efficiency of silt ejector tunnels, or observations of the performance of the depressed 4th and 8th bays, had not already shattered the high hopes formed of their success, that it had been found expedient to avoid entering into unnecessary details of an unpleasant topic. When the silt tunnels were under construction some people actually entertained serious apprehensions about the safety of some bridges, from excessive scour of the canal bed, as a result of heavy silt exclusion by these tunnels. One season's working of the tunnels removed the apprehensions, but still kept up somewhat subdued hopes of their success. Later on came the stage of proving the success of silt tunnels by selected data of bed scour and improvement of the Canal. Finally all hopes were centered on future anticipations, and if these anticipations are fulfilled, the silt trouble on this canal might disappear, and the stable conditions obtaining on the Sirhind Canal might be obtained in this case as well.

Mr. Khanna asked what was that which kept alive false anticipation in face of repeated failures of all measures for improving the capacities of channels by the exclusion of heavy silts from them ? Apparently the wrong idea that heavy silts in flowing water caused silting up of channels still persisted. The following paragraph from Mr. Wood's paper No. 23 of the Punjab Irrigation Branch, which Mr. Khanna had already twice quoted elsewhere, should dispel the impression that the silting trouble of the Lower Chenab Canal was caused by heavy grades of silt, and that the exclusion or elimination of heavy grades of silt would put an end to the silting trouble.

" The Sirhind Canal with a discharge ranging up to a maximum of 8500 cusecs, works to a bed slope of 1 in 8000. Its offtake from the Sutlej, at Rupar, is much close to the point of emergence of the river from the hills than that of the Chenab canal at Khanki ; and therefore the river silt at Rupar must be of coarser and heavier quality than that of the Chenab at Khanki. The Chenab Canal, therefore, with a discharge ranging upto a maximum of 10700 cusecs, ought to work to a flatter bed slope than 1 in 8000 ; whereas in practice it has hitherto always remained silted up to a steeper gradient than 1 in 6250."

These remarks were perfectly correct. Silts entering the Sirhind Canal at head must necessarily be heavier and coarser than those entering the Lower Chenab Canal at Khanki, and yet the Sirhind Canal with considerably less discharge than that of the Chenab Canal, worked at flatter gradient than the Chenab Canal. In the case of the Sirhind Canal the improvement was generally attributed to the " Still-Pond " system of regulation. But Mr. Khosla, and old Roorkee Engineers must be remembering the manner of feeding the Upper Ganges Canal before the weir and regulator at Hardwar were built. A temporary wooden structure in the form of a groyne was built in the river for diverting the stream into the canal in winter. In summer, water from boulder strewn torrential river flowed straight into the canal. For seventy years or more water of the Ganges, without being subjected to the silt extraction treatment, fed the Upper Ganges Canal, without any silting trouble on the canal. The Western Jumna Canal had been similarly fed from a steep, torrential river for three quarters of a century. Since silt extraction came into vogue, the speaker understood, they had suddenly discovered that that canal was also suffering from silt trouble.

Continuing the discussion Mr. Khanna said that, as pointed out by him in a pamphlet, entitled "Silt Theory of Flow of Water" just published, the grades of silt that line the beds and sides of natural and artificial channels were entirely determined by the slopes and volumes of flow of those channels. The very existence of a fall, a rapid, or a steep sloped stretch of a river, a stream, or an artificial channel, implied that the materials, lining the particular channel at the fall, the rapid, or the steep sloped stretch, were strong enough to withstand the force of flow. Flowing water possessed the attribute or quality of transporting materials required for lining its channels suitably. Silt extraction by the silt excluding devices, and twisting and turning of a stream, or a channel, to divest it of the materials provided by nature for preservation of its regime, could never effect improvement in the condition of channel, by defeating the forces of nature. If silt free channels were required, we must guide and humour nature and not oppose its forces. And after all, silt trouble was not much of a formidable and insurmountable trouble. This was of quite a recent origin, and had been accentuated by our mistaken belief that the quantities and grades of silt in suspension in water were the cause of this trouble. Simple hillsmen who made and maintained their little irrigation channels from the hill torrents, and

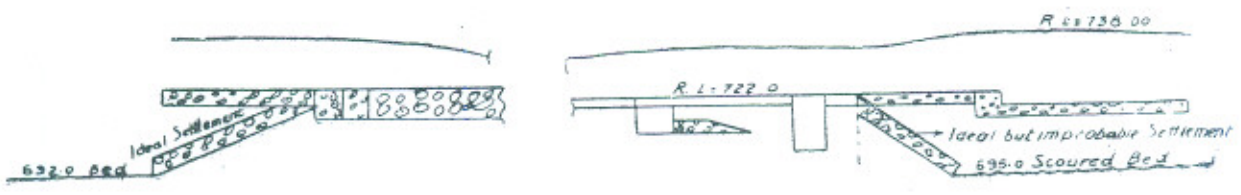
plain villagers, who irrigated their fields from the inundations of rivers, did not suffer from the silt trouble. And if we left our channels alone, and took a few ordinary precautions for their maintenance and upkeep, we would find that silt in suspension in water was a blessing of nature, and not a curse.

Mr. **Blench** congratulated Mr. Khosla on his lucid exposition, and valuable data. The work required no comment, as it had been seen by the Congress last year, and there was no doubt as to the excellence of its execution.

Like Rasul Headworks, and other old river works Khanki was suffering from being far too broad, even for a record flood. The regime breadth for 8 lakhs was about 2,400 feet against the approximate 4,000 feet of Khanki. The result is a bela and two distinct channels, even in record flood. The channel on the canal side normally tends to development, pulling the major silt charge with it. Thus, at Rasul, after a season of careful shutter regulation in an attempt to equalize the two river channels it was found that the most prevalent silt diameter in the right channel was less than 0·20mm, whilst that in the left (canal) channel was over 0·30mm. One might reasonably expect the right and centre under-sluices at Khanki to reduce silt trouble in the canal, if properly used.

One design point seemed to have been neglected. It was the unfortunate custom to interpret flood damage in terms of water-level only. The flood bed-level was just as important. It might be assumed as follows. Suppose a flood to divide into two main channels taking 3/8 each, and a central shallow one taking the remaining 1/4. Take 8 lakhs as record flood. Then it was required to find the deepest bed level (neglecting local whirlpool action) in a channel of 3 lakhs discharge. Lacey's $Qf^2 = 3.8V^6$ taking f as approximately 1·00. This gave a mean velocity of 6·55 feet/sec. Now use his $V = 1.15 \frac{\delta}{\sqrt{fR}}$, giving R=32·4 feet. R would be very nearly the mean depth. Assume elliptic section, so that maximum depth would be 1·27 times of the mean, and we get maximum depth 42 feet nearly. This meant that in a flood of record level 738·00 (as per Mr. Khosla's paper) we should expect a river bed level of 696·00.

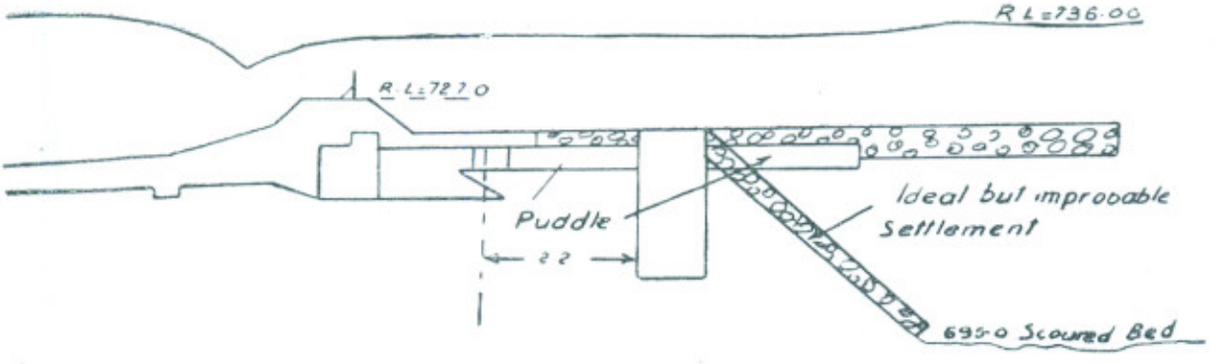
These conditions are shown in the sketch below, on the section depicted by Plate II Figure 1.



It will be seen that the river bed is below the lowest weir foundations. If the loose stone upstream and downstream could settle as shown the weir might be safe. But it would certainly not stand on sand in such conditions. The stone coated slope would collapse, and the sand below the 42-foot upstream floor would settle in sympathy, along with its own block coating. Assuming total collapse did not occur, a hollow would be left after the flood, and the effective length of the weir reduced. In addition to the effect mentioned the depression head over the 42-foot length would lead to blowing up as soon as hydrostatic connection was effected between upstream and the underside of the floor. Thus, it was quite clear why the old weir gave trouble. Every big flood must have added to hollowness, which would be detected in times of heading up. The speaker thought, it was also clear why weirs of the Sutlej Valley Project type were far sounder than the old over-broad ones in times of flood.

The record flood water and bed levels for the section shown by Plate III, Figure 2, are shown in the following sketch:—

PLATE III FIG: 2



Only upstream need be considered, as downstream was manifestly safe. Here, as in the pre-reconstruction design, there was every danger of hollows forming under the 22-foot floor upstream of the 30-foot pile line, a somewhat remoter chance of it occurring downstream of the 30 foot pile line ; a very good chance of the upstream portion being damaged under depression head when it acted as a weir 27 feet above river flood bed.

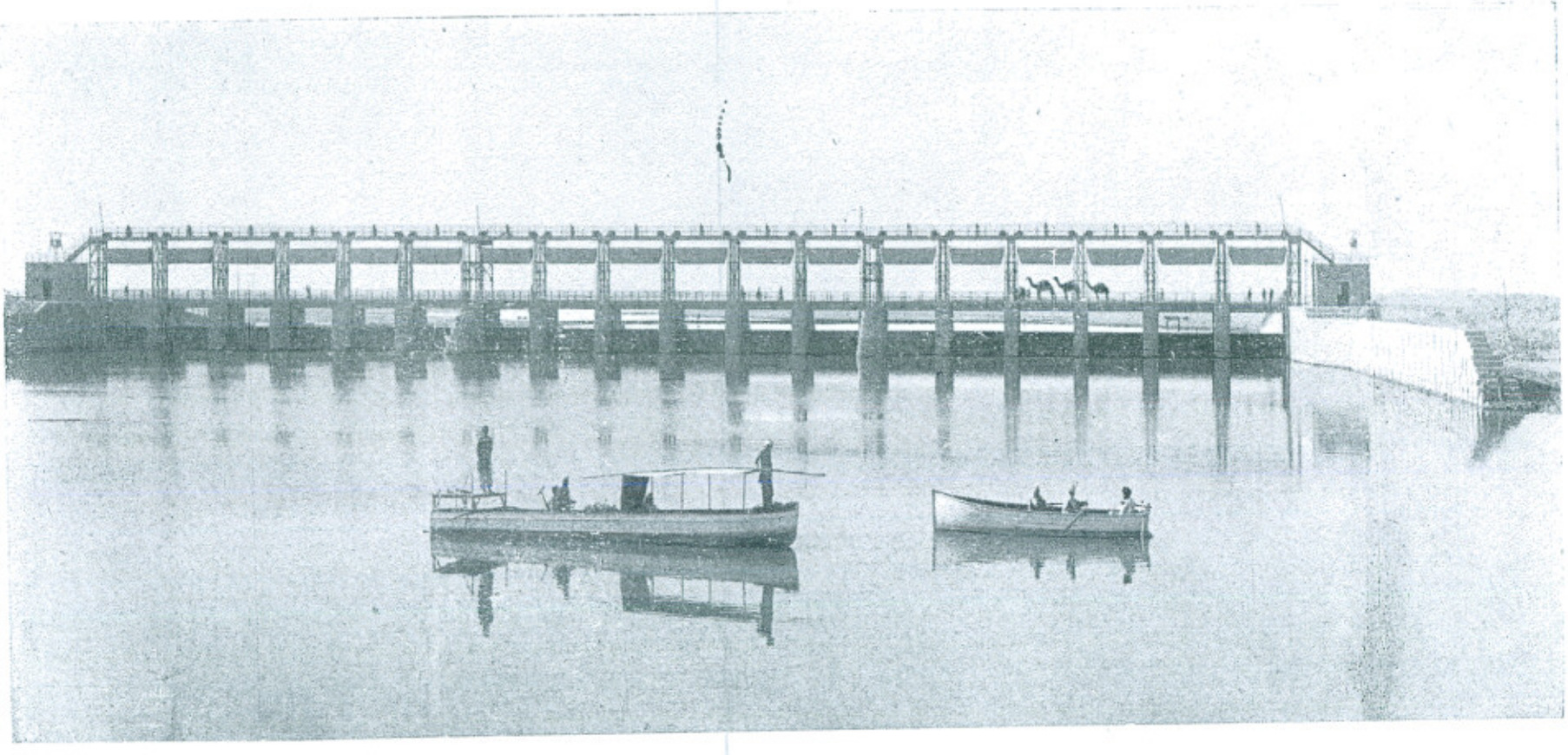
Applying the same test to the undersluice bays it appeared to the speaker that they were reasonably safe, thanks to the lower upstream floor level, and the much longer upstream flexible protection.

That these calculations were sound was proved at Rasul where a little over 8 lakhs had been experienced, and the weir badly damaged, the centre of Bay 4 being completely washed away. The flood level upstream was approx. 724·0. The upstream floor level was 708·0 about. The wells did not go below the gravel bed at 688 level. Calculating as for Khanki, but taking f about 0·95 we find that the river bed must have been down to 45 feet below F. S. L. *i.e.*, 679·0 level. The record plan of repair to Bay 4 showed that the stone profile (used in closing off the work), situated 115 feet above the most upstream portion of the reconstructed upstream loose protection was laid at 678·4 R. L., a striking confirmation of the results of up-to-date theory.

The speaker concluded that Rasul was saved by the gravel bed ; and in the next 8 lakh flood it might be expected to fail wherever the gravel bed was damaged last time, unless, of course, the divergence of flow that might be produced by the presence of the weir was felt at the upstream end of the protection, and counteracted the possible local whirlpool action.

Mr. **Kanwar Sain** congratulated Mr. Khosla on the successful completion of the reconstruction of the Khanki Weir as undoubtedly remodelling of the existing weir on the scale it had been done at Khanki, was a far more difficult job than building an absolutely new weir, specially as the quantities of most items were not less than some of the S.V.P.weirs. The actual work in lowering the floors of bays No. 4 and 8 must have presented a lot of constructional difficulties and fully taxed Mr. Khosla's professional capabilities.

The cost of the original Headworks was a little over 28 lacs, while the cost of reconstruction was Rs. 38 lacs, even though the work was done at remarkably low rates. One would feel inclined to say that this was a case of " *dhele ki burhia takka sir munai* ", but as Mr. Khosla has pointed out on page 110, the stakes involved were too great for the Government to adopt a policy of "Wait and See ", before incurring the heavy expenditure. In the beginning when the canal had been opened, perhaps the great success of the colony could hardly have been pictured in their minds by the first builders of the canal, but those, who know the Lyallpur colony as it existed at the time of speaking, would be stunned to imagine the results of a general collapse of the Lower Chenab Canal system. Mr. Darling, Financial Commissioner, Development, in his book " The Punjab Peasant in Prosperity and Debt " page 275 had drawn attention to the effects in this area, if there ever were a decrease in efficiency and security in the canal administration of the province. He asked " How could the million inhabitants of the Lyallpur colony exist if the Headworks of the Lower Chenab Canal were destroyed ? " If such a catastrophe actually happened, many, who were thriving, would be reduced to beggary. In its potential effects it might be a bigger calamity than even the Quetta Earthquake.



Upstream view of Central undersluices (Bay 4).

There were certain points, however, to which the speaker took objection. On page 113, Mr. Khosla had said." For efficient functioning of the above scheme it is also necessary that the bela should remain stable as far as possible and the nose held in its present place. This could only be secured with doubtful certainty by extensive protection which was found to be prohibitive in first cost and in subsequent maintenance. This part of the work was, therefore, dropped. A shifting bela necessarily adds to the silt trouble in the canal." Now the justification for depressing the bays No. 4 and 8 was also the necessity for silt exclusion. As a silt ejector had been added in front of the head regulators at Khanki, the necessity of constructing two costly undersluices for silt exclusion might easily be questioned, specially, as pointed out by Mr. Khosla himself, the efficient functioning of the undersluices depended on the stability of the bela, which work could not be undertaken on account of prohibitive expense. There was another objection to the central undersluices, *i.e.*, if there ever be any trouble during floods on this set of undersluices how would relief measures be arranged, as it was so far away from either of the banks and trouble in undersluices was by no means an unusual feature. The weir as it stood then along with the undersluices was capable of passing the maximum discharge of 800 000 cusecs with the same high flood level upstream. The actual maximum flood at Khanki according to Executive Engineer, Discharge's report of 1929 was only about 625,000 cusecs. This would indicate that the central undersluices could easily be left out, so far as flood considerations were concerned.

The second point which the speaker referred to, was the water cement ratio. Mr. Khosla did not seem to attach much importance to the water cement ratio. This, however, appeared to the speaker to be avery important point as there was always a tendency inherent in the contractor and the labour to put in rather too much water in order to increase workability. The difference between sloppy and workable concrete would be realized from the following instance :—

Slump 10 inch very sloppy ; 7 days' test 1500 lb. per sq. inch ; 20 days' test 2590 lb. per sq., inch. Against this, the same concrete with 5 inch slump gave a strength of 3020 lb. per sq. inch on 7 days' test and 5010 lb. per sq. inch on 28 days' test. It was no secret why concretors liked sloppy mixtures, but it was high time to realize how much strength and density was lost by superfluous water. It had been stated somewhere in the Concrete Year Book that every excess pail of water killed two pails of cement and this was by no means an exaggeration.

Mr. Khosla had laid a lot of stress on the virtues of laying concrete in layers as against putting the whole depth at the same time. He had stated that at Merala, Rasul, Ferozepore and Islam Headworks concrete put in horizontal layers separated due to three causes. So far as the speaker knew, at Suleimanke the trouble referred to by Mr. Khosla was really on account of a very quick setting cement having been used—tests

at Alipur showed that the cement took its initial set within 5 minutes. Bills of the firm for several wagons of cement which had failed to comply the setting test were rejected. Mr. Kanwar Sain asked if Mr. Khosla could say that the Engineers who had built Merala, Rasul, Ferozepur and Islam Headworks did not know that the presence of laitance or dirt between two layers was objectionable or that cement mortar was required between two layers or that the old concrete had to be properly cleaned, but even in spite of this,—and it could not be said that they were less keen about the workmanship of their weirs—those weirs came to grief on this account. As a result of this experience, at Panjnad the whole concrete was put in simultaneously before the lower layers had taken a permanent set. The speaker thought that Mr. Khosla had not been able to make a strong case to come back to the old method of putting concrete layers. He took his points one by one.

On page 123 Mr. Khosla gave the draw-backs of putting the concrete *en masse*. His first objection was the existence of vertical joints. On the reverse the speaker's objection to putting the concrete all in horizontal layers was the absence of clear expansion joints. He asked Mr. Khosla if the vertical joints at Panjand had given any real trouble.

Mr. Khosla's second objection was the difficulty of clearing the deep joints under the overlapping layers of surface reinforcement projecting from the adjoining blocks. If there was a through vertical joint the necessity of overlapping of the surface reinforcement hardly arose. Also if premolded expansion joints were used in the work as explained in Paper No. 181 presented to the Congress last year, this difficulty would disappear.

His third objection was the indeterminate internal stresses set up in thick mass of concrete due to the setting heat of cement. So far as the speaker had been able to study this point, the variation in small thicknesses of 5 or 6 feet should not worry anybody specially as it was so easy to keep the whole concrete immersed under water after a few days of its being placed.

His fourth objection was additional expense. If the stock length of bars was 40 feet, the joints could easily be spaced 40 feet apart. There was not a single joint at Panjnad which was so small as 12 feet in any direction. In Paper No. 181 presented to the Congress last year already referred to, the suitable spacing for joints had been suggested as 30 to 60 feet. In fact if proper clear expansion joints were provided, the cost of overlaps which had been given by Mr. Khosla as 5 per cent. for concrete being laid in layers would be saved, and this could easily cover the expense of providing the expansion joints. Mr. Khosla did not take into account the cost involved in cleaning the horizontal layers and of adding cement slurry before adding the fresh layer and of putting in vertical reinforcement to tie the horizontal layers, and these items should mean a fairly considerable amount of expenditure. At Khanki $\frac{5}{8}$" vertical rods had been

placed at 5 feet intervals. Now the tensile strength of $\frac{5}{8}$" bar was 624 lb. Over a width of 5 feet this gave 10 lb. per inch width, while one degree change of temperature alone was capable of producing a force of 13 lbs. per sq. inch in 1 : 2 : 4 concrete. Only time would prove if the measures taken at Khanki to join the horizontal layers were adequate.

His fifth point was that in the case of vertical joints the entire floor thickness had to be the same mix. At Panjnad the lower layer was 1 : 4 : 8 and the top 1 foot was 1 : 2 : 4 and the speaker said that it was found possible to put the upper layer before the lower layer had taken up a permanent set. In any case if any difficulty in doing this it was experienced, one might choose. as a lesser evil, to allow one horizontal layer by ensuring to put in sufficient vertical reinforcement and standing the extra expense of putting in cement slurry and cleaning the top surface of the old concrete perfectly well before putting in the fresh concrete. One would be sure of doing this if only one layer had to be done in this way rather than several.

The idea of putting in a slightly richer mix in the lowest layer in contact with sand appeared to be a very commendable one.

The next point which the speaker referred to was regarding concrete laid by baskets. Mr. Khosla had suggested putting in concrete by baskets. He had two objections to the method of putting in concrete directly from the tipping trucks :—

(*a*) that it was impossible to keep off the sand on the wheels and other foreign matter getting mixed up with the floor concrete.

(*b*) that in long leads segregation of mortar resulted.

The first difficulty, Mr. Kanwar Sain thought, could be overcome by laying the track for the tramway on wooden sleepers higher than the sand surface. Regarding the second objection for small leads, the trouble of segregation should not be felt, specially if too much water was not used in the concrete.

In this connection the speaker drew attention to the British Code of Practice for Reinforced Concrete which was perhaps the best authority on the subject.

Under the sub-head " Transporting Concrete " in clause 401 (*b*) it states " Concrete shall be handled from the place of mixing to the place of final deposit as rapidly as practicable by methods which will prevent the segregation or loss of ingredients. It shall be deposited as nearly as practicable in its final position to avoid rehandling or flowing ". In difficult situations rehandling may be unavoidable, but to make rehandling a rule appeared to be an unnecessary expense and delay in placing the concrete in its final position after water had been added to it. In fact the transporting method should be such as would

produce no segregation. The method of transporting wet mixed concrete in tramway tipping trucks for long leads did cause segregation. Several methods were used in up-to-date countries to overcome this objection, but all such methods might prove more costly in India, as compared to rehandling by baskets. If the whole process was likely to take more than 30 minutes, the minimum time allowed for the initial setting of cement, it was suggested that only dry ingredients should be mixed in the mixer and carried in tipping wagons, water being added at the other end. The time of rotating the mixer drum could be reduced to half for dry mixing and some saving effected in this way to meet the extra expense in double handling.

Mr. **Raghbir Singh** said that Mr. Khosla's Paper was very exhaustive and did not permit of any elaboration. He had dealt with all constructional details in full. He had only a few words to add.

The author had described how and why the main glacis concrete was laid in layers instead of the full depth in the one layer. In this connection he (the speaker) mentioned that all concrete of the glacis at Suleimanke Headworks was laid in layers, but before commencing the next one, the top surface of the old concrete was chipped and thoroughly cleaned with wire brushes so as to expose the aggregate. A thin layer of neat cement slurry was laid on the top immediately before placing fresh concrete of the next layer. After the Islam disaster, trial pits were made during 1930 in the glacis to find out the state of the concrete, and it is mentioned on page 1 of the history of Suleimanke Headworks for 1929-30 that the concrete was not found in layers. This shows that if proper care were taken in cleaning up the surface, the danger of the layers separating was greatly minimized. The speaker said that as in other human affairs so also in laying concrete, cleanliness was godliness.

The technique of laying concrete in layers had further advanced at Khanki, and vertical reinforcement and binder plumbs were such positive ties that one need have no fear in the matter. In addition the binder plumbs secured quite an appreciable economy in cement.

Another point, the speaker continued, was that good concrete could only be produced with good supervision, and this required the whole time presence of the officers on the spot. At Khanki the Sub Divisional Officers were on the work from sunrise to sunset and even later. The office work was cut down to minimum. There was no correspondence between the Executive Engineer and the Sub-Divisional Officers or between the Sub-Divisional Officers themselves. As to the Overseers they had no office work at all.

Decisions were made on the spot by mutual consultation between the officers. This ensured promptness and encouraged team spirit. He said that in spite of the heavy construction, the routine office work took him half an hour a day on the average, and that half an hour had often to be found before sunrise.

Mr. Khosla had described the various difficulties that had to be faced in connection with unwatering and heavy pumping. The main thing in pumping is the judicious location of the sumps, and the desirability of keeping the leading drain clear of silt, so that as far as possible clear water enters the sump well. If sand is allowed to go in with the water not only does expensive dredging become a necessity, but the pumps wear out and require constant renewal. At Khanki the impellers were renewed once a year, if at all.

The author had mentioned a saving of 6 to 8 feet of lift in pumping by the construction of unwatering opening under the marginal bund but it was not only that. It meant all the difference between success and failure. The addition of 6 to 8 feet in lift would have required a double stage pumping arrangement for which five additional Steam portable engines with 8 to 10 inch pumps would have been necessary, and these were not available at Khanki or anywhere else in the Province and if obtained new they would have arrived too late to be of any use.

Lastly the speaker dwelt on another important aspect in the organization of this work, the strict enforcement of sanitation on the work, and in the material yards. The medical needs of the labourers were fully met and due regard was also paid to that of donkeys and camels of whom nearly 2000 were employed on the work. Suitable steps were taken to prevent spread of epidemics A sanitary inspector with a gang was employed the whole time. The water supply for the labour camps was arranged from tube wells and hand pumps. The works were occasionally visited by the District Medical Officer of Health.

Mr. **C. L. Handa** dwelt on certain aspects of the reconstruction work at Khanki.

On a job of this magnitude the organization and transport of materials formed an important factor. In recent constructions elsewhere railway sidings were available right upto the mixers. At Khanki it was a case of rejuvenating an old weir, part of which had to be kept open for floods. Thus it was not possible to make embankments for sidings. The rail-head being on the left bank every bit of material involved a carriage of one to two miles on pack animals through a congested route. During the rush as much as 30,000 cubic feet had to be carried in a day and most of it between the hours of 10 p.m. to 7 a.m. The total carriage amounted to 60 lakhs of donkey miles or two hundred trips of a loaded donkey round the world.

The main route for carriage was uncertain and liable to interruptions during freshets. Thoughtful reserves had therefore to be provided in the Weir. During the second season, the freshets were persistent and prolonged and practically no carriage could be done for a whole month in February.

The situation would have been pretty awkward but for the huge reserve of ballast that had been built up in time. During this period sheet-piles, steamcoal and cement were carried across in country boats which had to be collected at short notice.

On page 126 of his paper, Mr. Khosla had made mention of the liberal use of precast units. The pier noses, fish tails, wheel guards, coping stones, in fact all special stones of intricate shape were cast in specially made moulds in 1 : 2 : 4 concrete.

These units accelerated the speed of construction and provided a harder surface than would have been possible with dressed sandstone. Expensive dressing was also saved. This alone would have run into fifteen thousand rupees on a job of this magnitude.

The main advantage, however, was in bridges where the precast troughs straight away provided a working platform for the erection of steel-work. The troughs were capable of carrying heavy loads and the erection of gates and the completion of the bridge slabs were on simultaneously.

Before closing the speaker referred to the unwatering culvert in the Right Bank mentioned by the author on pag 129. The culvert consisted of two barrels 5′ ×7′ ×125 feet long. The height of fill was 24 feet above the bottom of founds which were 6 feet below spring level. Apart from the facility that this gave to pumping operations, it had a special interest for the engineer in its mode of design and construction. The floor was reinforced for uplift pressure and the reinforcement was carried into the abutments through toothed vertical grooves that were left in the brickwork. The abutments thus formed cantilevers after the bars had been concreted in. The centering for the roof slab consisted of sand-filling lightly plastered over. The actual work was fairly simple and involved a minimum of forms. It was completed in about 3 weeks. This concrete-cum-brickwork construction reduced the sections to almost half and cut down the cost by 40 per cent and had great possibilities both for speed and economy.

Mr. **M. L. Batra** congratulated the author in describing in great detail the Reconstruction of the Khanki Weir. The author on page 128 had made a brief mention of the paints used for painting the new steel-work in Bays 4 and 8. Evidently the experience gained at Panjnad and Khanki by the author was ignored and Wailes Dove Bitumastic Solution and Anodite Paints tried on whole Bays 4 and 8 respectively for underwater work and Khanki mixture could not find a place at Khanki itself. The protection of steelwork under water was of great importance. At Panjnad Headworks, the weight of the steel in gates was about 1120 tons and cost approximately Rs. 5,39,000. Various paints had been given a trial since the construction. Originally 33 gates were painted with Barico grey, two with Wailes Dove Bitumastic Solution, and two with Gouremastic black solution. Barico grey failed hopelessly

and heavy pitting resulted which was in places as deep as 1/32nd of an inch. Considering that the thickness of the skin plate of these gates is only $\frac{3}{8}$" this was pretty bad. Khanki mixture stood the best followed by Wailes Dove Bitumastic Solution. Trials were subsequently made with Siderosthen and Stablex paints but these also did not stand well. Khanki mixture had so far been found to stand best and was also the cheapest paint for the purpose, although it was difficult to apply and took somewhat long in drying. It was, however, found possible to paint the underwater portions of the Panjnad gates in a 20 days closure with good results though the paint did not completely dry before submerging. Attempts to get a quick drying paint should not be given up.

The success of the Khanki mixture as of any other paint depended on the care with which the steel work was properly cleaned up.

The following conclusions were arrived at during the year to year painting at Panjnad :—

(1) Only actual rust should be scraped out and the paint where it has life in it should not be scraped.

(2) Scraping should be done thoroughly so as to expose the metal with case hardened keen edged steel scraper. No paint or rust removers should be used. Dry sand may be rubbed after scraping to clean properly.

(3) Sand blasting is too expensive and too slow.

(4) No oil should be used in cleaning.

(5) The best and the cheapest paint to use is the Khanki mixture. The scraped patches should be covered at once with one coat of this paint preferably during the better part of the day. The whole of the surface can then be given the requisite number of coats according to the condition of the steel-work.

(6) Good care should be taken during painting to thoroughly examine the surface after painting for any pin points or bubbles left as these give rise to rusting. These when found should be touched at once. The surface must not simply be painted with straight strokes of the brush but the paint should thoroughly be brushed into pits by strokes of the brush at right angles to the plate and all joints and rivets should be effectively sealed.

(7) Each painter should have the Khanki mixture in specially prepared cans to contain about $\frac{1}{2}$ gallon of the paint with arrangement at the bottom for accommodating burning charcoal to keep the mixture hot.

(8) It is well to give a coat of Khanki mixture every year to the underwater steel work.

(9) When originally painting steel-work two to three coats are sufficient.

The method of preparation is detailed in Article I, Paragraph 54 of the Handbook of Professional Orders. The mixture consists of coal-tar, mineral pitch, slaked white lime or preferably cement and kerosene oil in the following proportions :—

Coal Tar	..	84 lb.
Mineral Pitch	..	10 ,,
Cement	..	9 ,,
Kerosene Oil	..	9 ,,
		112 ,, =1 cwt.

The mixture is prepared by heating the pitch and coal tar separately, then mixing them over a fire and stirring well and adding cement gradually while stirring, then withdrawing from fire, adding kerosene oil and stirring well. The mixture should be heated to 350° to 450° F. Overheating will burn the mixture. The covering capacity of the Khanki mixture is 2500 s. ft. to a cwt. and the cost of 2 coats of paint including hot application and all costs but excluding the cost of preparing the surface works out to Re. 1-8 per % s.ft.

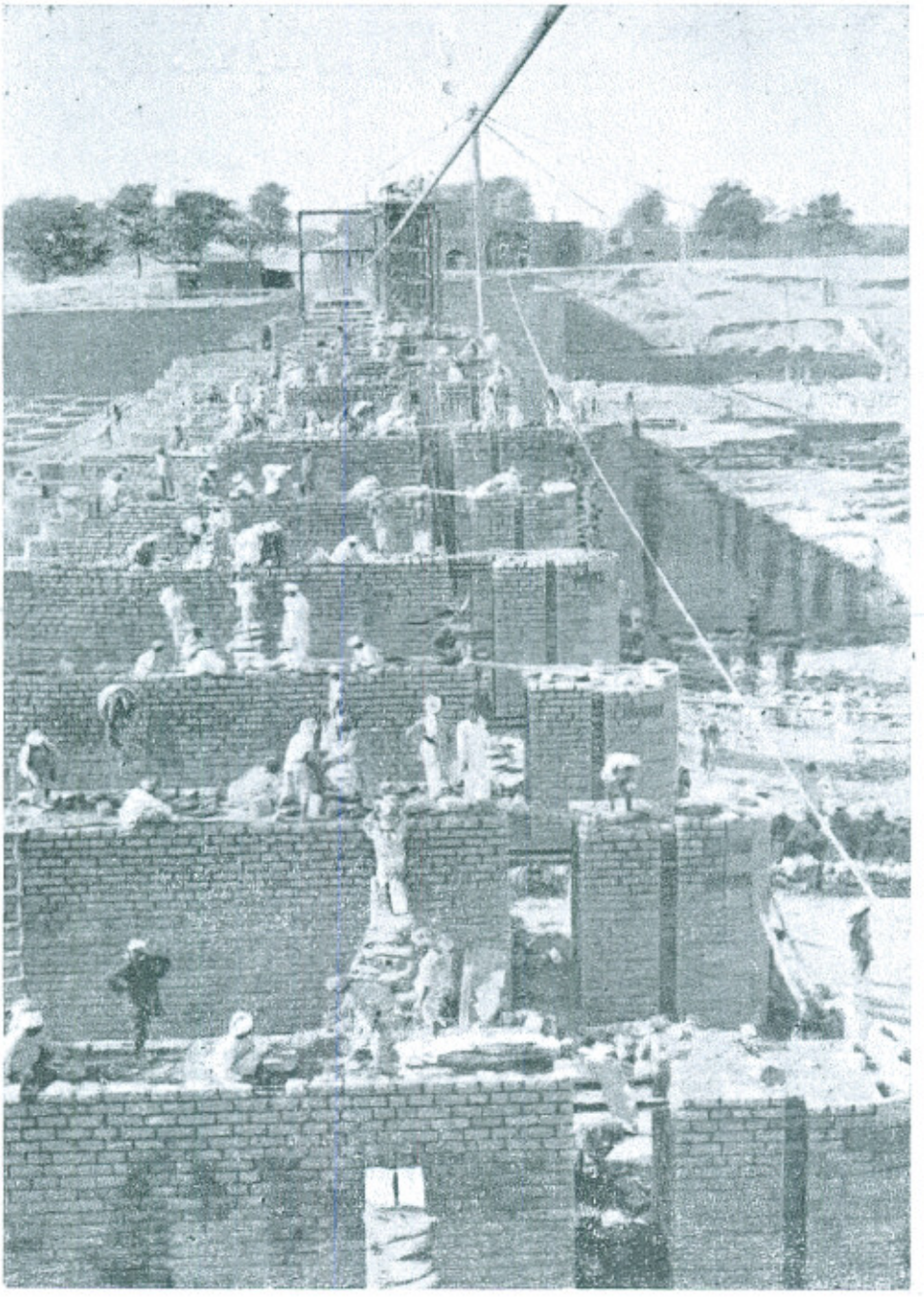
Mr. **B. K. Kapur** congratulated the author on his comprehensive and interesting paper. The scheme of reconstruction of the Weir as stated on page 110 aimed at securing the safety of the Weir and the exclusion of harmful silt from the canal.

The cost figures given in Appendix V showed that the silt excluding devices alone cost more than half of the total cost of about Rs. 38 lacs, and their efficacy was till then very doubtful.

He suggested that the object aimed at could have been attained by depressing bays No. 4 and 8 by 2 feet and having 8 feet shutters in these two bays, thereby saving about Rs. 12 lacs.

In Appendix VII, the author had calculated the discharge through the undersluices by the flume formula, perhaps because a standing wave formed below the undersluices. The speaker suggested that the actual discharge through the under sluices might be about 20 % less as they would work as submerged orifices .

On page 112, the author stated that the object of the Central and the Right undersluices was to establish and maintain certain conditions of curvature of flow, but he contradicted himself on the next page, when



Piers of Bay 8 in progress.

he said that for an efficient functioning of the scheme it was also necessary that the bela should remain stable as far as possible and the nose should be held in its place. This work was stated to have been dropped on account of its " prohibitive cost" and " doubtful certainty."

As regards the silt tunnels, these could be worked only during the summer months and even then their effect was only on a part of the water flowing into the canal, while the major portion of the canal supply was drawn from the part of the pocket beyond the tunnels and thus the effect of these tunnels, if any, was greatly mitigated.

He agreed with Mr. Khanna's remarks that the tunnels would remove some of the coarse silt, but not all, and that if the water entering the canal contained even a small percentage of these coarser grades of silt, these would settle down in the bottom, thereby nullifying the effect of the tunnels.

He suggested the construction of a divide wall about 100 feet from the Head Regulator, thereby dividing the pocket into 2 parts. This was sure to reduce the silt trouble as well as to stop the silting of the pocket. It would also greatly facilitate regulation as it would be possible to keep the undersluice gates open, and keep the pocket clear, without closing the canal.

It might be mentioned that the silt deposit in the pocket in front of the Canal Head could only occur if the cross sectional area of the pocket was more than that required for the supply passing through it and if this area were reduced by the construction of a divide wall as suggested above, no silt could possibly accumulate in front of the Canal Head.

In this connection the speaker quoted the remarks made by Mr. Woods on page 18 of the Panjab Irrigation Branch Paper No. 23.

" Engineers who have dealt with the control of the Head Works of the Lower Chenab Canal at Khanki during the past 20 years have shown a general disposition to attribute the periodical increase or decrease of silt deposits in the head reach of the Canal to the direction of a set of the river currents, towards or away from the Canal Head, or to methods of manipulating the gates of the weir sluices or the Weir. And they have devoted their attention chiefly to controlling the direction of the local river currents by building groynes or spurs in the river upstream and downstream of the works, or else they have blamed these same spurs for failure of operations to exclude excess of silt from the Canal."

An analysis of the data given by Mr. Woods also showed that shoaling always occurred in front of the Canal Head Regulator when the quantity of water passing through the undersluices was not sufficient to fill the entire cross sectional area of the pocket.

On page 114, the author had referred to the change in hydraulic conditions caused by the withdrawal of silt from the Canal. The speaker pointed out that during winter there was no supply passing below the Weir, while during summer the discharge passing into the Canal was so small as compared to the supply in the river that a little silt exclusion could hardly have any material effect on the slope of the river bed.

The cause of this rise below the Weir might be due to the fact that before the construction of the Weir, the water flowed in a number of small channels which could work with a flat gradient, while after the construction of the Weir, the water was regulated to pass through each bay of the Weir in turn to keep the channel upstream clear, and this resulted in a wide and shallow channel downstream, which required a steeper slope to overcome the increased frictional resistances of the bed. This rise could perhaps be arrested by running the normal river supply through the three undersluices which were made available after the remodelling and dropping the shutters only in floods.

As regards the construction itself after congratulating the officers in charge on their high standard of workmanship and efficiency, the speaker offered the following remarks :—

He suggested that the arrows might be more efficient if the arms were made to slope up from the nose downwards.

The difficulties, pointed out by the author in the case of laying concrete in one day in the entire thickness were rather imaginary, and it was not always necessary to leave vertical joints, nor was there any difficulty in clearing these joints. He did not agree with the author that additional expense was involved in the overlaps in the reinforcement.

In fact in the case of the Deg Fall it was found more economical to lay the concrete in one mass, and a big saving was effected in the quantity of reinforcement used by bending up the bars to take reverse bending moment stresses near the supports, which could not have been possible if the concrete were placed in layers.

As regards the cement water ratio, the amount of water to be used was very important, as it depended on a number of factors. For instance, it would vary according to the condition in which the aggregate and sand were available at site and would also vary according to the temperature and humidity of the atmosphere, so that less water would be used in the mornings and evenings as compared to noon. The speaker's experience at the Deg Fall was that the quantity of water used varied from about 4 gallons to 6 gallons per bag of cement.

It was, however, necessary that the quantity of water to be used was fixed by the officer-in-charge for periods of 2 or 3 hours at a time and to keep a watch on the mix so as to produce concrete of a uniform quality.

It should however be taken as a working rule that it was best to use the minimum quantity of water which would produce a workable mix.

The use of the slump test had a valuable moral effect and should be insisted on, but it was best to decide the water content by personal observation as there were so many uncertain factors.

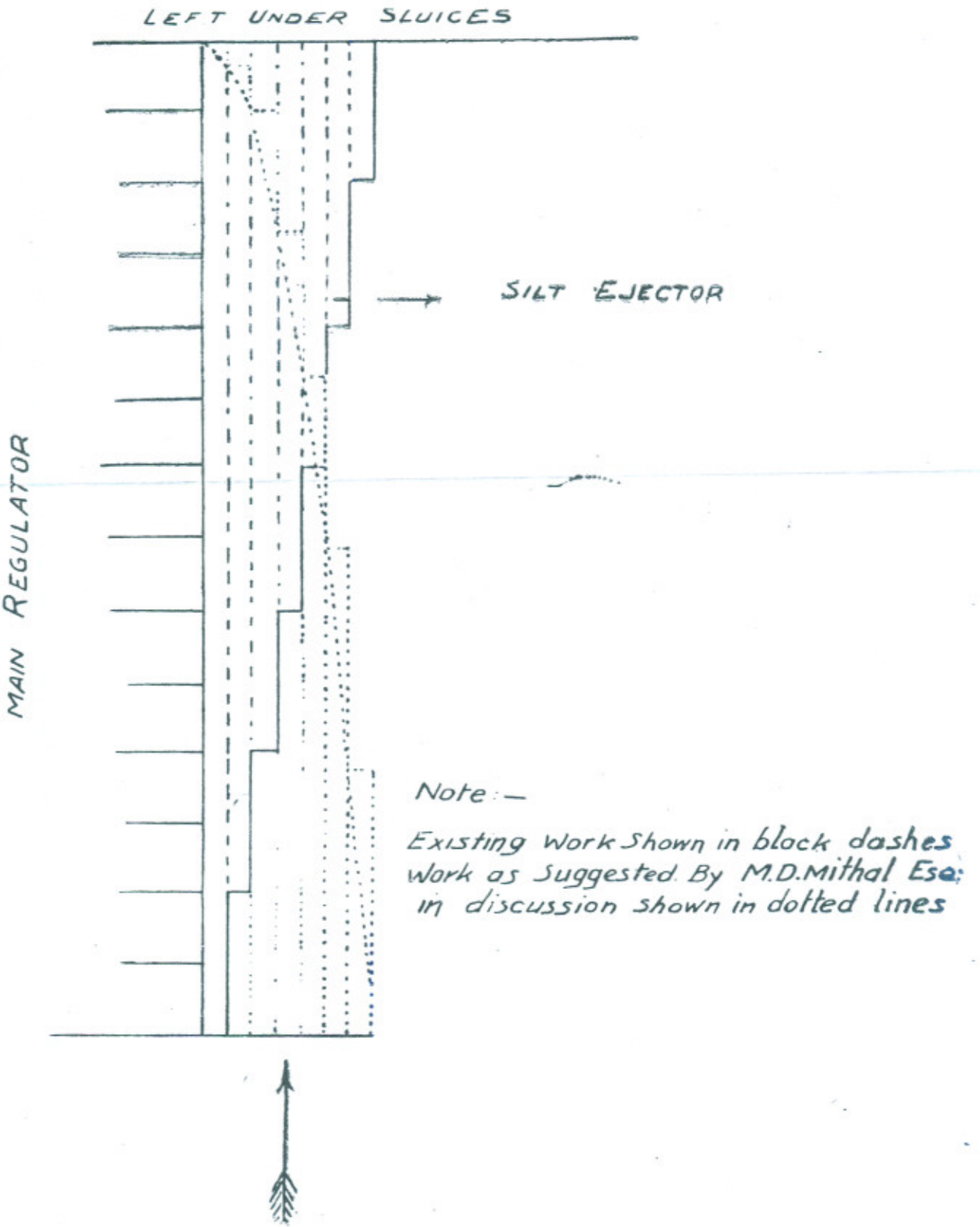
Mr. **M. D. Mithal** thanked Mr. Khosla for assembling the detailed information about the reconstruction of Khanki Weir. However, he requested Mr. Khosla to say something about the theory that led him to adopt the particular design for silt exclusion as visible in the photograph opposite page III of the paper.

The photograph showed that tunnels increased in number as the work proceeded downstream and that each tunnel presented straight face to the water entering the pocket.

In fitness of things it would have been better to ' streamline ' the work and to start all the tunnels at the same upstream end.

The downstream end of the tunnels could lie on a parabola big enough to ensure against the entry of the water from the tunnels into the regulator.

The proposal is embodied in the sketch given below.



Mr. **R. K. Gupta** pointed out that the various layers of concrete always got separated from each other even when the previous layer was thoroughly cleaned. This was perhaps due to shrinkage of concrete in setting which made the upper layer disconnected from the lower layer already set before the top layer was laid.

The second point which was not clear was the extra cost involved in extra length of reinforcement required for overlaps. The length of bars available in the market being fixed, if the size of compartments was accordingly fixed, there should be no extra length required as overlaps. The latter would be necessary in any case at these points even if the concrete were laid in layers."

Mr. **W. J. Benson** referred to the author's remarks in his section on silt exclusion that the Still Pond System of Regulation had proved very successful at Rupar. It might be of interest to mention that although this system had been in use for twenty or thirty years, the Open Flow method was tried for a short time, and when he went to Rupar in 1931 the question was being discussed as to whether the Open Flow System should continue.

The Sirhind Canal had run for many years free of silt troubles in its main line. Soundings were taken every ten days in the first twelve miles and they indicated that, with the Still Pond System, the canal silted in the hot weather but that the cold weather supplies could always be relied on to remove this silt. With these conditions, there was no silt problem such as was experienced at Khanki. But when the Open Flow System was tried at Rupar, the silt which was deposited in the hot weather increased noticeably, and the cold weather supplies did not remove what had been deposited. It was therefore decided in 1932 to return to the Still Pond System of regulation and the speaker believed that this system was still in force. In 1932 it was expected that the return to the old system would mean a reduction in silt in the canal but actually the silt increased. The reason put forward for this was that the river had run with a much higher supply than usual during the months when silt was carried and that the quantity of silt per cubic foot of water increased with the river discharge. Consequently, for the same discharge in the canal, more silt would be drawn in than would be when the canal was fed from a river with normal supplies. (A normal hot weather river discharge at Rupar was 40000 to 50000 cs ; and the canal drew 9000 cs.) It would be of interest to know if similar conditions had been observed at Khanki regarding the relationship between river velocity and silt.

The raising of the cill of the canal regulator at Rupar was credited for most of the success of the silt exclusion. The construction of the silt ejector tunnels at Khanki had the effect of raising the cill by five feet and should therefore be as effective in excluding silt from the Lower Chenab Canal as the raising of the cill at Rupar had been. But one point had to be proved in connection with the silt tunnels. The silt ejector might be removing 30% of the silt entering the undersluice

pocket but if these tunnels were not used, the silt that they removed might never enter the pocket at all. It would be interesting to know if Mr. Khosla had any figure to indicate that this was not so.

It was almost impossible to get any information regarding the actual path that individual particles of water followed when entering a 90% offtake. It was generally known that the bottom water got a sharper curvature than that at the top but, beyond this, nothing much was recorded. At Rupar a set of observations was made to verify this fact and it was found to be so. The regulator at Rupar had twelve bays and, for water entering the pocket in the same vertical plane, the bottom water might enter the canal through the first upstream bay while the top water would enter the canal through the third. In the observations made, with approximately equal discharges in the canal and undersluices, it was found that more bottom water entered the canal than escaped through the undersluices. This, of course, was a point which was not in favour of the Open Flow System because the bottom water carried the heavy silt. It was hoped that similar observations would be made at Khanki shortly, especially to see whether the bottom water was drawn into the silt tunnels or was drawn up and over them and, in this manner, got into the canal.

As regards the steel work erection, this was done, as Mr. Khosla stated, by the Central Workshops. As the speaker was at these workshops in 1934 a few remarks on the erection of the gates might be of interest. The gates were made on the same principle as most gates which were now in use at undersluices of other headworks and no novel feature had been introduced. They had a flat skinplate supported by horizontal joists and had "free rollers" to allow of easy operation. They were lifted from a superstructure and were counterbalanced so that the gearing had only to operate against friction from the free rollers and the load on the bearings of the rope drums.

Each vertical column of the superstructure was lifted into position in one piece on to the pier on which it was to be erected. The lifting was done with a derrick pole, about sixty feet high, which was held in an upright position by wire rope guys. When both columns of a bay were up, the derrick pole hoisted the cross girders of the superstructure and when these were bolted, the lifting of the remainder of the material was done from the superstructure itself. The gates arrived in halves. As they were wider than the grooves in the masonry they had to be lifted above the top of the piers and then slipped into the grooves. The two halves were rivetted with pneumatic hammers operated from a portable air compressor. Next, the empty counterbalance boxes were hoisted to their uppermost position, secured to the superstructure and filled with stone ballast. The operating mechanism was hoisted in pieces on to the superstructure and, when assembled, the lifting ropes were lapped round the rope drums, secured to the gates and counterbalance boxes, and then the counterbalances were released from the superstructure and allowed to swing free.

Mr. **Wheatley** in a written communication complimented the author on having produced a very interesting and instructive paper, which should prove of benefit to those who might be entrusted with constructions of a similar nature in future.

The writer was asked to add a few words in connection with the design and erection of the gates and super-structure, etc., for which part of the work he was responsible. The whole of the design, manufacture and erection of the steel work and machinery was entrusted to the P. W. D. Central Workshops of which the writer was in charge.

Although, it was known in April 1933,that very expensive repairs would have to be started on the weir the following winter, it was not until October that an official decision as to the type and span of gates to be used was arrived at and it was, therefore, essential that the design of the steel work as a whole should be such as to permit of easy and speedy fabrication and erection.

In view of the position of the work—(*i.e.*, in the middle of the river bed in the case of Bay No. 4 and on right bank in the case of Bay No. 8)—it was also necessary that the steel work should be despatched in easily transportable sections.

The main features of the eventual design are shown in Plate VI. The superstructure columns, each of which were 3·0 tons, were despatched as complete units and the overbridge on which the decking and machinery were supported and which consisted of a frame-work of R. S. Joists was despatched in its component parts which were subsequently bolted up at site. The gates were built up of 5/16″ thick skin plates supported on a frame-work of 15″ × 6″ × 45 lb. R. S. Joists and weighed approximately 8 tons each. These were despatched in four parts, the heaviest of which weighed four tons and constituted the largest individual piece to be handled.

With a view to quickening up erection, field rivetting was cut down to a minimum and, with the exception of the gates, machined " fit " bolts with spring washers were used for all building up at site.

The method adopted for erection was essentially the same for each of the two bays. As a result of experience gained in the erection of the steel work in Bay No. 4 certain slight alterations to tackle and erection plant were made for Bay No. 8 but the general programme and methods were unaltered.

Work was started from one flank, the superstructure being erected first and afterwards utilized as a gantry from which to handle the gates and machinery. The height of the over-bridge from cill level was 46 feet and this and its supporting columns were placed in position by means of a 60 feet teakwood derrick pole which was obtained from Panjnad, the derrick being " walked " from span to span around the

noses of piers as the work progressed. This portion of the work gave no trouble whatsoever ; it went together like " Meccano " and once started, erection of the superstructure proceeded at a rate of a span per day.

The erection of the gates was slightly more difficult as owing to the fact that there was no road bridge to work from, they had to be handled at cill level and rivetted up in their grooves. As previously mentioned these were despatched from the Central Workshops in four pieces, the two vertical end girders being detached from the main frame-work and the skin plate horizontally. The lower half of the gate was the first to be handled into position lengthwise across the span and directly under the over-bridge from which latter place it was subsequently lifted until clear of the top of the piers, twisted round through 90°, and then lowered into its grooves. With the lower half in position it was not possible to get the upper half of the gate directly underthe over-bridge and a good deal of manoeuvring and careful slinging and guying was necessary, in order to lift them up over the lower halves, before they could be swung round and lowered into the grooves on top of them. Once the two halves of the gates were housed in the grooves, the end girders were slid into position and the whole bolted up temporarily pending rivetting. The rate of progress on the erectionof the gates (excluding rivetting which was not started until the machinery and counter-balances had been erected) was one gate per day.

The lifting machinery, hand railing and planking was handled and erected by means of a special light gantry fixed to the main girders of the over-bridge and designed to travel along them from span to span.

While the machinery was being erected the counter-balance casings (which weighed 3¼ tons each without the filling) were hoisted up and supported on the tops of the piers whence they were lifted in due course with their own suspension ropes into their up positions by the gearing, the lower end of these ropes being then attached to the gates.

The actual rivetting up of the gates was done in two bits, first the horizontal jointing skin plate and secondly the rivetting of the end girders to the main frame-work. The rivetting of the skin plate joint was done whilst the machinery and counter balances were being erected and whilst the gates were resting on the cill. As the end girders were not accessible with the gates in this (*i.e.*, the down) position owing to their being shrouded by the grooves, this part of the work had to wait and was carried out as follows :—

After the counter-balance casings had been hoisted into position as described above and the suspension ropes fixed to the gates, they were filled with ballast and the gates then lifted clear of the grooves by the standing machinery which had by that time been erected.

Once the gates had been lifted the end girders were exposed, the rivetting up was easily accomplished by men working from the tops of the piers, the gates being gradually lowered into their grooves as the rivetting proceeded.

All field rivetting was done with pneumatic hammers, air supply being obtained from a Portable Oil-Engine-driven-Compressor.

As already stated one of the objects aimed at in designing the steel work was speed and ease in erection and results had shown that these objects had been attained in actual practice. Working programmes were drawn up beforehand for the erection of the Sluices in Bays Nos. 4 and 8 respectively, but when it came to carrying out the work it was found that the time fixed was in most cases improved upon. To begin with progress was rather slow, but towards the end some really remarkable times were achieved ; for instance the last six gates in Bay No. 8 were transported across the river and erected in position in four days.

The total time taken to erect the 18 spans of Bay No. 8 including all field rivetting was 44 days, or an average of just under $2\frac{1}{2}$ days per span. The total weight of materials per span was approximately 20 tons and the weight of the heaviest piece to be handled approximately 4 tons.

In the case of Bay No. 8, orders were originally placed, for the supply of 12 spans only, but at the end of January, 1935, instructions were received to manufacture a further six spans, making 18 in all. Despite the fact that the steel required for the fabrication of the gates and some parts of the superstructure had to be obtained from England and was not received until about the 25th of April, fabrication was completed and the materials transported to site and placed in position by the 3th of May, the field rivettin g being completed on the 19th of May.

The final completion of work in these last six bays was delayed owing to the late arrival of the gate suspension ropes. These did not reach Khanki until the 11th of June, when they were at once installed and all the 18 bays handed over in working order on the 15th of June, or 70 days from the date of starting the erection.

The author had mentioned in the Paper that the gates in Bay No. 8 were manufactured from special steel containing a small percentage of copper. This special steel was used as it had been found that the addition of a small percentage of copper—(which might vary from 0·25 to 0·75) to ordinary mild steel increased considerably its resistance to corrosion, in certain instances ; for example as exposure to atmosphere con'aining smoke, or acid fumes, or to sea water. The amount of increased protection afforded in the case of exposure to alkaline waters such as of the Punjab Rivers had not as yet been ascertained, but such preliminary observations as had been made went to show that the addition of copper did definitely result

in reducing the rate at which corrosion normally occurs. For the manufacture of the gates at Khanki steel containing an average percentage of 0·6 of copper was used, the cost of which was approximately Rs. 30 per ton more than that of standard mild steel.

Tests were at present being carried out with a view to determining more accurately the advantages of this special steel and it was hoped it would be possible to give more information on this point shortly.

MR. **A.N. Khosla** in replying to the discussion said that Mr. Khanna appeared to be ignorant of the seriousness of silt trouble on the Lower Chenab and other Canals and averse to believe anything that did not fit in with his theories. His insinuation that a specific mention of results achieved had been withheld, as the latter had been disappointing, was unfounded. The silt conditions in the canal had steadily and definitely improved during the last two years, as would be amply clear from a reference to the official report on the subject.

Cases were on record where due to adverse set of river or unsuitable regulation, head reaches of canals had been choked in a matter of a few hours, so that feeding of full supplies became impossible. In one case it took two years to bring the canal bed back to its normal level. If Mr. Khanna would care to study such cases, he would find that his simple theory was not even remotely applicable, in view of the extreme variations in silt charge of river water during winter and flood months. The silt trouble was not caused merely by heavy grades but by all grades if the sum total exceeded a certain limit, other factors remaining unchanged. Temperature had a considerable effect.

Mr. Blench was not correct in saying that like other old weirs, Khanki was suffering from being far too broad. His contention that the S.V.P. Weirs with narrow water-way were sounder was equally incorrect. The fact that the Panjnad Weir had, as a result of the Islam failure to be enlarged by addition of 14 new bays was sufficient evidence in this respect, also " belas " persisted above all the S. V. P. Weirs. The Suleimanke Weir has a width of 1600 feet between the guide banks. This width is very nearly equal to the minimum stable water-way for a 3 lacs flood. But " belas " persist all the same.

Mr. Blench had, however, drawn attention to a very important point in weir design. During floods, either due to parallel flow or local concentration, deep channels form which are capable of causing failure upstream as well as downstream by inducing the foundation soil to slide in these deep holes due to earth pressure as distinct from seepage gradient. This pointed to the necessity of suitable flexible aprons and vertical cut offs upstream as well. The downstream pile line was essential to provide against failure of the foundation soil by earth pressure if deep holes formed and against that by hydraulic gradient due to seepage flow. Mr. Blench's assumptions for finding out the depth of scour were somewhat

incorrect. The scour should be worked out for the discharge per foot run and not for the maximum flood discharge running through the minimum stable water-way. The scour in the weir bays with only 145 cusecs per foot run will be less than that in the undersluices with 387 cusecs per foot run. The depth of scour can be worked out from the formula :—

$$d = 1{\cdot}11\, q^{0{\cdot}61} \quad \text{(derived from Kennedy).}$$

or the formula :—

$$d = \frac{0{\cdot}9q^{2/3}}{f^{1/3}} \quad \text{(derived from Lacey).}$$

when $f = 0.933$ for Kanki sand

d = depth of scour

and q = discharge per foot run.

In reply to Mr. Kanwar Sain, the author stated that a certain amount of reserve of stone was maintained on the ramps leading to bay 4 and with the newly installed lock-coil ropeway, transport of men would be considerably accelerated. The position was being carefully considered. For rapid transport in an emergency, two alternatives were under consideration. A light suspension bridge or an additional ropeway running parallel to the existing one so that two cradles could run at one and the same time.

As to the water cement ratio, opinion would remain divided but the author maintained that the Engineer's judgment regarding a workable mix would give better results than the slump tests, which would vary with the temperature at which the concrete was laid. The class of labour available had to be kept in mind. The tests on composite trough beam, mentioned in the introduction, were sufficient proof that what was considered as a good workable mix from eye judgment, had given excellent results. The concrete developed over 6000 lb. to a square inch and did not fail.

Regarding laying of concrete in layers, enough had been said in the text. Until recently, the behaviour of cement concrete was not sufficiently understood. Knowledge had advanced since the days of Khanki, Rasul and Marala and so also since the construction of Suleimanke, Ferozepur and Islam Weirs both in point of design and constructional details. Panjnad Weir was the first to recognize the lessons from the earlier weir and embodied sound practice. The method of layers at Khanki was entirely different from that used in earlier weirs. It embodied all the good features and entirely eliminated all sources of weakness.

Mr. Kanwar Sain had confused the joints between individual construction compartments with expansion joints. All construction joints were not expansion joints. To make construction joints 40′×40′ would require $6\times40\times40=9{,}600$ c.ft. of concrete to be laid in one

compartment in one day. This would be impracticable in most cases. The compartments of 10 to 15 feet used at Panjnad were the correct practical limit.

As to rehandling concrete by baskets, this method was found to be the most sound. Practice in India could not be compared with that in America where manual labour was 25 to 30 times as expensive as in India. The additional cost in laying by baskets was small and was more than made up by eliminating sleepers, tracks, cleaning, etc. In point of speed it was no less fast. The outturn obtained from mixers was about as high as on any previous construction. The idea of carrying dry mixes to site of work and of adding water there was impracticable.

The author thanked Messrs. Raghbir Singh and Handa for elucidating the text and for the additional information supplied.

He also thanked Mr. Batra for his most useful contribution about painting of steel work. His note was the result of very careful tests and research at Panjnad and with that the author fully concurred. The common electric hair dryers would provide an excellent hot air blast to remove moisture from the face of gates immediately before applying the paint.

In reply to Mr. Kapur, the author referred to his replies to Mr. Khanna. The silt excluding devices had proved successful. Mr. Kapur's idea of the divide wall was worth careful consideration. The author disagreed with Mr. Wood's observations as quoted by Mr. Kapur. The facts were very different to what Mr. Wood had presumed. The reasons for retrogression and recovery of river bed level as a result of withdrawals of canals, were very clearly given in the Nicholson-Trench Report and need not be repeated here.

Mr. Kapur's remarks about the arrows were most useful and merited careful consideration.

The case of Deg Fall was entirely different from that of a weir. What would prove economical in one case might prove extremely expensive in the other.

Mr. Kapur's remarks about the water cement ratio were illuminating and bore out the author's contention.

In reply to Mr. Mithal, the author stated that the reasons for the stepped layout of the tunnels were given in the text. They intercepted silt along a maximum frontage.

The replies to Mr. Kanwar Sain's criticism furnished replies to Mr. Gupta's two points.

Mr. Benson had furnished some very useful information with regard to the system of regulation at Rupar and the relation between silt

charge in canal water and the river discharge. Exactly similar phenomenon had been observed at Khanki.

The silt analyses at Khanki definitely proved that the silt charge in the canal was considerably less than that in the pocket or flume and that this reduction was due to the comparatively large quantity of silt withdrawn by the tunnels. These latter carry much more silt per cusec of discharge than the canal.

The direction of bottom jets of water at Khanki was similar to that at Rupar. It was an important fact to bear in mind.

The author thanked Mr. Benson for the useful notes on erection of steel work.

The author was greatly indebted to Mr. Wheatley for the very useful note communicated by him on the fabrication and erection of steel work. This note materially added to the usefulness of the paper.

THE FOLLOWING IS A STATEMENT OF LOADS, DEFLECTIONS AND CRACKS AS RECORDED DURING THE PROCESS OF LOADING.

Date.	Time of loading. From H.	From M.	To H.	To M.	Load tons.	Deflection at centre inches. Morning	Evening.	Remarks.
Initial Load ..	..	..	..	..	8·0	..	..	Weight of two troughs made to full section ~8 tons.
29th January ..	17	10	19	40	15·0 23·0	..	3/64	
30th „ ..	10	23	12	23	..	5/64	..	30th morning, ends lifted at extremities by a hair breadth.
	13	55	18	10	20·22 43·22	..	16/64	
31st „ ..	10	5	12	15	..	17/64	..	Very fine hair cracks noticed for the first time at 50 tons load.
	14	0	18	0	20·1 63·32	..	28/64	
1st February ..	10	40	12	40	..	29/64	..	In the morning cracks had appreciably widened and two more appeared 9" from centre or either side. Ends lifted about ¼".
	15	20	17	50	18·11 81·43	..	37/64	
2nd „ ..	10	0	12	45	..	39/64	..	In the morning the first diagonal cracks due to shear were noticed in the end quarter spans. These were hair cracks and remained so till 110 tons load. In the evening two cracks appreciably widened, and all cracks started extending towards neutral axis. The elastic limit of the beam was probably passed at or about 93 tons.
	15	0	18	10	14·67 96·10	..	54/64	
3rd „ ..	..	..	..	..	0·0 96·10	70/64	72/64	3 cracks on front and 5 at back widened considerably during the intervening night. All cracks reached very near the N. A. Shear cracks in end quarter spans remained unchanged.
4th „ ..	10	40	12	45	4·25 100·35	74/64	88/64	In the morning fine cracks were noticed for the 1st time between the precast and insitu work shown X X in Figure 4 crack No. 17 on the back extended above N. A. In the evening cracks widened to a max. of 1/5".
No load was added between 5th and 10th.								
8th „ ..	No	load	added		100·35	106/64		
10th „ ..	No	load	added		100·35	106/64		
11th „ ..	10	30	12	0	..	..	110/64	At 105 tons 2 cracks on each side reached within 5" of top. At 109 tons the beam extension which occurred entirely on left end amounted to 1¼". On right end the point of support remained unchanged. The concrete of trough as well of support showed signs of crushing at the left end. At 109·5 tons, the bottom piles of load just touched the top of beam at the right end. At 110·16 tons the piles on the left also touched the top of trough and further loading was discontinued as the load ceased to rest at the quarter span points.
	13	0	17	5	9·81 110·16	..	4¼"	
12th „ ..	Load removed.							The maximum sliding or elongation of beam at left end was 1¼" the right side remaining unchanged.
13th „ ..								Cracks shown dotted in figure 4 practically disppeared. The beam recovered ¾" in the middle so that the deflection was reduced from 4¼" to 3½". The lift at the ends reduced from 1¼" to 1". The supports were carefully checked. No settlement had occurred.

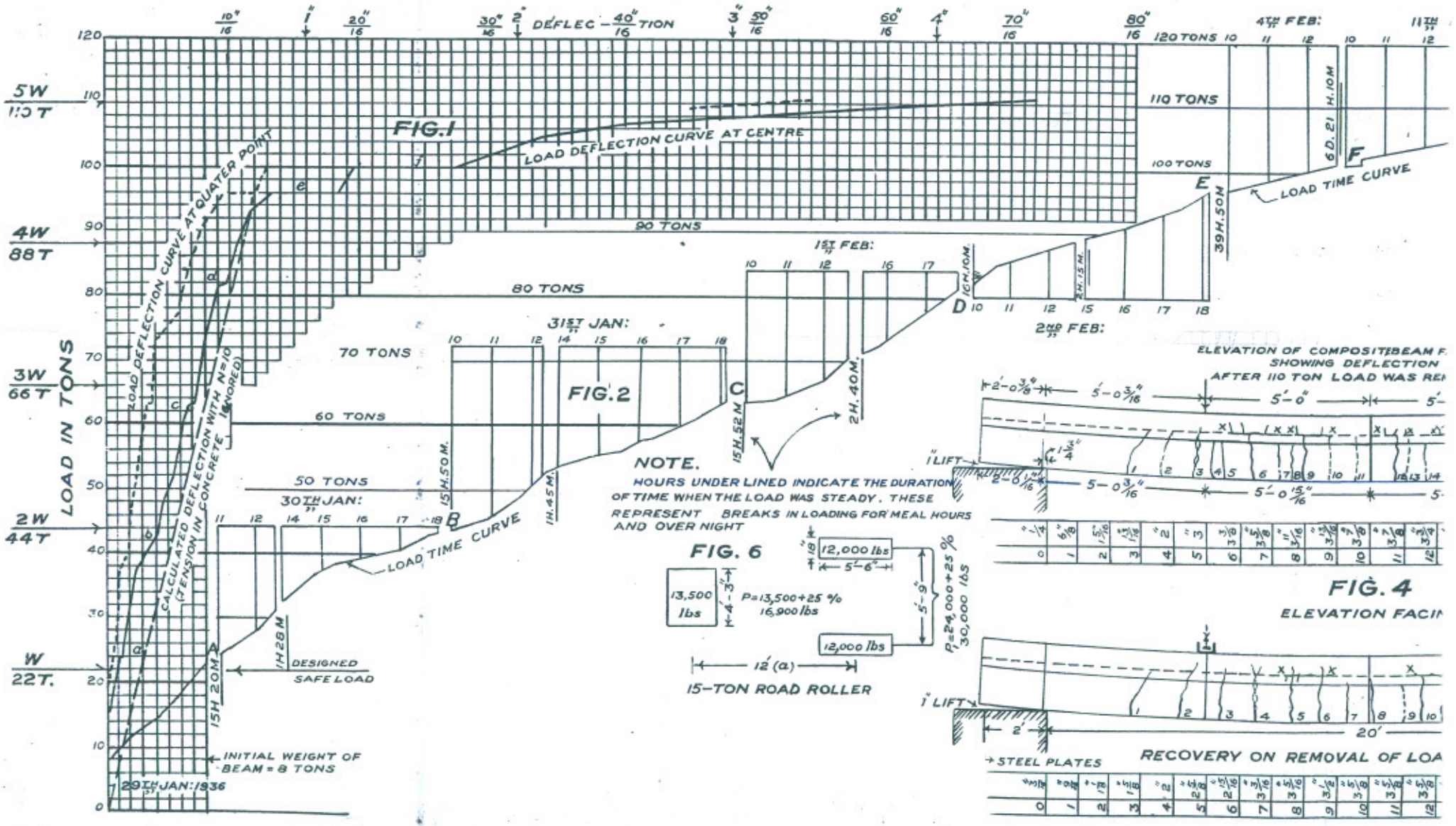
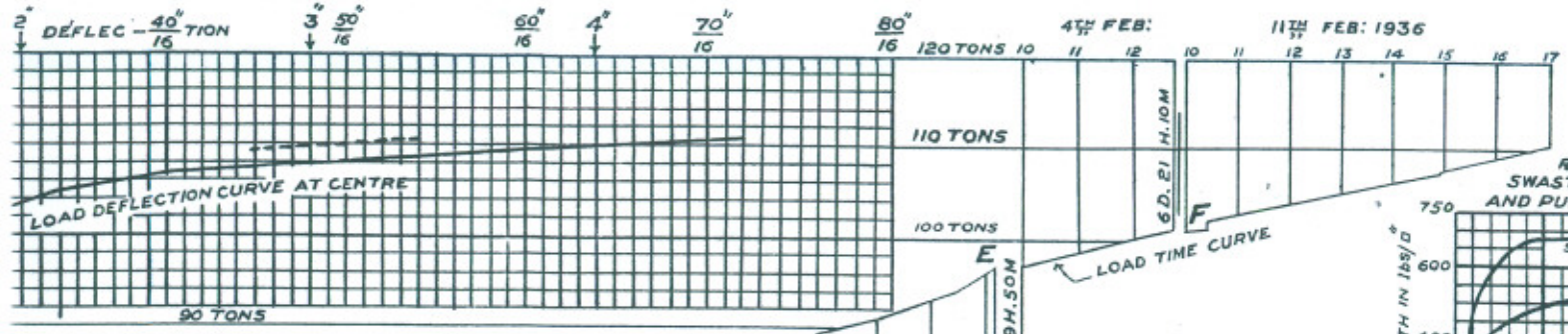
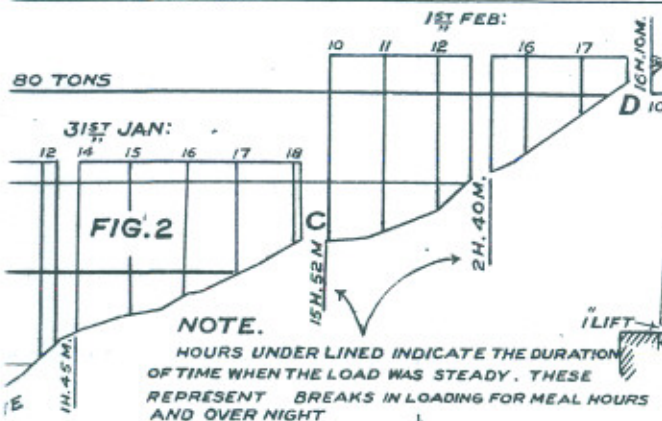

DEFLECTION
LOAD IN TONS
5W 110 T
4W 88T
3W 66T
2W 44T
W 22T.
LOAD DEFLECTION CURVE AT CENTRE
LOAD DEFLECTION CURVE AT QUATER POINT
CALCULATED DEFLECTION WITH N=10 (TENSION IN CONCRETE IGNORED)
LOAD TIME CURVE
DESIGNED SAFE LOAD
INITIAL WEIGHT OF BEAM = 8 TONS
29TH JAN: 1936
30TH JAN:
31ST JAN:
1ST FEB:
2ND FEB:
4TH FEB:
11TH
120 TONS
110 TONS
100 TONS
90 TONS
80 TONS
70 TONS
60 TONS
50 TONS
FIG. 1
FIG. 2
NOTE.
HOURS UNDER LINED INDICATE THE DURATION OF TIME WHEN THE LOAD WAS STEADY. THESE REPRESENT BREAKS IN LOADING FOR MEAL HOURS AND OVER NIGHT
FIG. 6
13,500 lbs
P=13,500+25 % 16,900 lbs
12,000 lbs
5'-6"
5'-9"
12'(a)
15-TON ROAD ROLLER
ELEVATION OF COMPOSITE BEAM F
SHOWING DEFLECTION
AFTER 110 TON LOAD WAS RE
1" LIFT
FIG. 4
ELEVATION FACI
STEEL PLATES
RECOVERY ON REMOVAL OF LOA

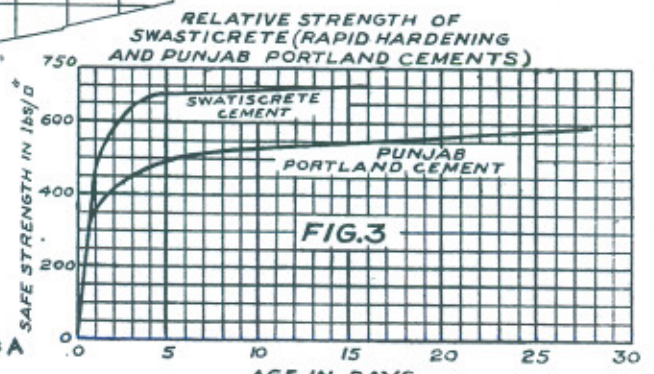
PLATE VII (PAPER NO 195)





NOTE.

HOURS UNDER LINED INDICATE THE DURATION OF TIME WHEN THE LOAD WAS STEADY. THESE REPRESENT BREAKS IN LOADING FOR MEAL HOURS AND OVER NIGHT



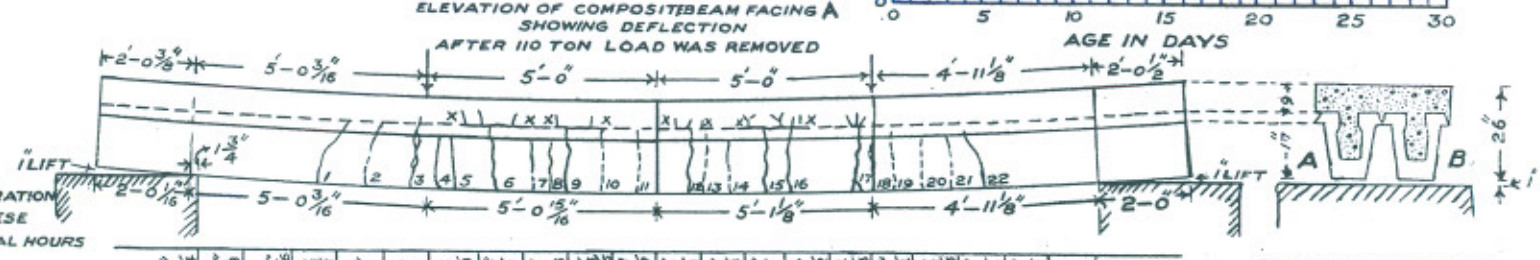


FIG. 4

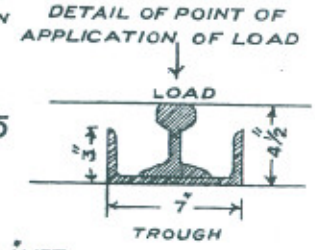
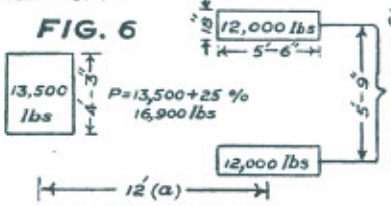
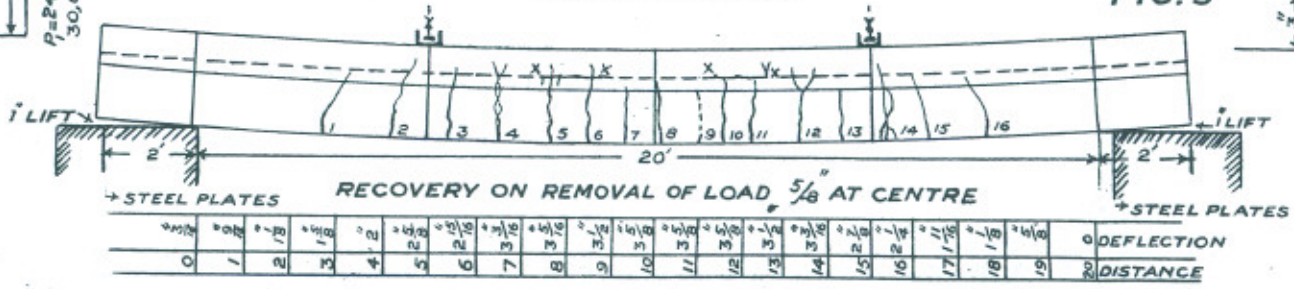


FIG. 5



15-TON ROAD ROLLER

FIG. 6



RECOVERY ON REMOVAL OF LOAD 5/8" AT CENTRE

ERRATA.

Page 148. *After* " For lining the surge shaft " in para 1, *add* ; " The surge shaft itself acts as the safety valve of the tunnel and the particular type constructed consisted as shown in plate 5 of a main shaft with a central riser, the platform on which this riser rests, having four ports. The effect of this is that when the valves of the tunnel are being opened up, the water falls first down the central riser as there is no restriction and an immediate difference of head is obtained between the water at the tunnel entrance at the head works and the surge shaft. In consequence a velocity is produced in the tunnel within little surging in the shaft."