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# PROTECTION OF THE UPSTREAM FORESHORE, MANGLA REGULATOR, 1931-32.

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Mangla Regulator, the Head Regulator of the Upper Jhelum Canal consists of a masonry gravity dam 354 feet long between abutments and 80.0 feet high with founds generally at R.L. 837.6 and machinery platform at R. L. 917.0. Water is admitted to the canal through two tiers of sluices, the cill of the lower of which is at R. L. 859.25. The wing walls on both flanks are of the same height as the main work the foundations being level. Those on the river side are 105 feet long and are in line with the face of the work, while the downstream wings are 60 ft. long and are curved to a splay of about 30°.

The ground at the site of the work consists of alternating strata of hard clay and soft sandstone which dip fairly steeply away from the river and at a small angle upstream. The regulator is founded on one of the sandstone strata, the foundations at the upstream side following it down to a minimum level of 820.0. Overlying this foundation rock stratum we have alternating clay and rock layers of varying thickness During construction of course the rock strata had to be cut back to form the foundation pit, and light core walls of concrete were subsequently provided to join up the masonry of the wing walls to the rock.

As is now well known the regulator was topped by the record flood of 9,00,000 cs. in August 1929. The river on that occasion rose to R. L. 920.0 *i.e.*, 3′ above the top of the regulator. The overflow did little damage to the mainwork itself but washed out the filling over the roadway and between the wing walls and the rock on the flanks, in some cases outflanking, and in others undermining, the core walls. The heavy pitching on both the river and canal sides was destroyed. The outflanking of the core walls was accompanied by cutting back of the face of the rock strata to a considerable distance, presumably by undermining due to erosion of the underlying clay, and had the flood not subsided rapidly the results of this outflanking would have been very serious.

The work undertaken as a consequence of this damage consisted principally of the strengthening and extension of the cut-off walls, each wing wall being joined up to the new face of the rock strata. The new core walls were taken up to the level of the regulator roadway and were designed as retaining walls to take the pressure due to the filling assuming the pitching to have been removed. The roadway was also protect-

ed by a concrete covering which was extended to the end of the cut off walls, thus guarding against any washing out of the filling in the event of the regulator again being topped. A new parapet was provided along the machinery platform rising to R. L. 921.5 and the parapet of the U-S wing walls was raised to the same level and extended to the ends of the new core walls. The pitching U-S and D-S was of course replaced.

The most important part of the work was the provision of the cut off walls. Before designing these the nature and extent of the rock strata was carefully studied, a special survey and report being prepared for the purpose by Mr. E. R. Gee of the Geological Survey of India. In this report Mr. Gee first drew attention to the necessity of securing the safety of the upper sand stone layer on the left flank, to which the upstream wing walls were being bonded. This sand stone layer out crops in the river bank upstream of the regulator as a cliff, the appearance of which is such as to give the impression that any damage to the regulator from its destruction is very remote.

The sandstone of the cliff however overlies a clay stratum and is liable to undermining by erosion. That this action was proceeding sufficiently rapidly to be dangerous was evident in several ways, though unfortunately the annual survey gave no direct information on the point as the lines on which cross sections are customarily taken are remote from the site.

On the occasion of the record flood the U-S left pitching was washed out only in the immediate vicinity of the regulator. Shis pitching, starting from the regulator at right angles to its face, originally continued as a revetment round the corner of the cliff and along itf face for about 100 ft. The portion along the face of the cliff was left undisturbed by the 1929 flood,but was totally obliterated by the comparatively small flood of 2,90,000 cs., in April 1930. The inference drawn from this was that the regime of the river at the site had been so changed by the 1929 flood as to cause it to attack the cliff much more strongly.

During the monsoon of 1930 Mangla was inspected by Mr. Hadow, Chief Engineer, who had been acquainted with the place in construction days. With reference to the situation at the cliff site Mr. Hadow recorded the opinion that much of the cliff had fallen and been washed away ; that the clay base underlying the sandstone had been lowered by erosion ; that all the heavy protection debris at the mouth of the Kalara Kas diversion had been removed, and that the river was much closer in to the cliff than formerly.

By far the strongest evidence of the recently accelerated action of the river, however, was the whirlpool. This is shown on the plan (Plate I) from which its length and breadth may be gauged. The maximum depth of the scour caused by it was some 45' below minimum winter water level. The whirlpool was first observed during the monsoon

of 1930 and the scour hole first surveyed in the autumn of that year. That it developed as the result of conditions set up by the 1929 flood there is little doubt and if it be conceded that the difference between the section at the site of the pool and the normal river section represents the erosion occurring in one year, the necessity for immediate action to control the situation is obvious.

In advising immediate action, the Engineers responsible for the work were also influenced by the opinion expressed by Mr. Gee that the longer the work was postponed the more difficult and expensive it was likely to be.

This advice was accepted by Government; presumably in consideration of the immense importance of the Mangla Regulator, on the uninterrupted functioning of which a considerable proportion of the provincial revenues depend, and proposals for permanently protecting the base of the cliff were called for.

**The design of the protection.**

The problem before the designers was to provide a permanent protection for about 500 ft. of under-water river bank subject to velocities of anything up to 20′ per second. It was obvious that the work must be constructed in running water. Unwatering was quite impracticable as the steepness of the bank was such as to make a ring bund impossible and expense rendered any form of coffer dam out of the question.

There were two possible alignments for the face of the work, either to follow the existing bank or to cut straight across the embayment, While the former would have been cheaper in first cost owing to the lesser depth of protection immediately required, there is little doubt that the latter, which was adopted, was the correct one. It ensured that the depth of the work over the greater part of the length was such that further undermining was improbable, and had the great advantage that it would break up the action of the whirlpool and thus remove the principal cause of erosion.

The following types of facing for the work were considered :—

(*a*) Stone in wire crates.

(*b*) Concrete blocks.

(*c*) A solid wall formed of concrete skipped between two lines of steel piling.

(*d*) A wall formed of wells sunk through a shingle bank previously placed for the purpose.

(*e*) A wall formed of bundles of hollow concrete piles, floated to site and set vertically.

(*f*) Solid concrete needles to be moulded in sections on the face of a shingle embankment and slid down into position.

(*g*) Hollow concrete needles floated to site and sunk in an inclined position on the face of the bank.

Of the above (*a*) or (*b*) is the obvious practical form of protection. The disadvantages of this type are however well known. In the first place, owing to the uncertainty of placing under water a heavy thickness has to be provided to ensure adequate cover. The cheapness of the first cost of crates has to be offset against their comparatively short life. Assuming a 10′ thickness as the minimum necessary for an embankment of this depth, the first cost of blocks would be about Rs. 2,00,000. That of crates plus their capitalised depreciation would be about the same. Experience shows that with this type of protection large numbers of blocks are displaced annually and have to be replaced. That 5% have to be replaced annually is a moderate estimate and capitalising this the equivalent first cost becomes Rs. 4,00,000.—A figure which as will be seen later was considerably bettered in the design adopted.

(*c*) (*d*) and (*e*) were rejected on account of high cost and doubtful practicability. With the depths prevailing the thickness required for any form of vertical wall involved enormous expense.

(*f*) formed the basis of the method finally adopted. This method of construction, the invention of Mr. E. S. Crump is as far as the author is aware, new to the engineering profession. It has the advantage that since the needles follow the slope of the bank and have not to exert any considerable retaining force thereon, they can be as light as is consistent with effective protection. While the protection is of a permanent nature not liable to deterioration or erosion, it is at the same time flexible. The needles are free individually to slide down the face of the bank and check any erosion at the toe as it occurs. The needles are of course lengthened at the top as necessary to cover the portion of the bank exposed by their movement. The method is also capable of being used on under water work.

The method appears to be a very valuable one, capable of application on a smaller scale to many river protection problems. The objection to it as it stood was the doubt as to whether it would be possible to control the needles as they descended under water. Experiment indicated that they might bury their noses in the face of the bank and come to rest before they had reached designed position.

(*g*) was turned down on account of doubts as to the practicability of manoeuvring the needles into their correct position when sinking them through the current likely to prevail. Also the effect of freshets on finished needles awaiting transport to the site was considered to hold the possibility of serious interference with the work.

As stated above the design finally decided upon was a modification of (*f*). The modification, an expensive one, consisted of the provision of a line of steel sheet piling down which the needles could be lowered with certainty of their reaching the designed position. Although merely an aid to the placing of the needles this line of piling was actually the principal part of the work. Itself expensive, the placing of it at a

suitable slope under water was a matter of considerable difficulty. The general section and plan of the work may be seen from Plates II and III.

The level of the top of the piles (R. L. 880·0) was so fixed as to provide a sufficient margin over the pond level during the working season, to enable a suitable length of needles be moulded above water level. The regulation operations at Mangla, which had, of course, to be maintained during the progress of the work, consist of distributing the Jhelum water between U. J. C. and L. J. C. water for the latter canal being passed down river to Rasul. There being no weir at Mangla, distribution is usually done by maintaining the pond at the level required to pass the Rasul supply over the bar ; and in the design a pond level of 874·0, sufficient to pass L. J. C. full supply over the bar, was provided for. This gave sufficient room for a 5′ section of needle to be moulded. In actual practice by taking L. J. C. water into the canal and escaping at Bong, five miles from Mangla, we were able to get much lower levels and mould the needles in greater lengths. The top of the embankment was given a covering of 2′ of concrete the proportions of the body of which were 1 : 4 : 8 while those of the face, 6″ thick were 1 : 3 : 6.

Experiment showed that the angle of repose of the filling was about 1½ to 1. The slope of the face was therefore fixed at 1¼ to 1 in order that the filling might easily pack behind it. Shingle filling was provided for in the original design but, as in practice we were able to obtain boulder filling at little extra cost and this had the great advantage that all danger of settlement was avoided, the latter was used.

The raised berm at the base of the cliff carried the line on which one end of the pile driver was mounted during construction. It also provides a means of passage along the bottom of the cliff when the river is above R. L. 880·0 and effectually protects the covered portion of the cliff from weathering. At the downstream end this raised bank was joined on to the extension of the regulator pitching, which after the flood of 1930 had been replaced by a very strong work consisting of stone in wire crates faced with concrete.

The ends of the embankment were constructed of solid concrete in order to ensure that there should be no general lateral movement of the piles and needles. The limits of the solid work were fixed by the level 868·0 to which it was possible to lower the pond level during low supply ; the abutments covering the reach where river bed at the toe of the embankment was above this level. The ends of the abutments were finished off by sloping them down at 1 in 10 from points distant from the commencement of the needles 64′ on the U. S. side and 20′ on the D. S. side.

The piling was designed to be placed in position by means of a special pile driver in advance of the filling, and held in position by a system of transomes and struts until the filling was completed The

piling was of the Universal type, consisting of 15″×5″×42″ lbs. R. S. Js. and clutches. It was second hand stuff obtained from the Sukkar Barrage, but had been admirably reconditioned by the Sukkar Engineers before despatch. The maximum length of piling obtainable was 50′ whereas 90% of the piles to be placed were over 50′ in length, the maximum length being 80′. Being placed at a slope the piles were liable to transverse bending under their own weight and it was calculated, and verified experimentally, that the deflection would be excessive, *i. e.*, more than 6″, in the case of untrussed lengths of over 50′. Trussing was therefore provided in such cases which meant that each pile had to be built up as a small girder, weighing from 2 to 2½ tons. The detail of this is shown on Plate IV.

This trussing, the depth of which was 5′ lead to many complications one of which was that the transomes had to be placed on top of the pile and the latter suspended from them. The original design as shown on Plate IV provided for two 15″×15″ joists as transomes. They bore on the strutted piles without attachment, and each intermediate pile was suspended from this by means of two ¾″ bolts. The transomes were to be in lengths of about 40′, and after inserting each strut, one transome was to be moved forward, (the piles meanwhile being suspended from the other) into position to support the piles up to the next strut as a cantilever. This involved keeping two continuous lines of transomes for the full length of piling unsupported by the filling (about 80′) and moving one line forward about 15 feet after slacking off all its suspension bolts, when each strut was put in. The modifications effected in this design will be described later.

The struts to the piling shown on Plate IV each consisted of a single 15″×5″ girder, trussed against lateral bending. The standard length was 24′ though shorter lengths were used for the piling at the upstream end where they could be supported from the natural bank of the river. The strut was attached to the piling, by a 7″×¼″ plate bolted directly on to the web of the pile and secured to the web of the strut by two angle cleats. This form of connection was sufficiently flexible to permit adjustment of the piling after the strut had been placed. The shore end of the strut rested on a wooden base plate faced with steel, bearing through wooden wedges on a bed plate consisting of two 5′ lengths of sleepers. The load taken by the strut was anything up to 12 tons. The spacing of the struts was limited to eight piles by the strength of the cantilever transomes.

The general section of the needles shown in Plate No. V was fixed at 2½′ ×5′, their length of course varying with the depth, being anything up to 80′. The weight of the needle was carried by two skids, composed of short lengths of pile clutch, bearing on the flanges or clutches of the driven piling and the underside of the needle wasarched between the points of support so as to avoid any risk of intermediate contact. In order to reduce the strain on the anchoring frame it was

important that the angle of friction of the bearing of the needles on the piles should be not greater than but nearly equal to the slope of the piling. Experiment showed that the frictional angle for steel on steel was much less than 1¼ to 1. So in order to increase this, the underside of the skids was filled with a ½ inch layer of 1 to 1 cement plaster. The original intention was to interlock the needles laterally by tonguing and grooving the sides. The practical difficulties attending the construction of moulds to give this form were however very great, and it was finally decided to groove both edges and to fill the double grooves with boulders after lowering.

**General Equipment**

Owing to the lack of space at the foreshore it was decided to manufacture the piles on the beach on the left bank down stream of the regulator *vide* Plate I. A small power drill, operated by a Crossley Engine was set up at this site and electric power and light made available by running a line from the nearest point of the Station system. Two portable electric drills were operated by this means. An oxy-acetylene welding plant formed part ofthe yard's equipment and though expensive to operate, was found invaluable on account of its speed. All cutting of the overhang of the driven piles was done with this machine. A tram line was laid connecting the yard with a specially constructed jetty at the river. Another line connected the cliff over the yard with the terminous of the B. G. canal railway, a distance of about three quarters of mile. Two pair of shear legs equipped with differential pullies strodding the jetty line were provided for loading the finished piles and a floating derrick also equipped with a differential served the same purpose at the jetty. The yard was protected by a ring bund from innundation by freshets. Piling arriving from Sukkur at Mangla was transhipped to tram trucks at the terminus and conveyed by tramway to the cliff top. Here it was slid down a specially built slide to the bench and stacked at one side of the yard. The piles were manufactured on platforms of rails laid at right angles to the jetty line clear of the shear legs; As there was always some uncertainty as to the length of piles repuired a few days ahead, it was necessary to keep a stock of different lengths ready. When required a pile was pulled along the line until opposite the shear legs, then man-handled across until the differentials could grasp it, and was then raised and loaded on two tram trucks equipped with specially designed saddles.

The floating derrick used for transhipping the piles from the tramway to the rafts at the jetty is illustrated in Photo. No. 1. It was designed to straddle the jetty with a pile on it, at all probable water levels. The procedure of loading was as follows :—the pile being run down to the end of the jetty the fore end was raised by the derrick. The derrick then moved sideways to permit the forward tram truck to be run back and taken off the line at the shore end of the jetty. The pile was then run forward until the rear truck was at the end of the jetty, when the fore end coula be lowered on to its raft without the trussing fouling the jetty. After depositing the forward end, the derrick was floated

back, when it picked up the rear end, carried it clear of the jetty and deposited it on its raft.

The rafts were designed and made locally out of empty 40 gal. crude oil drums. In designing them, in view of the rough water they had to negotiate, attention was paid to their stability, a metacentric height of 2′ being provided for. This accounts for the fact that in the photograph (No. 2) they appear unnecessarily buoyant. This appearance, coupled with a shortage of drums, tempted us to try a lighter raft with the result that we lost a pile in the river through the raft over-turning. The forward raft was constructed with a groove in the middle for the trussing, which permitted the end to over hang and bear directly on the driven piles, a convenience at the time of unloading. The rear raft had a saddle which prevented the pile slipping off when being raised on to the pile driver.

As during construction the majority of the river water was being taken into the canal, the beach site was virtually on the far or right bank of the river. The piles were therefore towed up this bank and had then to be brought across to the site of the work. As the velocity of the current was about 8 ft. per second this was a somewhat ticklish operation. The method followed was to take a rope across from the left bank, attach it to the rear raft, take in the slack and let the pile float across under the influence of the current. For convenience in handling the tow rope a second rope was stretched permanently across the river along which a light boat was operated as a ferry. When the pile arrived at the left bank it was towed upstream until the fore end was opposite the pile driver where it was then secured, the rear end being allowed to float out until the pile was in line for raising.

The pile driver was designed and made locally. The main boom inclined at a slope of $1\frac{1}{4}$ to 1, was 93 feet long and weighed about 3 tons. The cross frames were of the M section illustrated on Plate VI, Fig. 11 to accommodate the trussing on the pile. The boom was supported by two columns each carried by a trolly running on a B. G. line. The original arrangement of the columns was as shown in Plate VI, Fig. 2, the intention being to use the columns as shown therein at the upstream end of the work, where the natural berm was a good deal higher than the finished level of the embankment, and to add extra sections for use on the embankment itself. Actually it was found more convenient to raise the embankment at the back to the level of the original line, thus avoiding an alteration of that column, and to modify the forward column as shown in Plate II. The forward embankment was necessary to provide an over-load to take the thrust of the struts. The pile driver was moved along its tracks by pinching. The pile hoist was operated by a 10-ton hand winch arranged to be driven by a Petter oil engine available locally. The winch was fitted on the rear track upstream of the pile driver, the rope passing through two pulleys, one on the trolly of the rear column and the other at the head of the boom. With this arrangement it was

only necessary to move the engine and winch twice during the course of the work. The steam hammer was a No. 3 Mackiernan-Terry, a very light machine intended only to overcome friction in the clutches and not to drive the piles into the bed of the river. Actually the piles were driven in one to three feet only.

We may assume the pile driver to be in line with the pile last driven. The hoisting rope was then attached to the floating pile and the fore end hoisted to slide up the face of the driven piles. Guides were provided for passing the pile nose over the transomes and for directing it from the top end of the driven piles to the boom. When about a third of the way up the boom it was secured to the boom and the hoisting rope relieved of its burden. The pile driver was then pinched forward about 10 feet until the pile was clear of the overhanging transomes and the raft clear of the driven piles, when the pile driver was clamped to the line, the pile unshackled, and the hoisting completed. The pile driver was then run back into position for driving and the pile driven.

A rate of progress of 5 piles a day complete with struts was aimed at, but it was a considerable time before this was realized. The first twenty-two piles to be driven were untrussed and gave little trouble in driving, but for the first few days minor defects in the organization held us back. Then we struck the first serious snag. In order to provide against lateral movement of the piles as a whole a light bracing had been fitted between the struts. This was observed to be under considerable stress and at the same time it was noticed that the first few piles had sunk below the designed alignment. It was first thought from the state of the bracing that the piles were leaning over towards the downstream side but a theodolite observation showed that they were leaning in the opposite direction. It was concluded that owing to the steep slope longitudinally of the toe of the piling, the whole structure had slipped downstream. This movement was checked by providing anchorages in the concrete abutment fastened to the top and bottom of the first pile, and also a concrete key about 10′ square between the rock berm and the underside of the piles. After this progress improved but was still slow. Driving was easy but boring the holes for the suspension bolts and strut connections occupied considerable time. Our electric drills were not yet operating successfully and a ratchet drill was awkward to fit. We found the quickest method was to use the primitive hammer and chisel. However we attained to the rate of 5 piles per day on the last day we drove untrussed piles.

With the advent of the trussed piles further delays occurred. These were partly occasioned by defects in the organisation of the manufacture and transport of the piles, but also the actual driving was distinctly more difficult, due to the fact that the stiff trussed piles could not adapt themselves to defects in the alignment in the way that the untrussed piles did. As it was estimated that the last untrussed pile would have a sag of 6 inches the first two trussed piles were specially built with sags of

4″ and 2″ respectively. This got us over the change from one type to the other all right, but there was more trouble ahead. Having got the transport running easily we were still only driving two piles a day on the average, the delay being due to the actual time taken in driving and the fact that the heavy driving, shaking the whole structure, caused it to settle, requiring constant adjustment of the line of the struts. The hard driving was after some thought diagnosed as being due to the toe of the line being out. In order to keep this under observation a gauge was painted on the side of each pile, giving depth at a slope of 1¼ to one from a point near the toe and at the same time a chain was lightly attached to the same point on each pile by means of which the actual depth was measured; the chain being subsequently removed by breaking the attachment. From the difference between the actual depth and the depth as given by the pile gauge the position of the toe could be calculated and by this means it was found that the toe was out of line by something over 2 feet. The cause of the trouble was then obvious—the slope of the boom being fixed, that of the driven pile also being fixed but flatter, and the pile being stiff, driving would naturally be difficult. The question was how to get the toe back into line and to keep it there? The original design provided for control of the line by adjusting the angle of the pile when being driven by a variable suspension of the forward flange from the transome as shown in the sketch Fig. 1. Owing to the

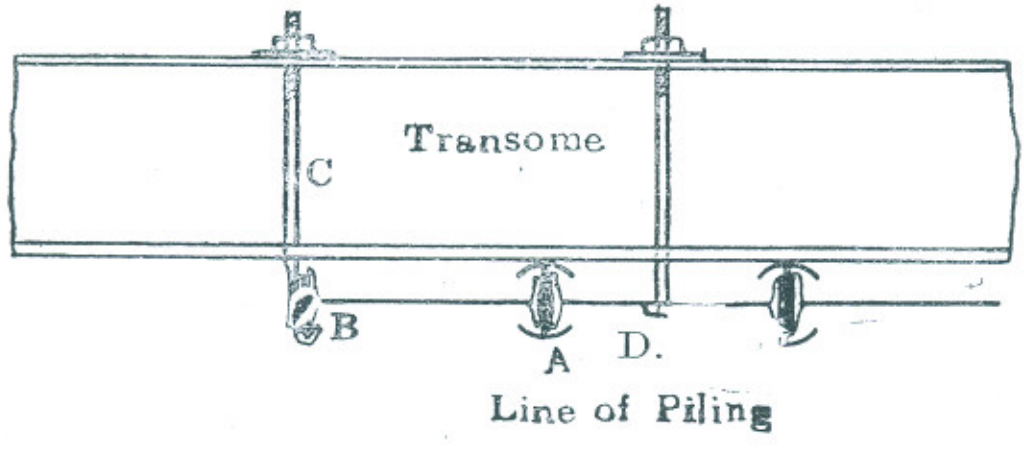



Fig. 1.

play between the clutch and girder at A, the alignment of the pile B can be varied by the bolt C over a considerable range. This method was however found to be quite ineffective in practice. If the pile D is not straight, the alignment of B is controlled by its efforts to adjust itself to D and any control exerted by C is lost in torsion of the pile in a very short length.

**Control of alignment**

In order to improve the driving and to obtain control over the line, the following changes were made in the design :—

(*a*) The continuous clutch was replaced by short lengths at top and bottom only. This made the driving pile largely

independent of the driven one and hence facilitated driving and control.

(*b*) Correction clutches, consisting of two clutches with one half flange removed, rivetted together and staggered, as sketch Fig. 2, were used as required at the bottom end. This provided control by definitely moving the line at the toe with each correction clutch used.

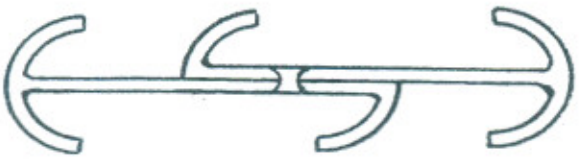


Fig. 2.

(*c*) The transome system illustrated in Plate VII, Fig. 1 was introduced. The object of this was to keep the transome behind the driving pile so that the latter could rise above the transome line, as it must do if held at both ends, the slope of the driven pile being flatter than that of the boom. The two main transomes were, as before, to be moved each time a strut was inserted. One of the subsidiary transomes was moved forward with each pile.

Other improvements effected at the same time were :—

(*d*) It was arranged to move the main transome and fit the struts at night, thus giving the whole day to driving. Struts were to be fitted irrespective of the number of piles driven if not less than three or more than eight.

(*e*) As this would probably mean uneven distribution of the struts the sleeper bed-plates were replaced by a continuous R. C. beam 12″×24″ designed to spread the 12-ton pressure of the strut over a suitable length.

(*f*) Difficulty had been experienced in adjusting the struts which so far had been done with wooden and steel wedges only. Arrangements were now made for fitting a 20-ton jack and using this for adjustment.

These measures were very successful; the correction clutches quickly brought the line under control with resultant ease in driving. A rate of progress of five piles a day was soon obtained and maintained. The new transome system was not ideal however, shifting the subsidiary transomes with each pile involved a certain amount of delay and shifting the main transomes took most of the night. Moreover, with the control established by the correction clutches, the advanced transome was no longer very objectionable as with the line correct, the driving pile would not rise above it.

A new system was therefore introduced, *vide* Plate VII, Fig. 2, which consisted of adding a new short transome daily. These transomes were placed at a slope merely because it was easier to add the new transome on top of the old than to place it underneath. At the same time the suspension bolts were replaced by straps fitting between the piles as shown on

Plate VII, fig. 2, thus obviating the boring of holes for the bolts. With these improvements progress was accelerated up to 8 piles a day and was limited only by the necessity of adding struts after the eighth pile. The piling nearing completion is shown in photo No. 3.

As stated above boulder filling was used for the embankment. This was obtained mostly from the right bank of the river being brought across by boats, and the author had a lively correspondence with the Kashmir customs authorities as to whether it was liable to duty, the river here forming the boundary between Kashmir and British territory. This was only brought to a conclusion when a general exemption for Government materials was given. As will be seen from Plate II the embankment was first constructed to a retired line to permit the placing of the piles in front thereof. The space between this face and the piling was filled following up the piling. Difficulty was experienced in getting the 12" boulders of which the main bank was constructed to pack in between the trussing of the piles. In the last six feet therefore, six inch boulders were substituted. As the filling was completed the struts were removed and used again at the front end of the piling.

On the 10th of January, 1932, a freshet of 75,000 cs. occurred in the river, which gave a water level of about R. L. 884·0 at the site of the work. At this time piling was nearly completed only a couple of days work remaining. When the water went down it was observed that the piling had subsided on to the filling in a length of about 100' where this was incomplete. It was at first feared that the toe had slipped out and thus spoiled the line, but investigation showed this not to be the case, the toe had merely penetrated further, as the result of which the struts sank and, bearing on the edge of the berm, had displaced the shore ends. About ten days were occupied in jacking the piles back into line and completing the filling, after which the piles were rapidly completed.

### Construction of needles

The general design of the needles has been described in page 6 above. Their construction was effected by moulding them in wooden forms about linked core rods, suspended from screwed rods in anchoring frames bolted to the top of the piling. The design of the anchoring frames is shown in Plate VIII. They are designed to take the pull due to the weight of the needle, less the buoyancy of the submerged part, resolved along the piling, less friction. Each frame carries four 1" rods, screwed for a travel of 5', the lower ends of which are arranged for attachment of the core rod links. Each of these links, which were composed of $2\frac{1}{2}" \times \frac{1}{4}"$ strap was holed for the attachment of two angle cleats, through which the link might be held from the bottom of the anchoring frame while the screwed rods were detached, screwed back and a new link inserted. Lowering to any designed length was thus effected.

The design of the moulds is shown in Plate V. The moulds remained in position throughout the construction of each needle, the side forms and bed forms being slacked off and lowered respectively while the needle section was lowered away from the forms. In order to prevent the groove filling falling out of the bottom, it was necessary to start the groove some distance from the lower end, for which special end forms were provided. Special arrangements were also necessary for the support of the side forms of the end needles.

The needles were made generally of 1 : 3 : 6 concrete. Owing to the necessity of speed in the work, lowering was effected 36 hours after pouring, though a longer setting time would have been desirable. We had many instances of slight damage to the needles owing to the strength being insufficient. Lowering was effected by a gang of four men, one to each rod, trained to screw the lowering nuts in time. Difficulty was occasionally experienced in getting the needles to move down owing to the side forms jamming and jacking had to be resorted to. Joints were purposely left between sections by giving a coat of mud plaster, in order that the needle might adapt itself to any deflection in the piling. For this reason the core rods were placed at the top of the sections. There were several instances of completed needles moving down several feet a few days after they had been finished presumably owing to movement of silt at the toe. Photos Nos. 4 and 5 show the needles at various stages.

**Filling gap.**

The next few paras. are inserted with some hesitation, as they are the record of a failure. However one sometimes learns more from failures than success and with a few modifications this particular failure might have succeeded.

At the downstream end of the work the alignment crossed a vertical cliff, about 30′ high, with its top at about R. L. 870·0 running D. S. at an angle of about 60° with the line of the work. As the piles could only be driven at right angles to the alignment, it was evident that where they met the cliff, there would be left a large area over which the filling would be unprotected. Here again the obvious solution was to place crates or blocks, and in this case crates had actually to be resorted to in the end. Our original intention however was to cover the space with concrete placed under water behind a wooden shield, from the under side of which was suspended a canvas bag intended to prevent loss of cement.

In order to design the shield it was necessary to have a fairly accurate survey of the face of the cliff for which purposes the device shown in the

sketch Fig. 3, was used. Here A is a piece of the 15″×5″ girder.

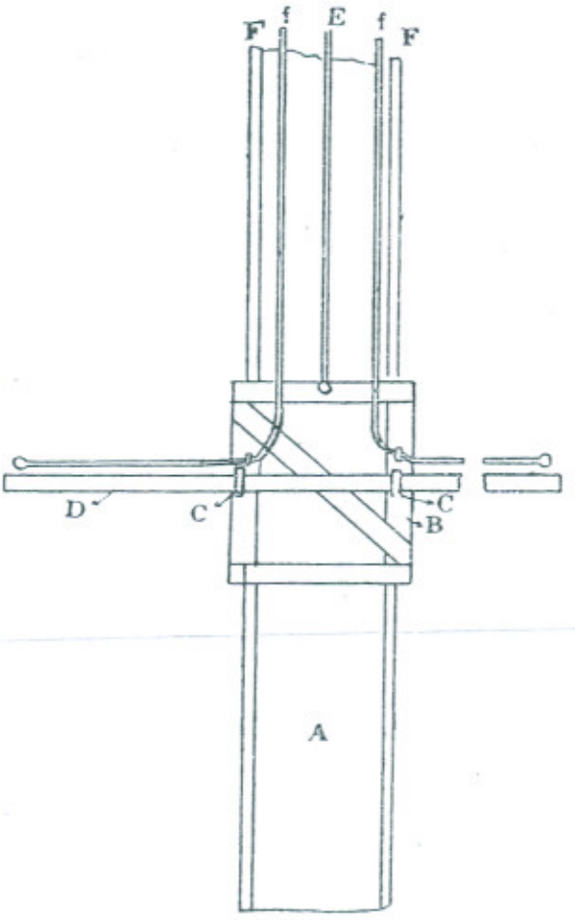



Fig. 3.

B a carriage made of two pieces of clutch joined and braced with $2\frac{1}{2}$″×$\frac{1}{4}$″ strap welded to them ; C C are rings welded to the carriage and carrying the rod D composed of an 8′ length of 2″ pipe. The position of the carriage on the girder was controlled by the wire E, while that of the pipe on the carriage was controlled and measured by the wires f. The girder was placed vertically in different positions along the face of the cliff and the offsetts of the cliff face from the girder measured. This survey showed that the space to be covered was roughly triangular the base of the triangle being about 20′ and the height 30′.

The design of the shield is shown in Plate IX. It could not, of course be put in until the other work was finished, by which time it was anticipated the river might be up R. L. 880·0. To provide for this level the extension of the shield, known as the handle, had to be made 28′ long bringing the total length of the structure up to over 60′. The shield was a composite structure, the body being constructed of wood while the

frame was of steel. The frame was placed on top of the body to be clear of the canvas bag. The shoots for the concrete, hinged at the bottom and connected by canvas hose to the body, were spaced so as to avoid a drop of more than 5′ for the concrete through water. The shield and handle were made separately, to be joined together when being placed. Unloaded the weight of the whole in air was about 2½ tons. In water the shield (without handle) would just float. The original idea was to float the shield over the hole, sink it into a vertical position, attach the handle and pull the whole over into the final position, but by the time we were ready to use the shield, the high velocities of the river made this method out of the question. When the attempt to place the shield was made, at the end of March, there were about 30,000 cs. in the river and the surface velocity over the hole was about 10 ft. per second.

The alternative method adopted was to slide the shield down the face of the needles and pull it over into position. The shield was built up on top of the embankment on tram trucks arranged so as to permit its being launched over the edge. (Photo No. 11). A shear leg with a 5-ton differential block was arranged over the edge of the embankment intended to lift the shield over the edge so as not to damage the canvas. A distance piece was fitted to the bottom end to avoid the canvas being trapped between the shield and the needles and a smooth bearing was arranged at the corner of the needles. The descent of the shield was controlled by two one-ton winches situated at the back of the embankment, their cables being attached to the bottom end of the shield, Mooring ropes were also provided upstream and downstream and a floating derrick carrying two differentials was intended to be used for lifting the bottom of the shield and working it into its final position. The shield was originally loaded with a ton of scrap iron, but when we got it about half-way down it became evident that this weight was not enough for the current. The shield was accordingly withdrawn and an additional two tons added. In withdrawing the shield the canvas was torn in one or two places which were repaired before lowering again. This time the shield went down easily and was pushed over by the current, without manœuvring, into more or less the designed position, nearly correct as regards line, but not quite low enough. The floating derrick was not of much use. It was difficult to handle in the current, so much so that to use it in the position intended, *i. e.*, directly in front of the shield, would have endangered the pipes. One of its hoisting cables also became entangled in the pipes and could not be used. Attempts were made with the remaining cable and the mooring ropes to move the shield out, but without success. Either the bed had silted and the spade was buried therein or the shield was held against the cliff with such force by the current that it could not be moved. Probably the latter.

No difficulty was experienced in raising the four lower pipes to the vertical, but all these pipes blocked after about 50 cft. of concrete had

been poured in each. As these pipes covered the main portion of the shield it was evident that things were not going well. The cause of blocking was not very clear, one possibility was that the canvas connections at the bottom of the pipes had blocked, but it was more probable that the shield was at a steeper angle than designed and the space below it consequently less. We now had only two pipes left. In raising them, No. 5 was damaged so badly as to be unserviceable and No. 6 the top one was found to be delivering on to the top of the last needle. As in this position it was evident that concrete would soon block the pipe it was decided to use grout instead. After putting in about 200 cft. of grout the suction end of a pump was introduced into the bottom of the pipe to determine whether the bag was holding the grout. The pump however gave nothing but clear water from which it was concluded that the grout was passing straight into the river. Grouting was therefore stopped, and after giving the concrete two days to set the shield was raised. The canvas came up with the shield, indicating that the concrete had not set in any considerable masses, and was full of large holes. From this it was evident that the bag had been so damaged during sinking and in manœuvring the shield into position that the river had had access to it and had washed out the cement.

The shield was therefore a failure but would, the author is convinced, have been a success if the canvas had been of better quality and the manœuvring power had been such that the shield could have been lifted about instead of being slid, *i. e.*, if the floating derrick had worked. A further improvement would have been to build the pipes into the shield in such a way as not to expose them to damage from the derrick, thus permitting the latter to work, and avoiding the flexible connections and moving of the pipes under water.

As stated above after removing the shield wire crates were dumped to cover the hole. Crates in this position will be shielded by the cliff to some extent and should last a considerable time.

Photos No. 6 and 7 show the shield before launching.

**Costs and General.**

A new method, in engineering, can only be said to be successful where it enables work to be done which has previously been impossible or makes possible the execution of work at less cost than old methods. It is important therefore to see how the cost of this work as carried out compares with the estimated cost, including capitalized maintenance, costs, of the old method of protection by wire crates or blocks, which was estimated as Rs. 4,00,000 for the facing only. The estimated cost of the work excluding departmental charges was Rs. 2,96,000. This included an item of Rs. 29,700 on account of duty on imports into Kashmir territory, which since the duty was repealed during the course of the work, and nothing was paid on this account, should be omitted from

our calculations, bringing the estimate down to Rs. 2,66,300. The actual expenditure on the work, also estimated to the extent that at the time of writing certain book debits have not been received and the estimate is still open, is Rs. 2,70,000, a figure which compares very favourably with the cost of blocks or crates as estimated above.

In the following table are given rate analyses of the cost of the two most interesting parts of the work, *i. e.*, the piling and the needles.

## ANALYSIS OF RATES.

### 1.—Sheet Piling.

| Piling. | Number. | Unit. | Rate. | Amount. | Rate per sq. foot of finished piling. |
|---|---|---|---|---|---|
| | | | | Rs. | Rs. |
| Piling f. o. r. Sukkur .. | 469·6 | tons | 112·0 | 52,595 | |
| Carriage .. | Do. | do. | 38·8 | 19,601 | |
| | | | | 72,196 | 3·70 |
| *Manufacture of piles, etc.—* | | | | | |
| Trussed piles .. | 200 | No. | 96·8 | 19,364 | |
| Untrussed do. .. | 28 | .. | 22·3 | 625 | |
| Struts .. | 44 | .. | 16·3 | 720 | |
| Transomes .. | 40 | Lft. | 3·4 | 120 | |
| Pile yard equipment .. | .. | .. | .. | 3,818 | |
| Do. operation .. | .. | .. | .. | 3,956 | |
| | | | | 28,603 | 1·46 |
| *River transport—* | | | | | |
| Carriage of piles on river | 228 | No. | 20·0 | 4,560 | |
| Do. struts | 30 | .. | 5·0 | 150 | |
| Do. transomes | 40 | .. | 5·0 | 200 | |
| Cost of floating derricks, Rafts, etc. | | .. | .. | 1,842 | |
| | | | | 6,752 | 0·34 |

1.—SHEET PILING—concluded.

| Piling. | Number. | Unit. | Rate. | Amount. | Rate per sq. foot of finished piling. |
|---|---|---|---|---|---|
| | | | | Rs. | Rs. |
| *Pile driving*— | | | | | |
| Raising and driving piles | 226 | No. | 22·6 | 5,095 | |
| Cost of pile driver, erection and dismantling of engine, track, etc. | .. | .. | .. | 10,524 | |
| Operation of winch and steam hammer. | .. | .. | .. | 3,320 | |
| Fitting struts .. | 44 | No. | 33·2 | 1,462 | |
| Do. transomes .. | 292 | Lft. | 5·1 | 1,497 | |
| Cutting tops of piles .. | 226 | No. | 3·75 | 847 | |
| | | | | 22,745 | 1·16 |
| Miscellaneous less write-back of unused material. | .. | .. | .. | 1,665 | 0·08 |
| | Total | | .. | 1,33,031 | 6·74 |

2.—CONCRETE NEEDLES.

| | | | | | Rate per c. ft. of needle. |
|---|---|---|---|---|---|
| Anchoring frames .. | 28 | No. | 115·0 | 3,217 | 6·8 |
| Forms .. | | | | 10,992 | 23·4 |
| Aggregate .. | 47,000 | %cft. | 12-0 | 5,640 | |
| Sand .. | 24,000 | %cft. | 6-0 | 1,440 | |
| | | | | 7,080 | |
| Cement .. | 6,110 | cwt. | 2-6-9 | 14,798 | |
| Labour .. | 46,920 | %cft. | 11-0 | 5,161 | |
| | | | | 27,039 | 57·5 |
| Core rods .. | | | | 4,798 | 10·2 |
| Lowering .. | 56 | No. | 55·2 | 3,090 | 6·6 |
| Miscellaneous .. | | | | 2,363 | 5·0 |
| Total .. | | | | 51,490 | 109·5 |

The author hopes that the discussion on this paper will produce some constructive criticism of the design and the methods employed in its execution. To start this he puts forward the following points, which occurred to him too late to be given effect to.

While admitting that the idea of constructing the piling laterally was sound, the author considers it was a pity that this was given effect to at the expense of flexibility in the abutments. The abutment reaches are very liable to undermining by further attack of the river and consequently it would have been a great advantage to have the needles continued through to the end. Stability of the piling could have been secured by anchoring the ends to masses of concrete placed behind the line of the needles and since the abutment work was all done in the dry, the needles could have been constructed on a light concrete facing to the filling, piling being unnecessary.

Considerable trouble was experienced throughout the pile driving owing to the strutted piles sinking after driving was completed under the component of the thrust of the inclined struts. This could have been avoided by arranging the struts normal to the plane of the piling but this would have increased the length of the piles considerably. Probably the simplest way of avoiding the trouble would have been to use a heavier hammer and drive the piling a few feet further in to the bed.

In one case the length of the needle placed was considerably in excess of the piling. It seems probable that the needle bent at the section joints and slid out along the bed in front of the toe. Had the needles been reinforced to carry their own weight, which would not have been expensive this could not have happened, also there would have been more certainty of their line being maintained as they sink owing to erosion at the toe.

As stated already, a longer setting time for the needles would have been advantageous. The use of rapid hardening cement was obviously indicated and the author attempted to obtain some for this purpose. He found, however, that the cost would have been double that of ordinary cement owing to the fact that rapid hardening cement is not covered by the concession rate at which Government obtain the latter. He has suggested to Government the advisability of endeavouring to obtain a concession for rapid hardening cement in order that this difficulty may be removed.

In the above comparison of costs it has been assumed that the cost of the future maintenance of this work will be negligible—whether this will be so or not time alone can tell.

The author anticipates that the result of breaking up the whirlpool will be to cause considerable silting of the scour hole in front of the site. It is possible there may be slight settlement of the needles before this occurs, but any such settlement can be readily and inexpensively made up at the top. The freshet of the 10th January caused a considerable silting of the site, but the majority of the silt was subsequently washed out when low pond levels were maintained for the purpose of moulding the needles. The author hopes to be able to place further information on the subject before he Congress when introducing the paper.

## DISCUSSION.

**Mr. Haigh** in introducing the paper before the Congress said that when writing the paper he had hoped that he would at this time be able to give members some information as to the behaviour of the work during the flood season and to compare this with the performance anticipated. This information he was now able to place before the Congress.

It would be remembered that when work was in progress before the construction of the needles, there had been a freshet which gave considerable trouble in displacing the driven piling. This same freshet as it subsided deposited a few feet of silt on the bed of the scour hole on which the needles would come to rest when lowered. He thought it was also probable that in places the original bed as surveyed at the end of the 1931 flood season did not represent the limits of the scour but similarly consisted of silt deposited therein. Consequently it was anticipated that flood action might cause settlement of the needles by eroding this silt before shingling up began. This shingle deposit was confidently expected as the result of the removal of the whirlpool.

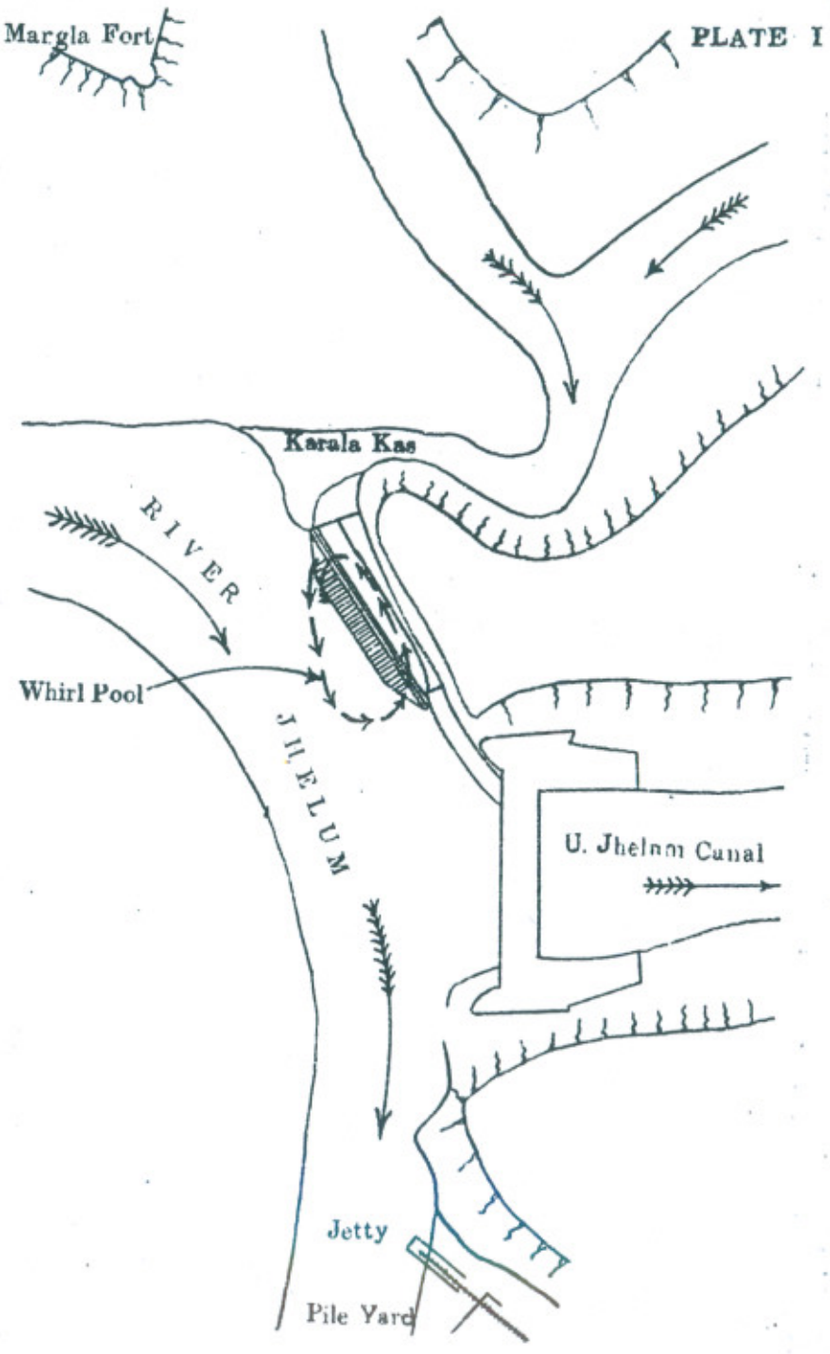
These anticipations appear to have been realized. The monsoon, while not a severe one, produced several small floods of the order of 2,00,000 cusecs and under the influence of these, twenty-four of the needles moved down distances varying from a few inches to 14 feet measured vertically. The subsidence occurred over the downstream half of the work only.

Soundings taken at the end of the flood season showed that there had been considerable rise in the river bed in front of the work which had been found to be due to shingle deposits. These extended throughout the length of the work and had a maximum thickness of about 10 feet.

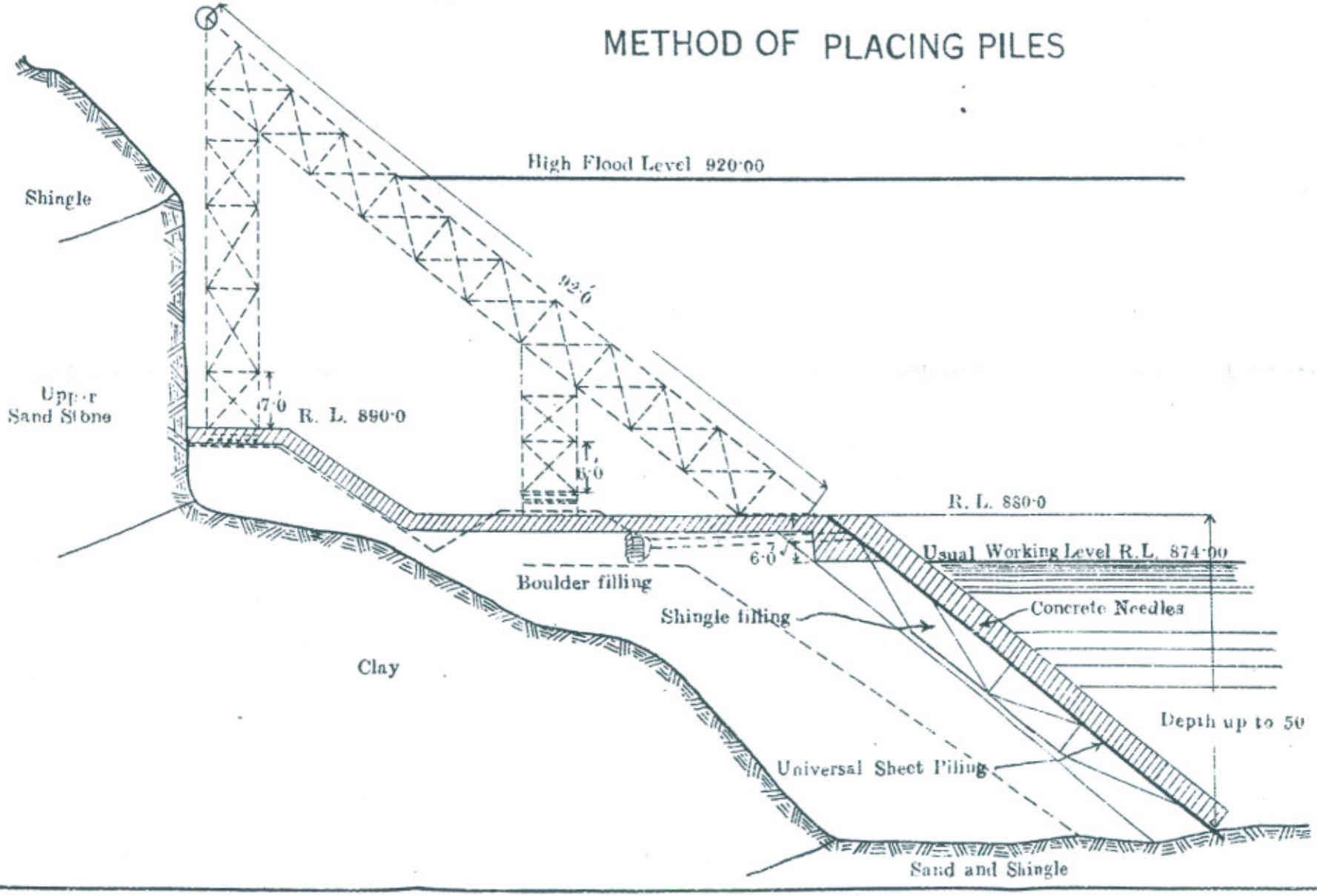
The only movement of the piles observed was behind needles Nos. 40 and 41 and was of negligible extent ; also, as these needles were reported not to have moved it would appear probable that the difference was due to an error of observation. There had been no settlement of the filling as was evident by the absence of any cracks other than contraction cracks at construction joints in the concrete covering.

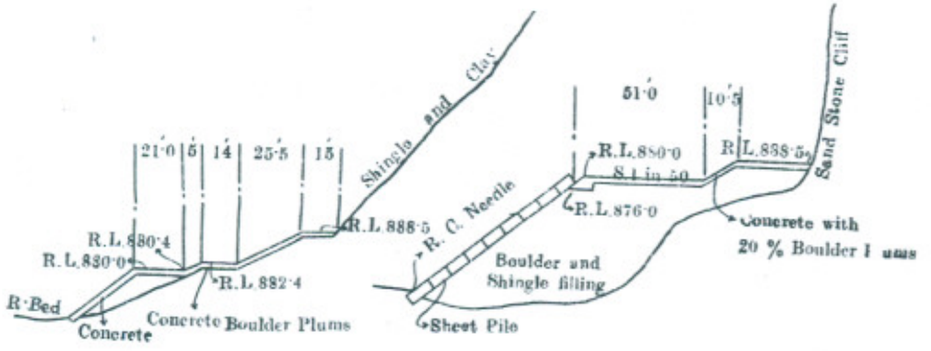
During the present season the needles which moved had been extended upto the old level. This was done without any difficulty and without refitting the anchoring frames. With the thickness of shingle now covering the toe of the needles it was unlikely that any further movement would occur and consequently the top of the needles had been finished off by providing a concrete cap tied on to the top of the piling by reinforcement and extending throughout the lengths of the work. A mud plaster joint was left between the top of the needles and the cap so as to permit the free settlement of the needles without damage to the

PLATE I


Margla Fort
Karala Kas
RIVER
JHELUM
Whirl Pool
U. Jhelum Canal
Jetty
Pile Yard

# METHOD OF PLACING PILES




21'0
5'
14'
25'5
15'
Shingle and Clay
R.L. 888·5
R.L. 880·4
R.L. 880·0
R.L. 882·4
R. Bed
Concrete
Concrete Boulder Plums
R. C. Needle
Boulder and Shingle filling
Sheet Pile
51'0
10'5
R.L. 880·0
8·1 in 50
R.L. 876·0
R.L. 888·5
Sand Stone Cliff
Concrete with 20 % Boulder Plums

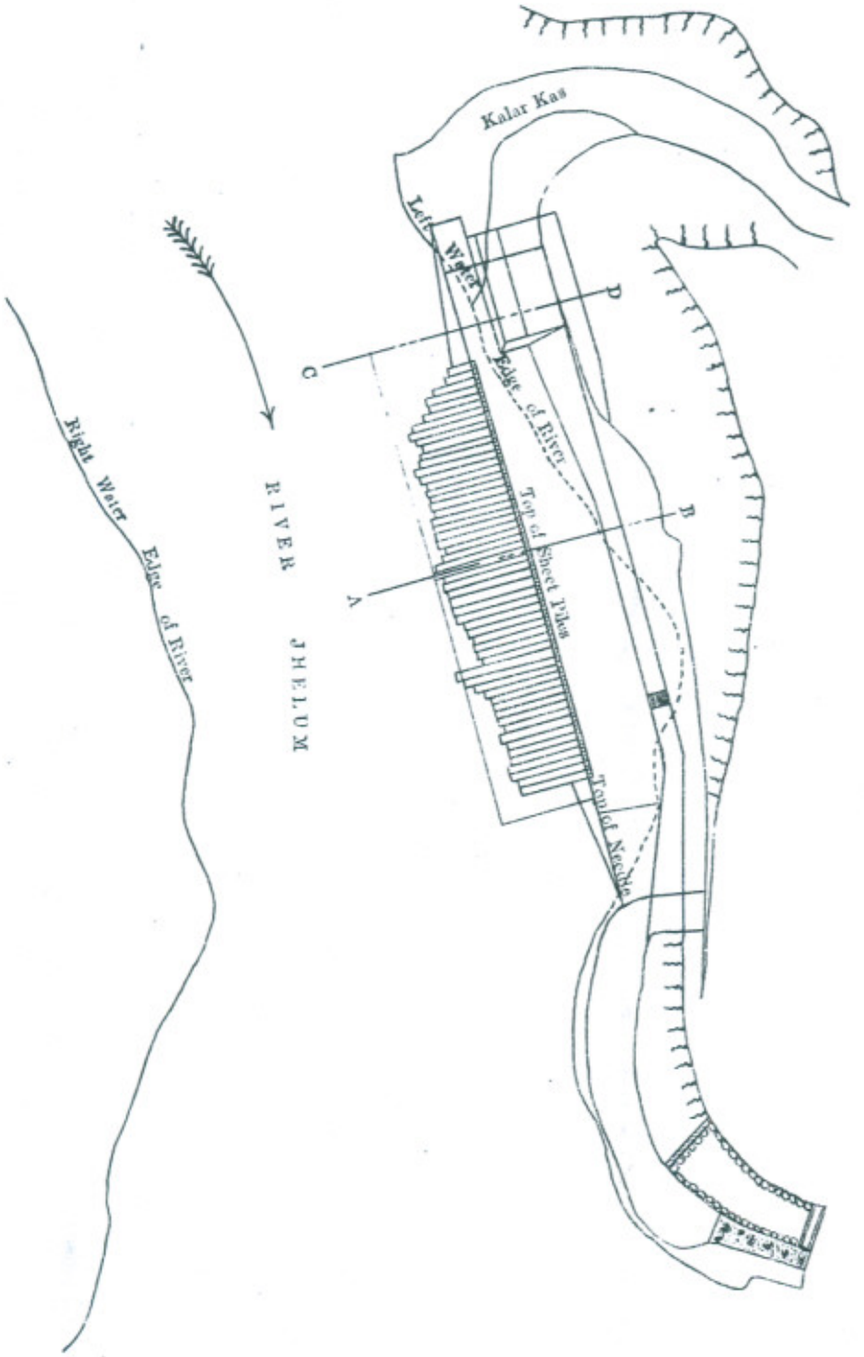

Kalar Kas
Left Water
Edge of River
Top of Sheet Piles
Toe of Needle
P
B
A
C
RIVER JHELUM
Right Water Edge of River

PLATE III

# TRUSSED PILE AND STRUT

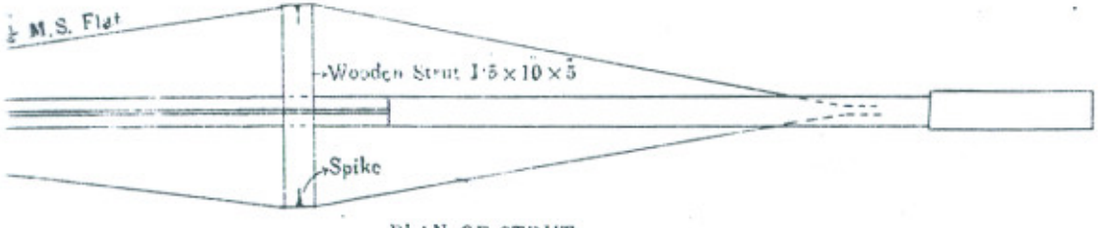



ELEVATION OF STRUT



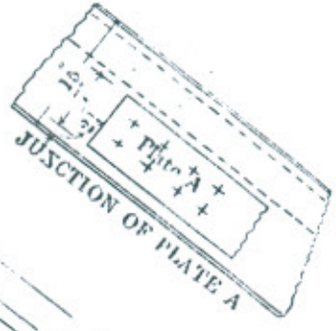







PLAN OF STRUT

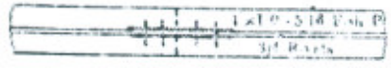
Detail of Joint in Pile





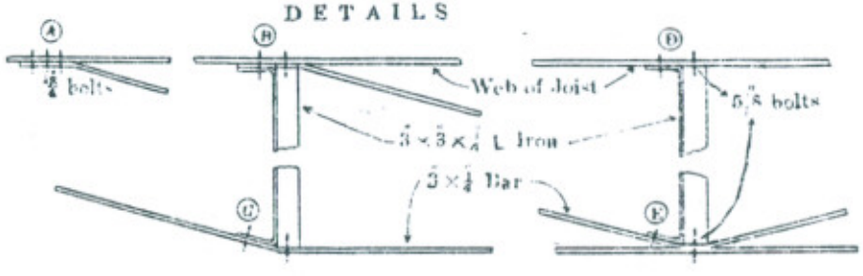


ELEVATION



PLAN

# TRUSSED PILE AND STRUT



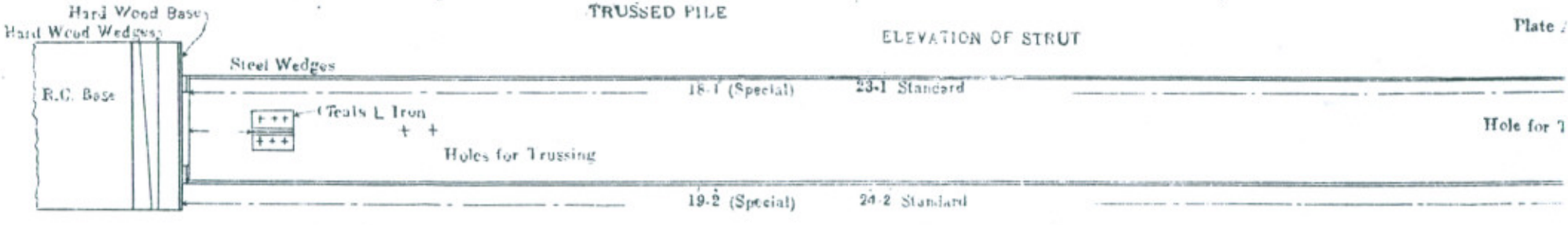


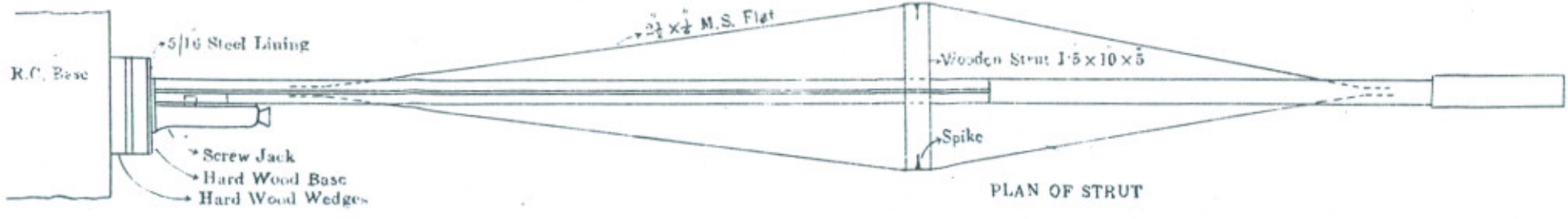


TRUSSED PILE

ELEVATION OF STRUT

Plate /




PLAN OF STRUT

PLATE V

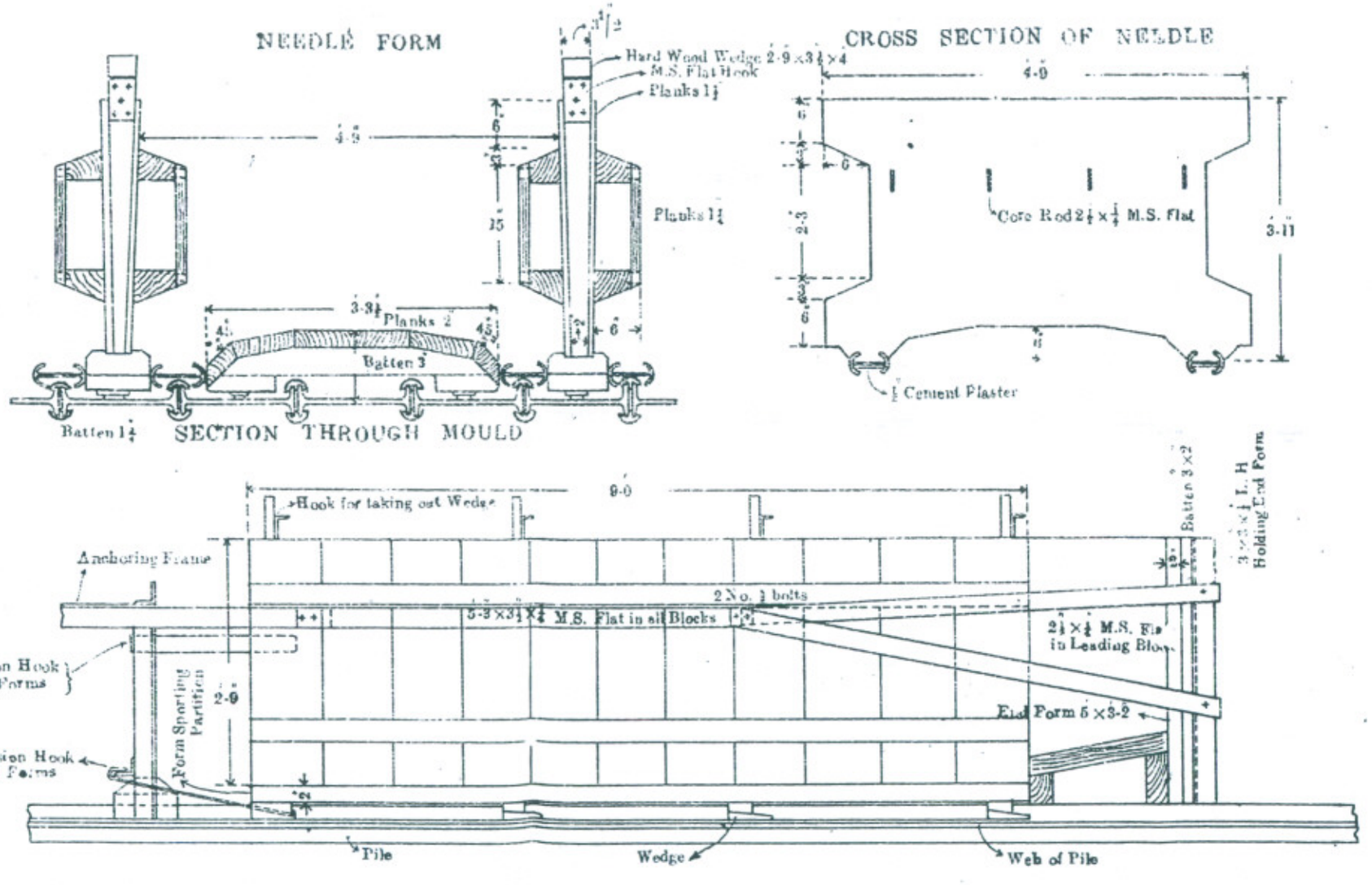
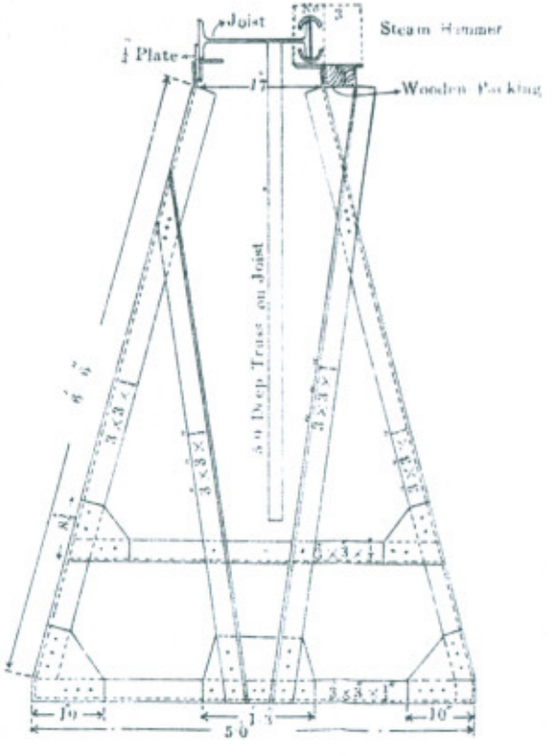

NEEDLE FORM
Hard Wood Wedge 2·9 ×3½×4
M.S. Flat Hook
Planks 1½
4·9
6
15
Planks 1½
3·3½
Planks 2
4½
4½
Batten 3
6
Batten 1½
SECTION THROUGH MOULD
CROSS SECTION OF NEEDLE
4·9
6
6
Core Rod 2½×½ M.S. Flat
3·11
6
½ Cement Plaster
9·0
Hook for taking out Wedge
Anchoring Frame
Batten 3×2
3×3×¼ L. H
Holding End Form
2 No. ½ bolts
5·3×3½×¼ M.S. Flat in all Blocks
2½×¼ M.S. Fla
in Leading Blo
Suspension Hook
for Side Forms
2·9
Form Sporting
Partition
End Form 5×3·2
Suspension Hook
for Bed Forms
Pile
Wedge
Web of Pile

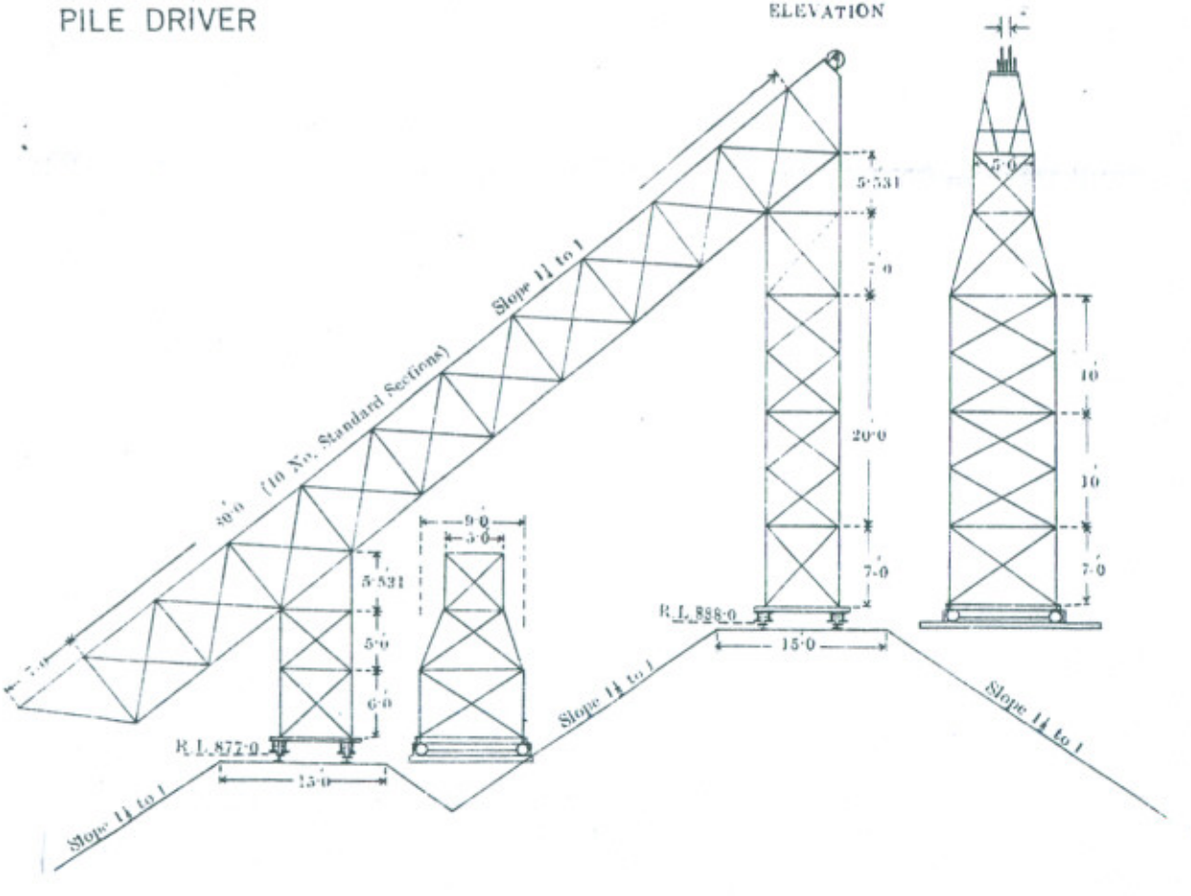
PLATE VI.

# PILE DRIVER

BOOM
CROSS SECTION

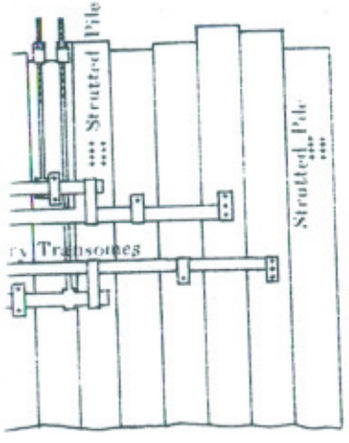



ELEVATION

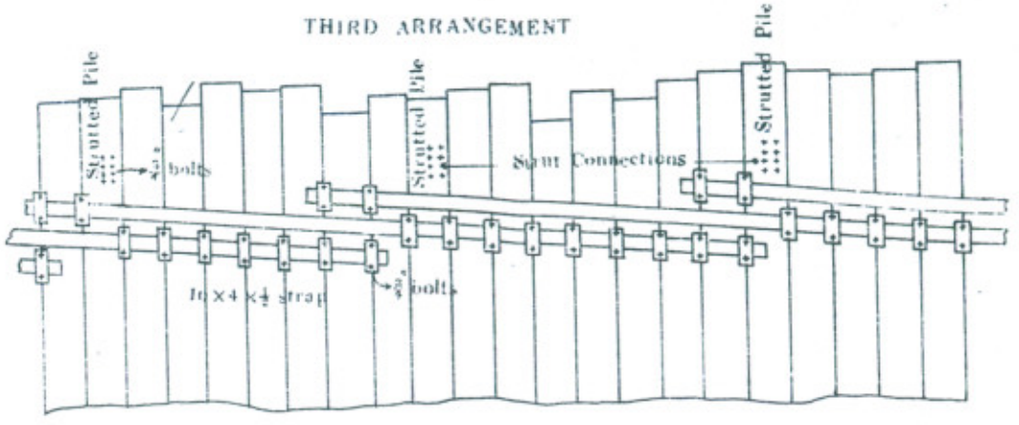


# DETAILS OF TRANSOMES

RANGEMENT

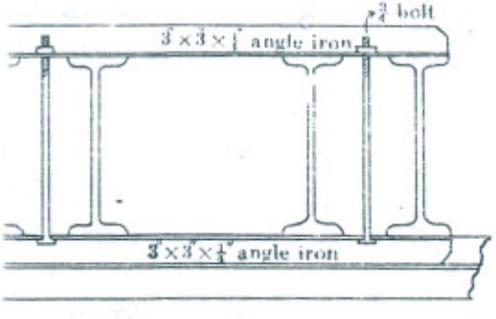



THIRD ARRANGEMENT

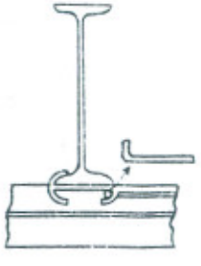



DETAILS
Scale 1/125

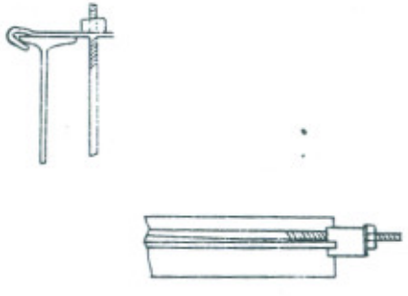
B



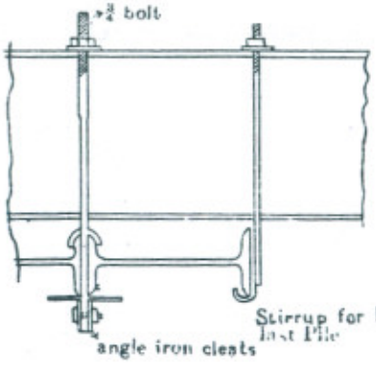

C



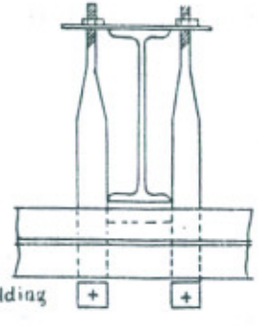
D



LONG: SECTION

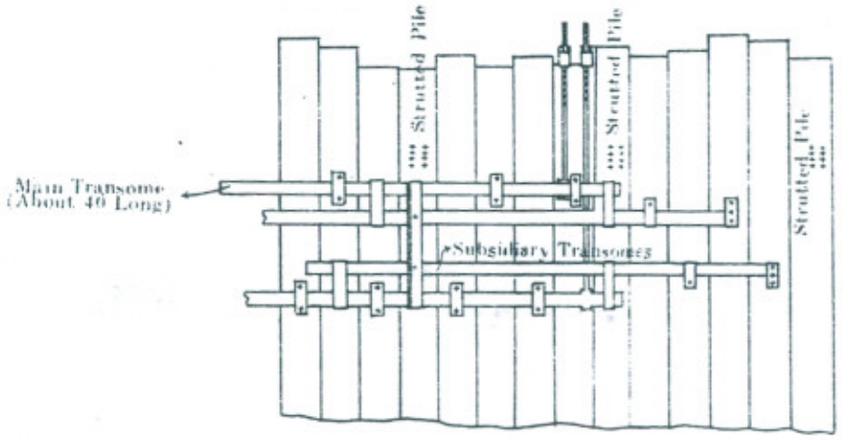



CROSS SECTION

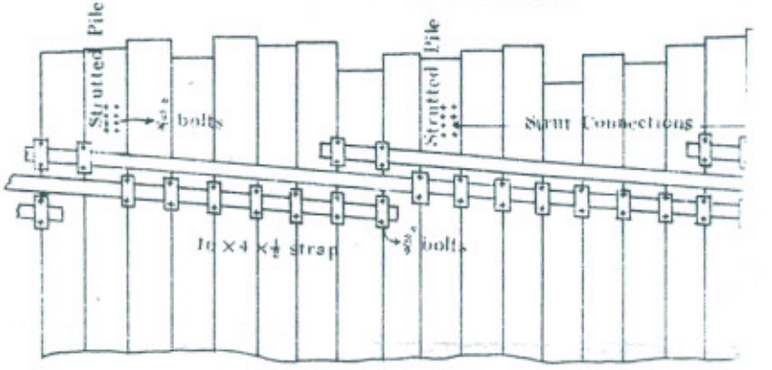


# DETAILS OF TRANSOMES

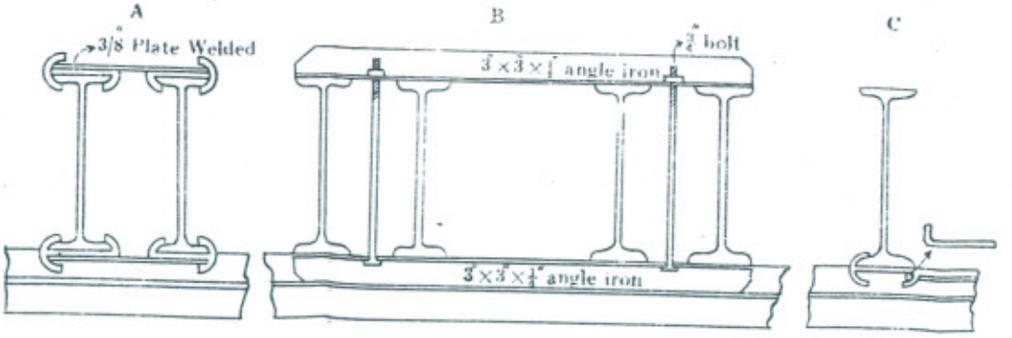
SECOND ARRANGEMENT



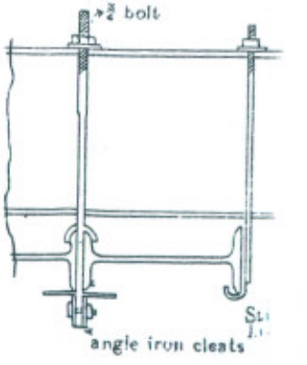

THIRD ARRANGEMENT

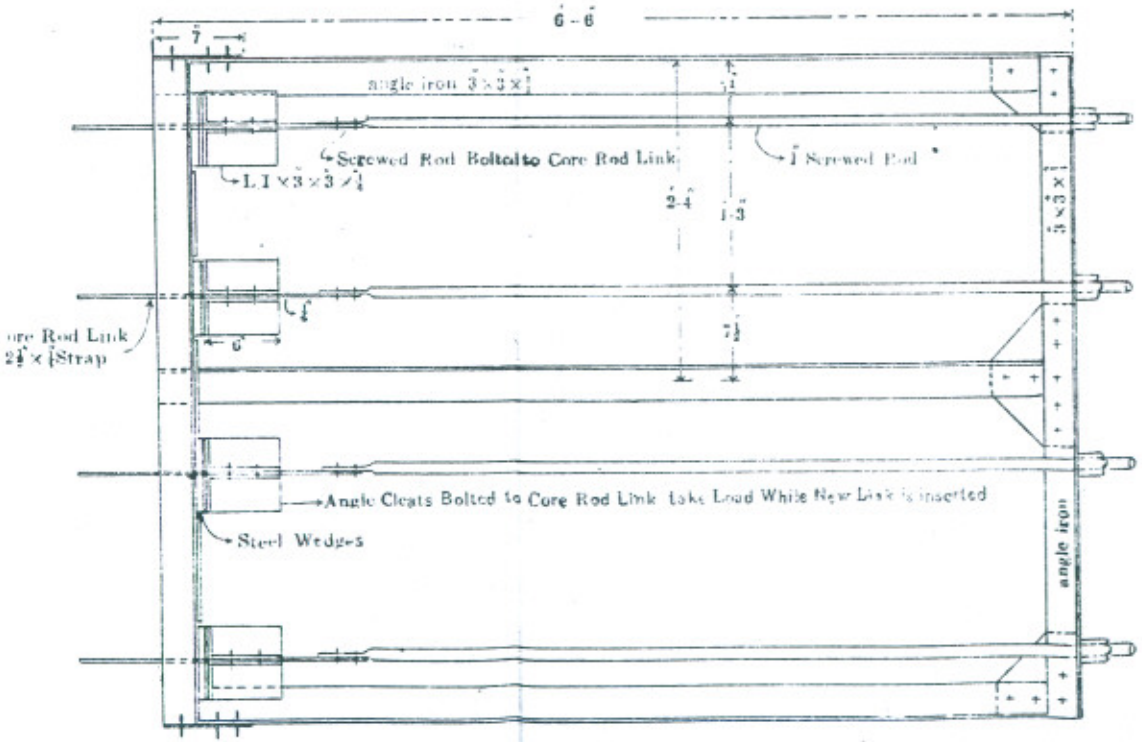



DETAILS
Scale 1/125

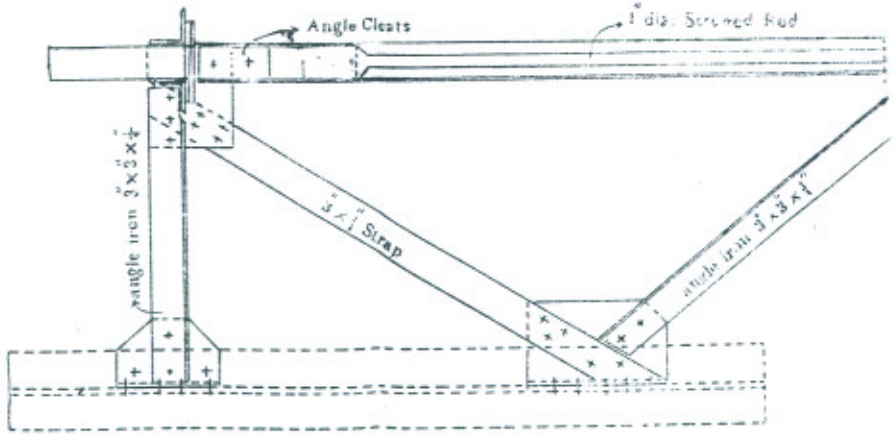



LONG: SECTION

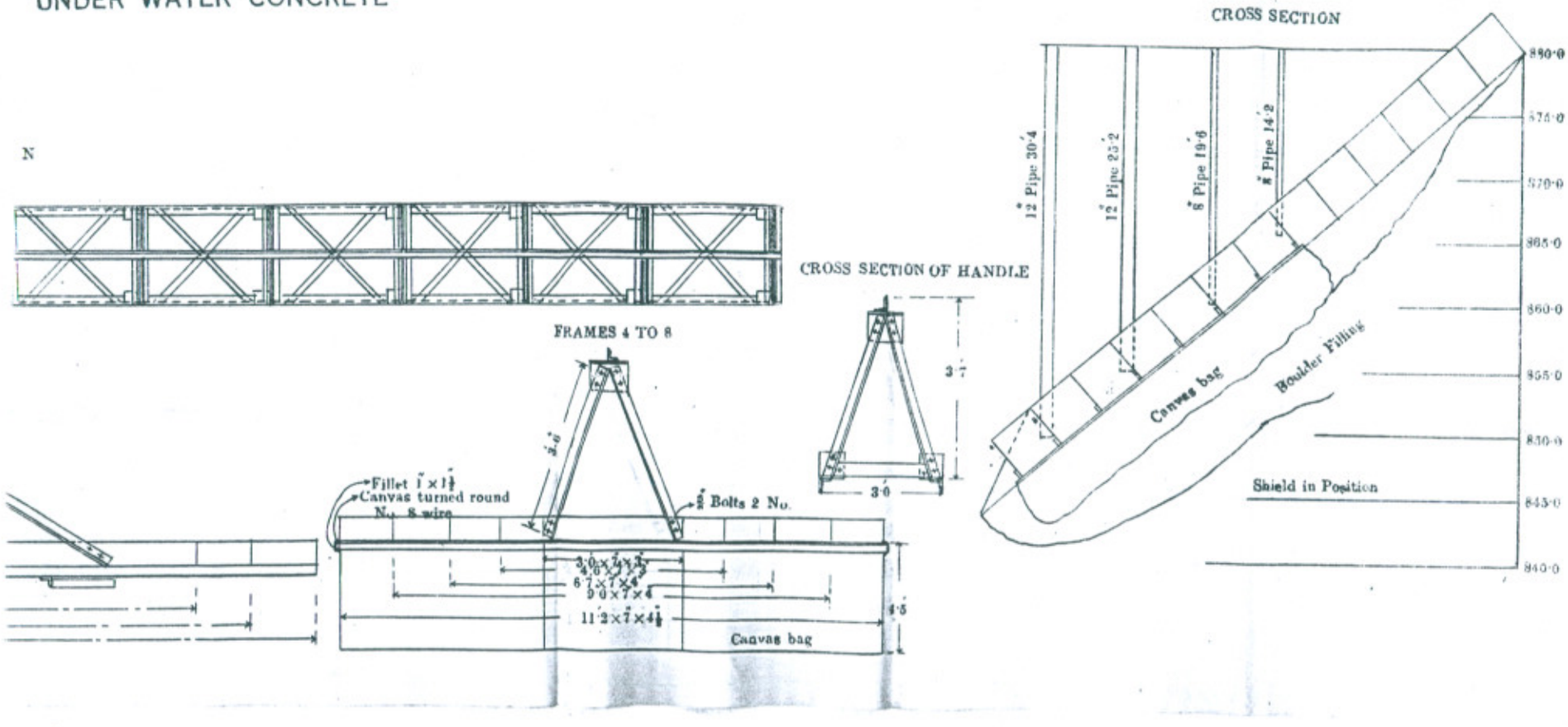





## ANCHORING FRAME



# UNDER WATER CONCRETE



# FORM FOR UNDER WATER CONCR

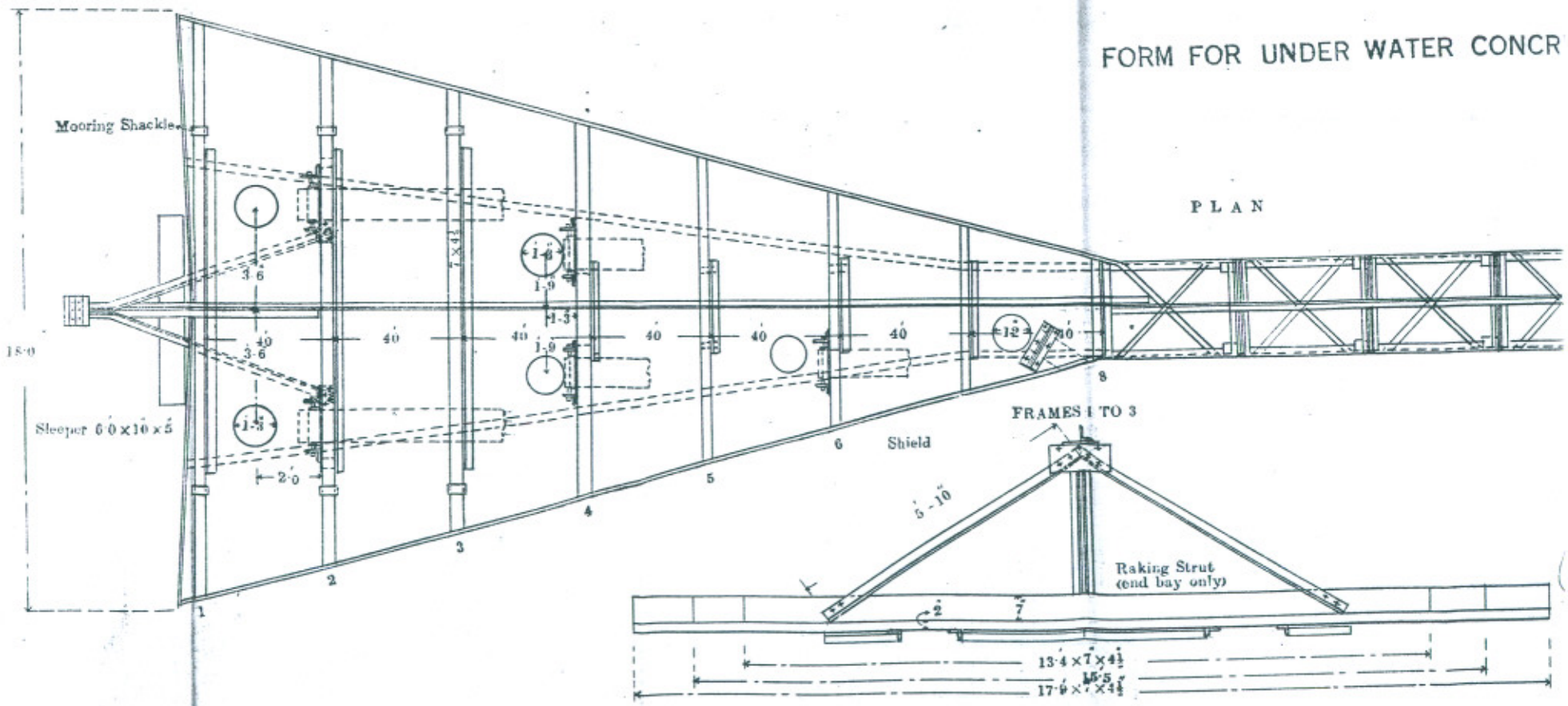


PHOTO No. 1.

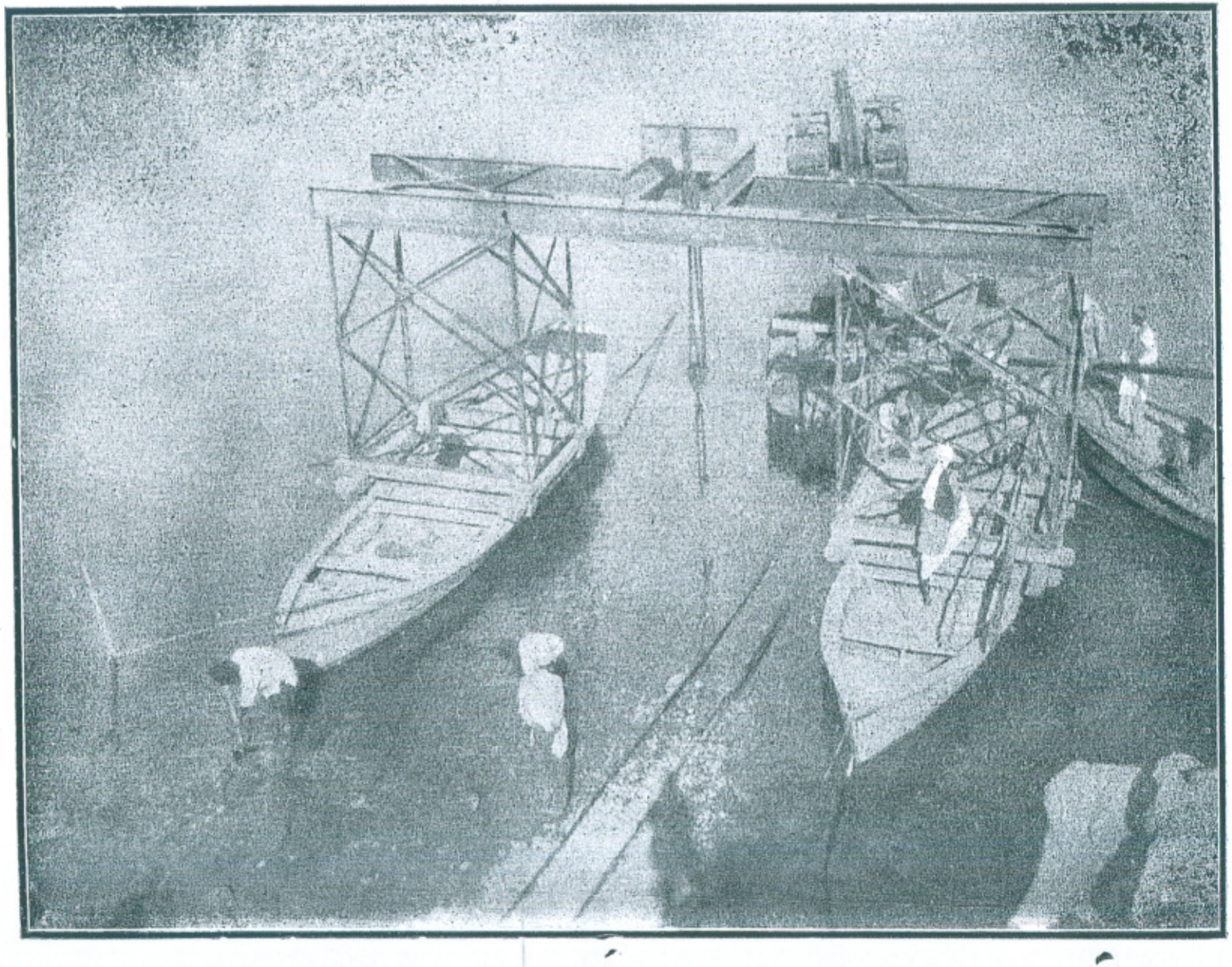


PHOTO No. 2.

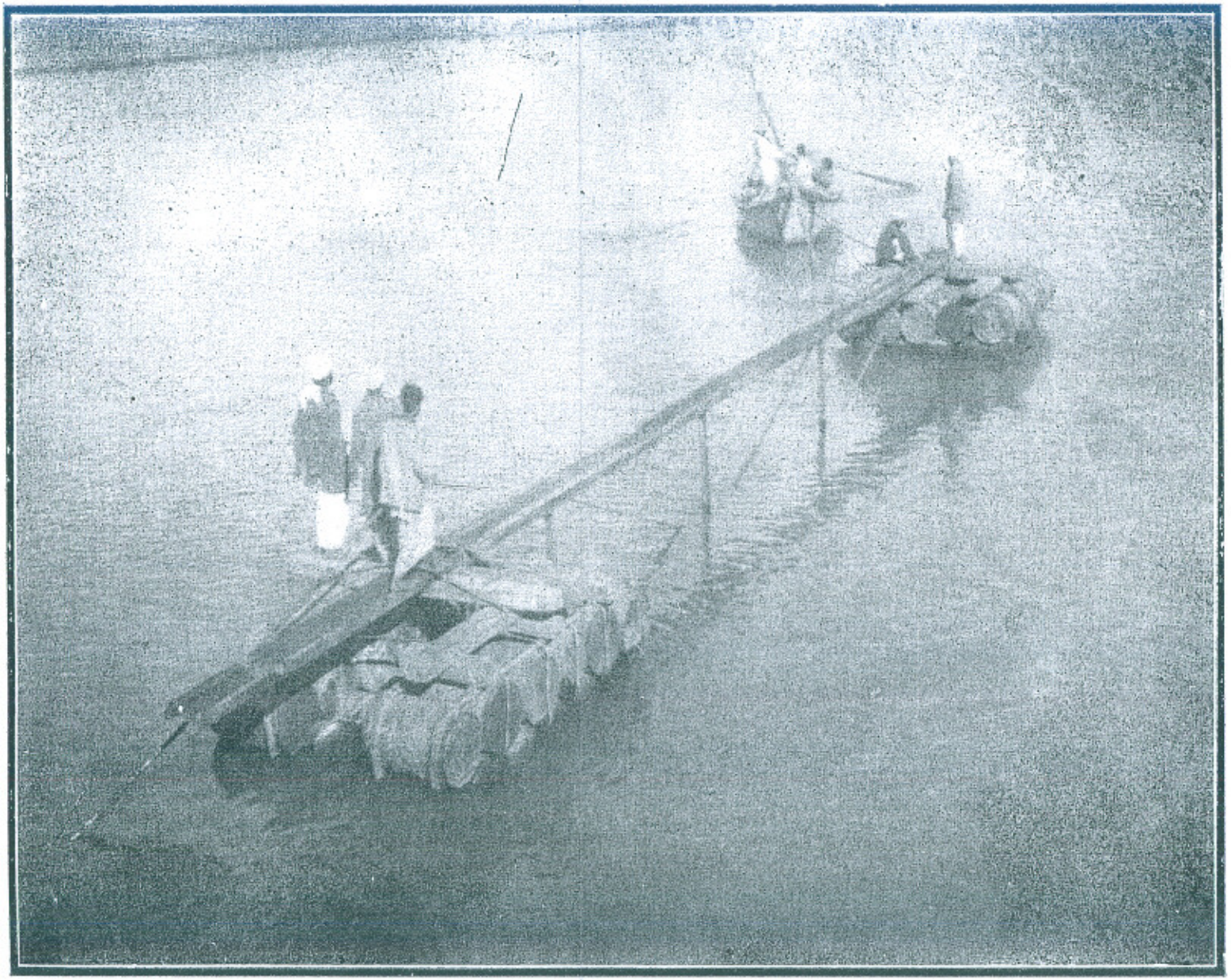


PHOTO No. 3.



PHOTO No. 4.

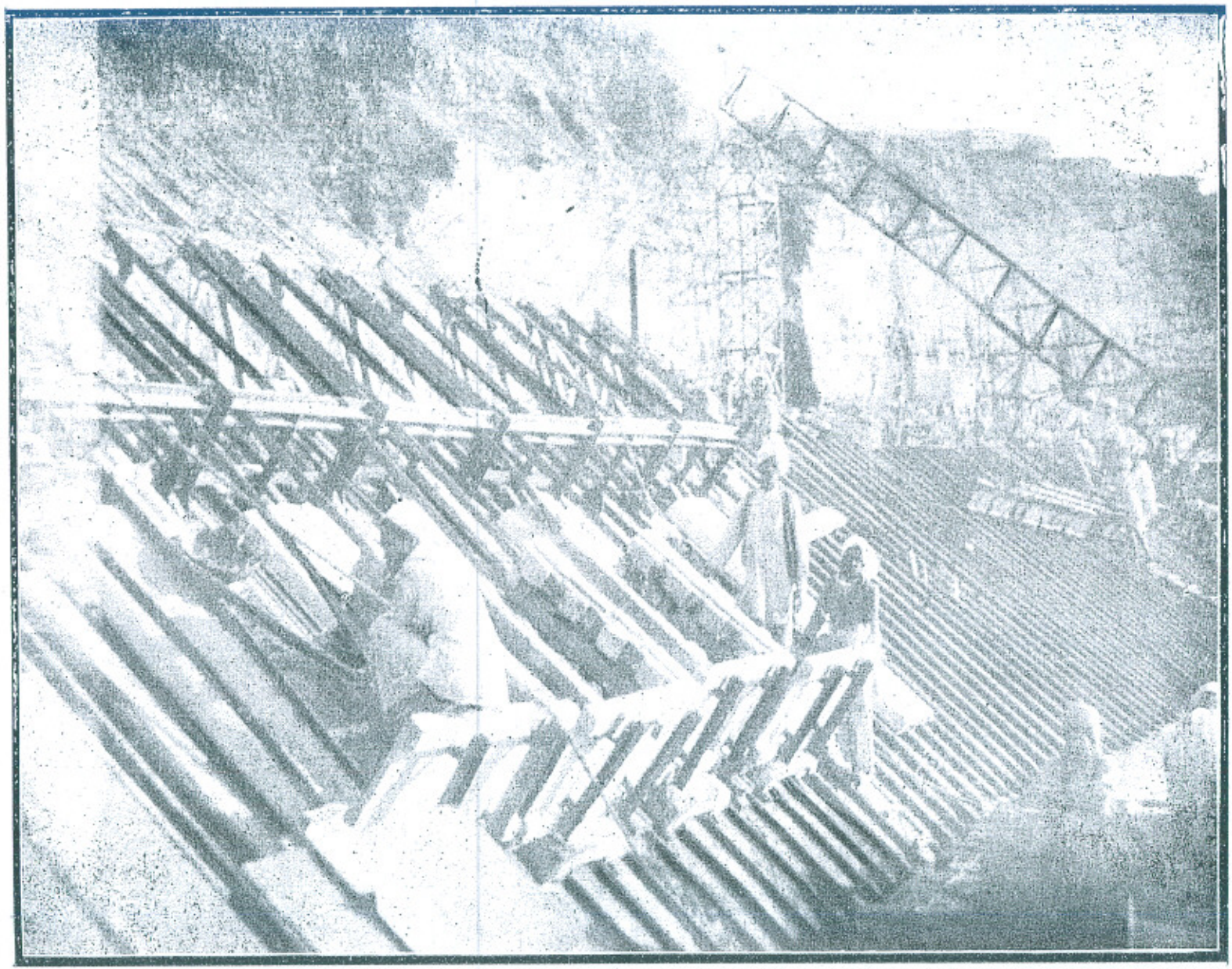


PHOTO No. 5.

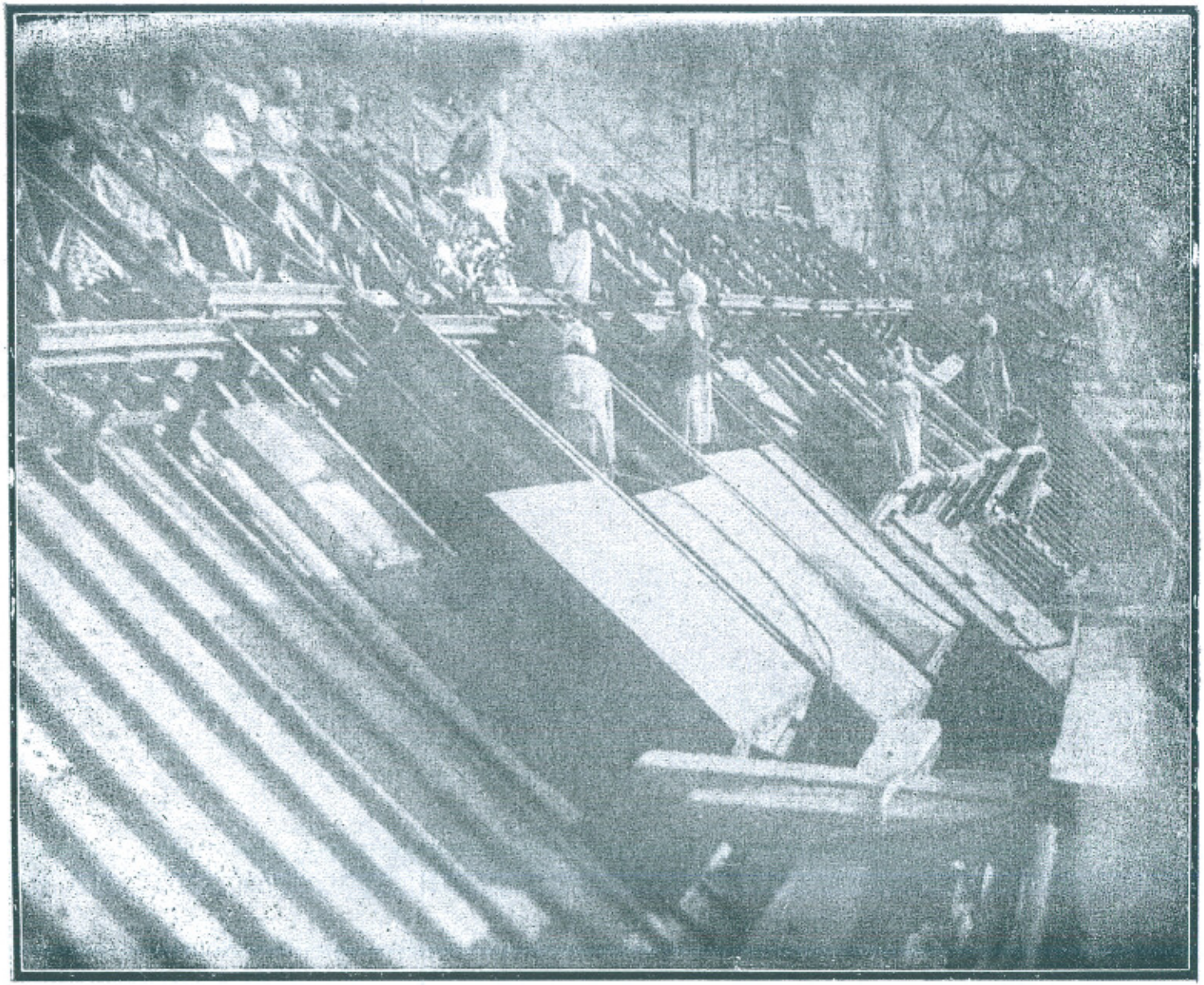


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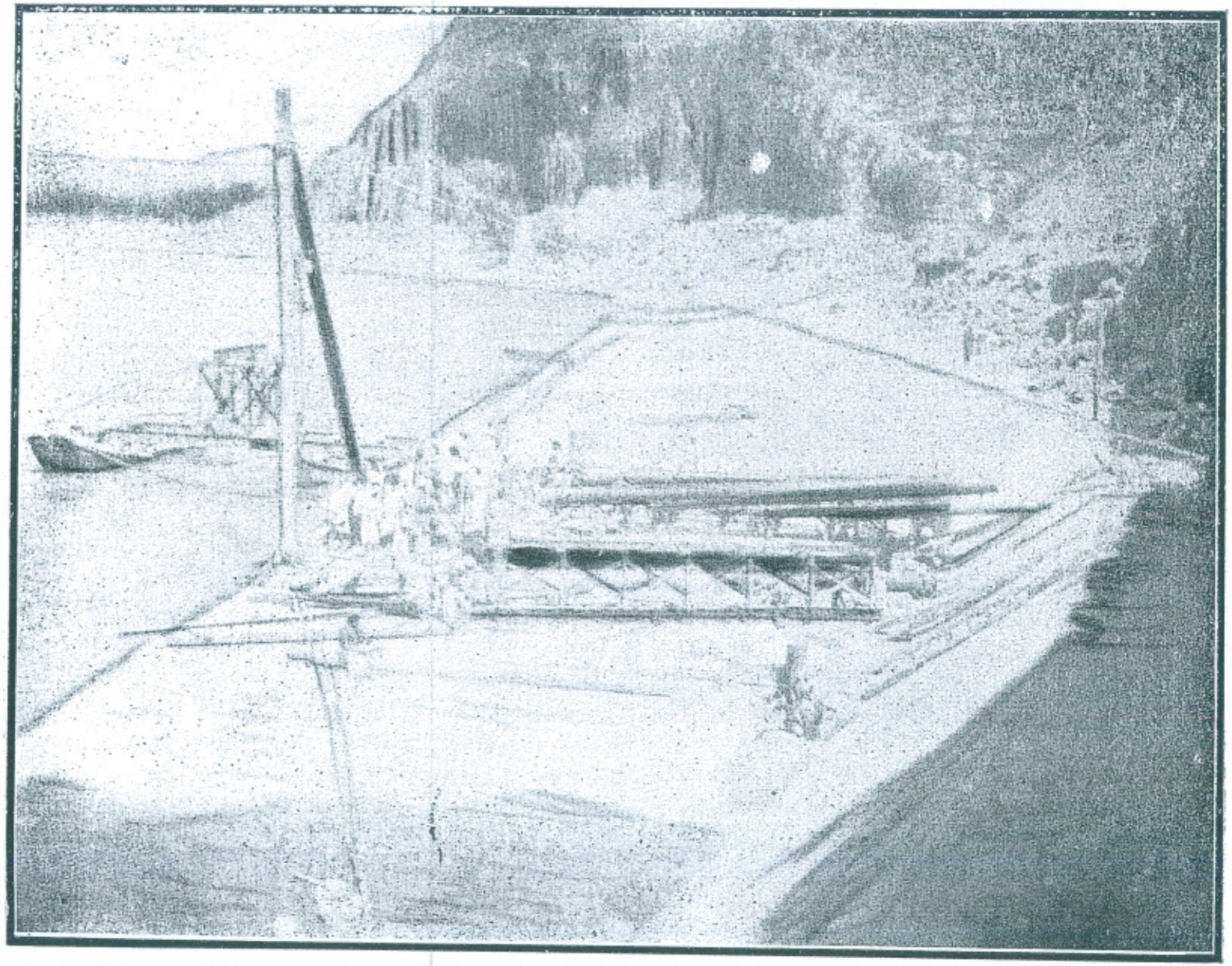
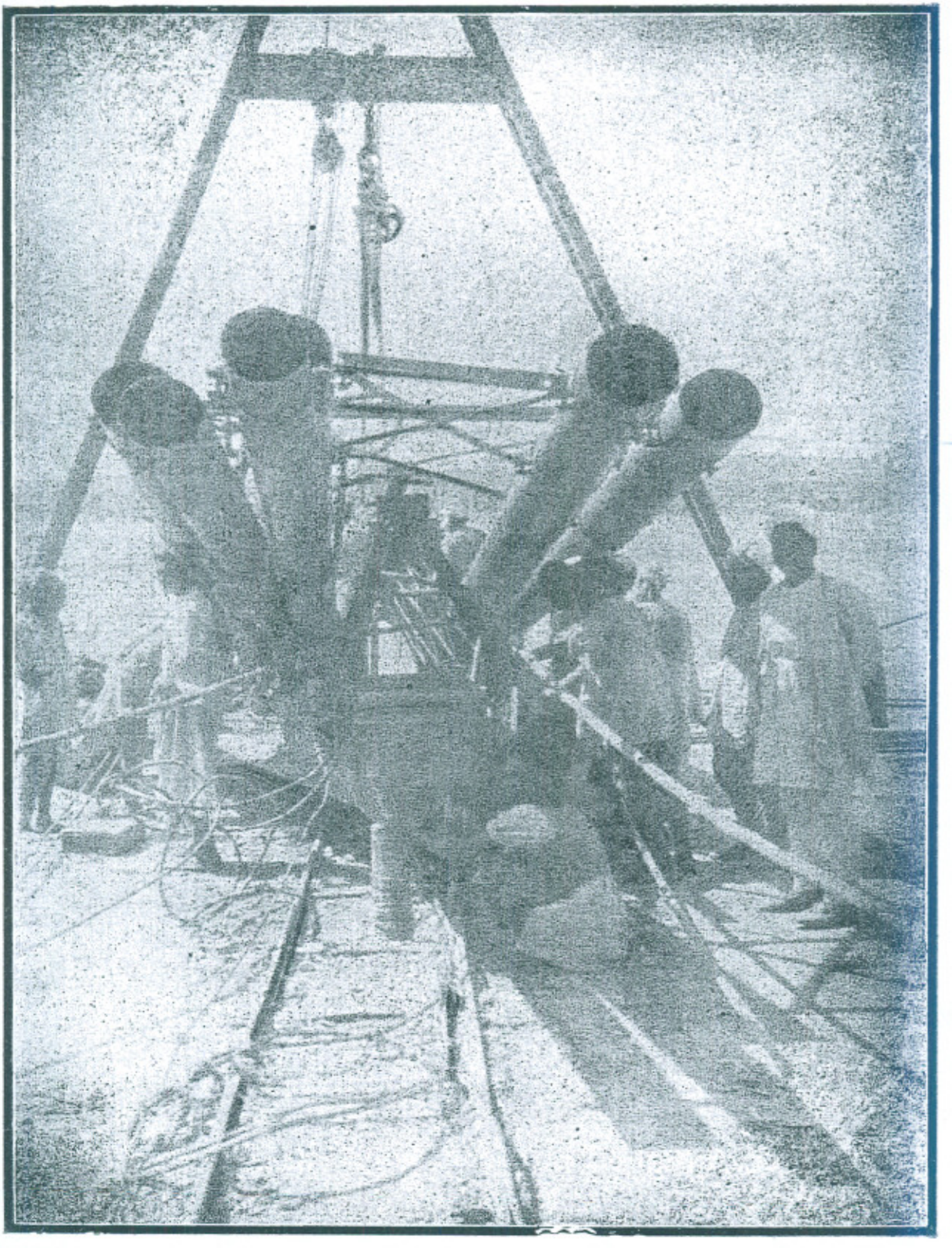


PHOTO No. 7.



cap. Should further movement occur.it would still be a simple matter to fill in the gap between the top of the needles and the cap.

The author expressed the hope that the paper would give rise to an interesting discussion.

**Mr. Colyer** had some interesting photographs of the damage done in the flood of 1929 which he wished to show by means of lantern slides but unfortunately there were no facilities for showing them The thing that struck him most was that the Regulator stood absolutely isolated, but safe, when the abutments on both sides of it had given way. He thought that this was an excellent *chit* to Mr. Hadow and congratulated him on the extraordinary success of the Regulator during the then maximum flood that had been experienced in 1928 when the speaker was in charge, followed by the even greater flood of 1929.

**Mr. Tinsley** said that he had traced from the history of the Mangla Head works that river bed levels in the vicinity of the work described in the paper in 1927 and 1928 were 861·0 and in 1929 found to be 854·0. What this difference was due to was not known, but in 1930 the bed level had gone down to 839·0, *i.e.*, 22 feet below what was two years previously. This year the minimum bed level of this particular section had risen from 839·0 to 845·0 which showed that silting or shingling up was taking place. The construction of the foreshore protection work had completely killed the back swirl and there was every reason to hope that the deep scour would eventually shingle up to a level of 861·0 as it was in 1927 and 1928.

Mr. Haigh said that the limited discussion had not given him a great deal to reply to. He would however like to associate himself with Mr. Colyer's tribute to Mr. Hadow and to endorse Mr. Tinsley's expectation that further shingling up in front of the work would occur in the future.