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THE SURVEY AND CONSTRUCTION OF THE KANGRA VALLEY RAILWAY.

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The idea of constructing a railway through the Kangra Valley was by no means new, and various projects had been under consideration since the year 1900.

Reconnaissance Surveys following different routes were carried out between 1910 and 1914, but all the reports based on these schemes showed that any form of railway would be unremunerative.

An ærial ropeway for the transport of goods was also considered and dropped for the same reason. Some other justification was therefore necessary.

When the Mandi (Uhl River) Hydro-Electric Project was first mooted, it was hoped to transport all the requisite machinery and material by road. An examination, however, of the probable tonnage involved, and the maximum weights to be carried, showed this to be impracticable.

It was originally estimated that the first development would require the transportation of some 20,000 tons of material from Pathankot to the Power Station site, out of which some 20 packages at least would weigh from 15 to 20 tons each, while most of the pipes for the penstock would weigh about 10 tons a piece. The main road from Pathankot to Baijnath was metalled (9 fe t wide), while the 16 miles beyond in Mandi State was unmetalled and unfit for motor traffic. It would therefore have been necessary to—

(*a*) Strengthen or rebuild all the bridges.

(*b*) Remetal the entire route once or twice during construction.

(*c*) Purchase tractors and lorries.

(*d*) Make special arrangements for the maintenance of the transmission line.

On the score of cost and the physical impossibility of carrying packages exceeding 22 tons during the second development of the scheme, there was no point in pursuing this investigation further.

Various Tramway schemes were also considered by the Hydro-Electric Branch of the Punjab Government :—

(1) To build a Tramway along the road. An examination of the road and its steep gradients placed this proposal out of court as a commercial proposition.

(2) To construct a Tramway making use of the easier stretches of the road alignment, and branching off on meeting difficult country. This was found impracticable.

(3) To build a tramway along the route reconnoitred by the N. W. Railway in 1914. The difficult nature of the country, however, precluded the adoption of this project also.

In view of the possibility of the N. W. Railway extending the broad gauge line from the existing terminus at Mukerian to Talwara, the Hydro-Electric authorities during 1922-23, explored the merits of a 2″-6″ gauge tramway over a new alignment from Talwara to Baijnath.

This scheme was turned down in favour of a metre gauge project which would allow of electrification at a future date, and was vigorously advocated by the Chief Engineer of the Hydro-Electric Branch as the most promising solution of the problem.

As a result, detailed investigations regarding the feasibility of a metre gauge tramway following the same alignment, were carried out during 1923-24, by the Hydro-Electric authorities, and the estimated cost of a line between Talwara and Shanan, over a total length of 84·43 miles, was Rs. 98·03 lakhs, or Rs. 1·16 lakhs per mile.

The intention was to extend the broad gauge Jullundur-Mukerian line to Talwara on the understanding that this portion would ultimately be paid for out of N. W. Railway funds, for which there appeared to be justification, the remainder of the line being constructed through the Agency of the P. W. D. Hydro-Electric Branch, with funds provided by the Punjab Government. A ruling grade of 5 per cent. compensated was selected, and a maximum curvature of 40°, and on the grounds of economy the Beas crossing was to be effected by a submersible bridge.

In 1925 the Punjab Government referred the matter of this construction to the Government of India and as a result of subsequent negotiations it was agreed that the line should be built from Pathankot in preference to Mukerian, and that it should be of 2′-6″ gauge, the construction and working of the line being undertaken by the N. W. Railway. As the traffic prospects of this line were not sufficient to justify this construction being undertaken by the Government of India as a commercial proposition, the Punjab Government agreed to guarantee the line. This guarantee was limited to a payment of Rs. four lakhs a year for a period of 13 years. In agreeing to this proposal the Punjab Government stressed the urgent necessity of communication being established at the earliest possible date in order that there should be no delay in the introduction of the supply of current from their Hydro-Electric scheme.

In April 1925 preliminary investigations were started.

Topography.

Plate I.—From its junction with the parent line at Pathankot to the terminus at Shanan, the Railway traverses the districts of Gurdaspur and Kangra and the Indian State of Mandi, the major portion of the line lying within the Kangra District.

The snow capped Dhauladhar range of the outer Himalayas, rising to a height of from 12,000 to 16,000 feet and following a general W. N. W to E. S. E. direction, forms the most prominent feature of the landscape within the view of the Railway.

From this picturesque mountain range, a series of low ridges reaching an altitude of from 3,000 to 5,000 feet, strike in a south-easterly direction towards the plains and divide the Sub-Himalayan tract into a series of open valleys which widen eastwards, to be cut off by the succeeding Sub-Himalayan ridge. Finally, to the east of Shanan, the main Dhauladhar range curving to the south-east closes the Kangra Valley, and separates it from the mountainous valleys of Kulu to the east.

The numerous torrential streams, fed from the snows of the Dhauladhar range, in general continue in the same southerly and south-westerly direction across these open alluvial valleys in deeply eroded courses. On reaching the south side of the Kangra Valley, they are diverted in a north-westerly or south-easterly direction along the north side of these foot hills. Here joining forces under the names of Banganga, Jugal and Neogal rivers, they cut through these lower ridges which bound the Kangra Valley to the south and, linking up with the tributaries which drain the southern slopes of these outer hills, they continue southwards to join the waters of the Beas river.

Taking advantage of these river valleys which traverse the foot hills, the railway runs for the greater part of its course over the open valleys of Jawali, Kangra, Palampur and Ahju to Shanan in Mandi State.

During early May these wide open valleys, covered with ripening wheat crops and hedge rows of sweet scented roses and honey suckle, contrast markedly with the mountainous grandeur of the Dhauladhar range to the north. From a point of view of scenery it would indeed be difficult to surpass the beauty of this Himalayan tract.

During May and June 1926 a survey of the area traversed by the railway was carried out by the Geological Survey of India.

Although Geological considerations did not play such an important part in the final location of the line as was the case in the Khyber Railway, the information was in some cases of very considerable importance.

In the section of line between Baijnath Paprola and Ahju it is a question whether sufficient consideration has been given to this aspect of the problem.

The alignment as finally fixed runs along the left bank of the Bhir Khud, a nullah with very precipitous side slopes, composed of massive jointed sandstones.

These dip into the river at an angle of some 35°, and a good deal of trouble has been experienced from slips in this section. It is possible that it would have been cheaper in the long run to have accepted a somewhat expensive crossing of the Bhir, and carried the alignment up the opposite bank.

Trouble has also been experienced in the Valley of the Banganga and the section between Nagrota and Palampur. Here sandstones alternate with bands of a dark red clay ; this clay weathers very rapidly, causing the overlying sandstone to fall away in large masses. In this case, although trouble was anticipated, the position had to be accepted as there was no alternative.

It is well known that the Kangra Valley is subject to intermittent earthquake shocks, and was the centre of a very destructive earthquake in 1905.

From the evidence then obtained it was found that during this earthquake, although buildings and structures located on alluvial tracts sustained considerable damage, those founded on hard rock remained comparatively immune.

These facts have, wherever possible, been taken into consideration in the design and siting of buildings and structures, a special earthquake-resisting design having been adopted for all buildings within the earthquake zones. Very useful information was obtained regarding the position of limestone deposits, and the suitability or otherwise of the various materials available for construction works.

General Description of the line.

Plate I and II.—The Railway is a single line of 2′-6″ gauge and its length from Pathankot to the Hydro-Electric Stores Yard at Shanan is 103·1 miles. Between Pathankot and Baijnath the maximum gradient is 2·5 per cent. and the maximum curvature 14° (=409 feet radius). Between Baijnath Paprola and Jogindernagar the gradient is 4 per cent. and the curvature 30° (=191 feet radius). Between Jogindernagar and the Hydro-Electric Yard at Shanan a 5 per cent. grade has been adopted, this portion of the line being treated as a siding, the terminus for passenger traffic being at Jogindernagar. Compensation for curvature has been allowed for at ·03 per cent. per degree, and all curves transitioned, the length of the transition being 150 feet. The quantity of earthwork in banks and cuttings is 5·8 million cubic yards ; there are two tunnels and over 1,000 openings including 53 major bridges, *i.e.*, bridges of 40 feet span or over. The tunnels and bridges are built to the 1922 recommended dimensions providing for an overall loading gauge 7′-6″ wide and 10′-6″ high.

Survey and Location Work. General.—Plates I and II.

As soon as orders were received survey parties were sent in to the field.

The only maps available from the Survey Department were to a scale of 2″ to 1 mile, and from these, and from a personal inspection of the ground, sufficient data was obtained to enable orders to be issued as to the general line to be adopted. It may be noted here that when survey work was almost complete, it was found that maps to a scale of 4″ to 1

mile were in print and available with the map section of the Forest Department at Dehra Dun. Had this only been known at the start, the major part of the preliminary survey work would have been avoided and detailed location could have been proceeded with at once.

Those who have had experience of railway construction (or it might almost be said of any form of construction work) where time is a vital factor, will realise that the fixing of the alignment was a matter of primary importance; the acquisition of land, preparation of Cross Sections, designs, and in fact everything being dependant upon it.

The problem was not an easy one. To have adopted the first alignment that suggested itself without investigating other possibilities, might have meant a great deal of unnecessary expenditure, while on the other hand there was the danger of overdoing the investigation of alternative routes, and a consequent loss of valuable time.

A mean had to be struck.

Section Pathankot to Guler.

The location of this portion of the line presented few difficulties. For the first 12 miles the alignment runs parallel and at a short distance to the south of the P. W. D. road, the Chakki river being crossed at mile 7·3. Here the first proposal had been to make use of the existing road bridge; this proposition, however, was eventually ruled out, as experience has shown that the combination of a road and railway bridge is a continual source of trouble. A separate bridge has been built a short distance downstream, giving us the advantage of protection from the road bridge above.

From mile 12 the alignment turns away from the road in a W. S. W. direction following the valley of the Garelli for the next four miles; here considerable development was necessary to reach the Talara plateau, the line making two complete semicircles. Once the plateau is reached the alignment offers no difficulties up to Guler at mile 45.

Section Guler to Kangra.

Immediately after leaving Guler trouble started, the problem being the crossing of the Banganga or Baner River.

Two main alternatives presented themselves, and they were briefly as follows:—

To remain on the right bank and to effect a crossing if possible at a point somewhere near the P. W. D. road bridge. This alignment had very distinct advantages; it would be on the right side of the river for Kangra, and the crossing of the Banganga would be reduced to a comparatively simple proposition. On investigation it had to be abandoned as it necessitated some very heavy tunnelling and the negotiation of an almost impossible bit of country just short of Kangra itself.

The second was to cross the river as soon as possible and to follow up the left bank ; the time spent in the gorge was to be reduced to a minimum by running to the maximum grade, as it was realised that, owing to the steepness of the side slopes and the very unstable nature of the ground, this portion would prove very costly. Experience has shewn that it is always best to " lump " the heavier work, instead of having to continue desperately contouring the outer features, thus getting away from the objective.

Immediately after leaving Guler and running through extremely difficult country, requiring a great deal of detailed location work, the line drops at the maximum gradient to the crossing of the Banganga at mile 47·5. Once crossed, it rises steadily again until it emerges from the gorge on to comparatively easy country.

At mile 52 another partial descent, involving further difficult location work, was found necessary in order to negotiate the crossing of the Bathu Khad (mile 53), an important tributary of the Banganga. Here again, full use was made of the grade on the descent and by the use of 100 feet high piers for the crossing, the effect was reduced to a minimum. From the Bathu the line continues to rise rapidly, and, after passing through a small tunnel at mile 54, it once more emerges from the steep side slopes of the river.

In easy country, and still rising, the alignment follows the left bank of the Daulatpur Nullah until it meets a massive conglomerate ridge which, running in an easterly to westerly direction, effectually blocked all efforts to get round ; a second and somewhat longer tunnel had to be accepted. Once through the ridge, a short fall brings us to Kangra station site at mile 59.

Section Kangra to Palampur.

From Kangra the first objective is the easy open country lying to the west of Nagrota. Still following the Banganga Valley, the line drops to the Reond Khad, the crossing of which was to prove a very difficult problem as, although only 200 feet wide, it runs to a depth of something over 200 feet.

From here the valley opens out considerably, and it was found economical to drop down on to the lower slopes in order to reduce the height of the crossings necessary over the numerous nullahs, which have their catchment in the high ground to the south.

A short rise brings us to the crossing of the Jugal, mile 61·8. The approach to the crossing is along the side of a steep conglomerate bluff some 300 feet high. During the preliminary reconnaissance it was thought that owing to the danger of slips occuring, the alignment along the cliff would not be feasible, and to avoid this a double crossing of the Banganga had been proposed. On closer investigation it was found that the conglomerate was both compact and well consolidated, and it was considered that the money thus saved justified the risk being taken. Results have entirely justified this decision.

Leaving the Jugal the line continues rising, until it emerges from the valley of the Banganga for the last time and from here up to the Nagrota Pass, some 3 miles beyond Nagrota itself, there is little of interest to note.

For a consideration of the next section three controlling points should be noted, namely, the Nagrota Pass, the Paror ridge and the crossing of the Neogal, the differences in level of the first two being only some 15 feet.

The development up to the Nagrota Pass, although involving fairly heavy work, produced no serious problem as far as location was concerned. Where development is necessary, such as in this case and in the case of Talara, it is always necessary to work out the alignment from the summit downwards taking account of controlling points.

From here two alternatives presented themselves: The temptation was to drop down on to the easy ground in the valley and develop again on arriving at Paror ridge; the second alternative, that of keeping height and following along the higher ground to the north, involving very much heavier work. Rise and fall means a recurring charge against working expenses and it was decided that the upper line would in the long run prove the most economical. From the Paror ridge to the Neogal is a distance of only 1,600 feet with a difference in level of 107 feet, which indicated the necessity of a very heavy cutting or possibly a tunnel through the ridge to get the necessary fall; trial lines were run down the ridge, but it was found that the extra length involved was not justifiable.

From the Neogal crossing, the line runs at a maximum grade up to Palampur station at mile 79·3, the question of alignment being purely one of detailed location, and making the best possible use of the ground.

Section Palampur to Baijnath Paprola.

The siting of Palampur station at a distance of 2½ miles from the town has caused a certain amount of criticism, but here again a study of the facts is necessary. The difference in level between Palampur station and the crossing of the Binwan Khud at Baijnath is approximately 600 feet, the distance being about 9 miles; after making allowances for future station sites and the contouring of certain main features, it was evident that there was little grade to spare; furthermore, the crossing of the Binwan was a controlling point, and the country offered little, if any, scope for development; these facts taken in conjunction will make the reason clear.

It is not necessary to go into this portion of the alignment in detail; the route followed runs straight across the drainage line of the valley and is a succession of deep long cuttings alternating with girder bridges or high banks over arched culverts. An alternative was tried of contouring round the nullahs and intervening spurs, but this was found impracticable, as not only did the country not accommodate the curvature, but a rough estimate of the extra length and curvature involved proved the shorter and straighter alignment to be the better and more economical of the two.

Baijnath Paprola to Shanan.

Baijnath Paprola station is situated in an open level stretch above the banks of the Binwan Khud. The crossing of the Binwan and the approach to it from both sides required a great deal of care in the detailed location work as the ground at our disposal was severely limited by the P. W. D. road to the north and the river itself to the south and west.

The next objective was the Ahju ridge, and it was found that the only access to it was by following up either one or other of the banks of the Bhir Khud; from the Binwan to Ahju the 4 per cent. grade is maintained without any appreciable break.

Location work in the Bhir proved exceptionally arduous as the valley is heavily wooded and the side slopes in places are precipitous.

The difference in level between Ahju and the Hydro-Electric Yard at Shanan is only some 109 feet and once more the same problem arose as in the case of the Nagrota Pass Paror ridge section ; in this case, however, by a comparison of the extra expenditure on works in the one case, and the capitalised cost of the extra running expenses in the other, the balance proved to be in favour of the lower route with the consequent rise again on approaching Shanan.

In extremely difficult country the temptation to introduce sharp curvature and heavy grades is great, partly because the tasks of both the Surveyor and the Construction Engineers are considerably lessened thereby and, partly owing to the fact that the evil consequences are not likely to be felt for some considerable time.

The loss of fall by the compensation necessary for sharp curvature is very serious, maintenance costs immediately go up, and speeds have to be reduced. Another point, which perhaps may not appear of such great importance, is that of comfort to passengers. Those who have travelled on the Kalka-Simla Railway will readily appreciate this.

As regards the question of grade it should be noted that the line rises and falls and that the gradients selected vary according to the nature of the country. The adoption of a steep ruling gradient throughout the greater part of the line is both unnecessary and impracticable and, the saving in capital cost by utilising the heaviest grades possible in isolated short lengths is not justifiable when it reduces train loads and puts up considerably the working expenses. In tackling this problem of grade and curvature it is necessary to have a full knowledge of the facts governing the problem, and to keep them in their true perspective.

Organisation and Plan of Operations.

As details of the organization may prove of assistance in the case of future railway construction of this nature, these have been given in Appendix I.

In order to consider the adequacy or otherwise of the organisation adopted, it will be necessary first to state briefly the various duties for which officers were held responsible.

From October 1925 up till November 1926, the Superintendent of Works' responsibilities were confined to the Kangra Valley Railway; in December 1926, however, re-organisation took place, and the various construction works in progress on the N. W. Railway were organised into circles.

In addition to his duties on the Kangra Valley Railway the Superintendent of Works was, under this re-organisation, made also responsible for the re-construction of the Khyber tunnels, the construction of the Ravi Bridge and the lines connected with it.

The duties of the Executive Engineer, Mechanical and Stores, were briefly: the receipt and issue of all Stores, Plant and Machinery and the maintenance of all Plant and Machinery in working order; in addition he was given Executive charge of the first 20 miles, including the Chakki Bridge, with one Sub Divisional Officer working under him. The total value of stores which passed through the depôt at Pathankot amounted to something over 80 lacs of rupees, and when other work was at its height, there were some 80 pumps, steam hoists, compressors and other types of machinery in use on the various works.

The other two Executive Engineers each had lengths of 40—45 miles with three Sub Divisional Officers working under them.

Owing to the fact of roads being practically non-existent, the Executive Engineer No. 1 Division had to carry out almost the whole of the inspection of his Division on foot, a complete inspection necessitating his absence from his Headquarters for the best part of a week.

With the exception of the larger girder bridges, the design and separation of all drawings was carried out in the Divisional offices, help being given in the work by type designs issued from the office of the Superintendent of Works.

In December 1926, the accounts, which had up to that date been prepared by the Superintendent of Works, were transferred to Divisions, thereby greatly increasing their work.

In the easier portion of the line, Sub-Divisional Officers had lengths of approximately 20 miles, but these in each case included one of the largest bridges on the line namely, the Chakki and the Gaj.

In the more difficult sections, Sub Divisions were reduced to lengths of eight to nine miles, while in the medium sections the lengths were about 12 miles.

In order to obtain some idea of the responsibilities of Sub Divisional Officers it may be noted that, on an average, yearly payments to contractors alone amounted to some eight lacs of rupees. Measurement work in country such as is met with on the K. V. Railway is extremely arduous, taking up time and labour comparable to that for measuring double the quantity of work in the plains.

Finally, it must be remembered that for the greater part of the time survey, construction, and estimating were being carried out simultaneously.

In Appendix I an alternative organisation has also been suggested; this may possibly be considered as on the generous side, but it is submitted that in a work where speed is of vital importance, economy in the matter of staff is not good policy.

As soon as the preliminaries of survey and land acquisition had been completed sufficiently to allow of construction work to start, a programme was prepared. This aimed at, and was based on the assumption of rail-head reaching Shanan by April 1928, the original date given to the Hydro-Electric Department.

In the preparation of this programme, and in its subsequent revisions it was realised, that on the completion of the three big river crossings, namely the Chakki, Gaj and the Banganga, lay the key to the whole position, and every effort was made to get these three completed to time.

It will also be obvious that delays if they were going to occur would most likely be met in the lower sections of the line, as in the upper sections more time would be available.

It is not proposed to go into details here as to the numerous causes of delay, as many of these will be dealt with subsequently when dealing with the works themselves.

Plate III shows the actual linking progress achieved from month to month, and on this, notes have been given which explain the cause of time being lost at various stages. That the programme aimed at originally was an optimistic one, there is no gainsaying, and whether it was an impossible one to work to is a very difficult question to answer, but the question which does arise is—on what basis should a programme be prepared?

It must be optimistic in order to give the necessary incentive, but at the same time it must also be practicable; delays are bound to occur and reasonable allowance must be made for them; a careful study must be made of the whole situation and the controlling points decided on. The "ideal" programme which allows of no delays is apt to defeat its own object, in that staff, when they see work getting far behind hand, are apt to become demoralised and treat the programme as a "scrap of paper"; also drastic revisions will eventually be found necessary, resulting in corresponding disorganisation of the work to meet new conditions.

Construction. General.

By May 1926 possession of land was given in the lower portion of the line and work was able to begin; previous to this, sanction had been obtained from zemindars to start work on certain pieces of waste land, but this was only in a few isolated cases.

The Kangra Valley is one of the wettest districts of the Punjab, the rains generally lasting from early in July up to the end of September, the rainfall in this period amounting to something between 70 and 100 inches, the latter figure being actually recorded at Palampur in 1927. There is also a considerable winter rainfall which occurs between

December and February. The working season can therefore be taken to extend from the end of September to the end of June, with a break of say a month in the winter, or a total period of eight months out of the 12.

Considering the line as a whole there are examples of almost every type of work likely to be met with on Railway Construction, and it was the variety that proved of such peculiar interest ; as a training ground it would be hard to find a better. It is now proposed to deal with the various difficulties met with under their different heads and the methods employed to combat them.

Earthwork.

As already mentioned the quantity of earthwork in cutting and bank amounted to some 5·8 million cub. yards and of this the greater part was either in rock, conglomerate, or in a formation consisting of hard compacted boulders.

In the long side-long cuttings of the Banganga, and again on the Nagrota Pass, Paror and Bhir Khad sections, there were always the two alternatives to be faced :— that of keeping out from the hillside, necessitating a large number of retaining walls, but a corresponding reduction in the amount of cutting required, the second being the converse of this. Although no hard and fast rule was made, the tendency was to keep in as much as possible, the reasons which mainly influenced the choice being, time, cost and the difficulty of obtaining suitable foundations on the steep and unstable slopes of the nullah beds.

Practically all the heavy work was done by imported labour, Gurkhas, Tibetans and Kashmiris appearing in fairly large numbers, but Pathans, of whom Afridis were in the majority, formed the greatest number.

Certain contractors tried using local labour but in addition to appearing unable to tackle the work their physique proved to be a further disability.

Ingersoll Rand Portable Compressors did excellent work, many of these having already seen life on the Khyber Railway ; owing to the limited number available they could only be used on the more important cuttings and it is considered that a larger number could have been usefully employed. The explosives used were either gun powder or gelignite ; in many cases contractors preferred to supply their own powder, but gelignite was supplied from railway magazines situated at intervals along the line.

Altogether some 7½ miles of tramway track were used on this work, but the use of this had to be confined to through cuttings where long leads were involved or where heavy rock and boulders required handling, elsewhere the long-suffering donkey came in for his share of the work.

Retaining Walls and Breast Walls.

As already mentioned, the tendency during final location was to keep in to the hill side ; this, although reducing the number of the retaining walls, necessitated (noticeably along the Banganga) a considerable amount

of breast walling. Plate IV, Figs. 2 and 3 shows two types of section used, the type shewn in Fig. 3 being suitable in cases where the wall was retaining a bank and heavily surcharged, and the type shewn in Fig. 2 being usually adopted for breast walls, where it was advisable to reduce the amount of cutting-back to a minimum, nearly all the batter being kept on the face. It must not be supposed that these types were strictly adhered to, as considerable modifications were made, depending on the actual conditions met with. For instance, both in the Banganga gorge and on other parts of the line, there are places where massive sandstone outcrops overlie thick bands of a reddish clay; once exposed the latter weather very rapidly. In such places it was found sufficient if little more than a skin of masonry were used, underpinning the rock above and preventing any further weathering of the clay beneath.

At Paror ridge, (where it will be remembered that a heavy cutting was found necessary in order to get down to the Neogal Crossing), a great deal of trouble has been experienced.

From the sketches given on Plate VIII it will be seen that the cutting takes both the railway and the P. W. D. road, the latter running at a high level on the North side and well benched back.

Although it was thought that a retaining wall would eventually be required, the cutting showed little signs of movement during the first year. In January of this year, however, cracks began to appear, first on the hill above the P. W. D. road, and afterwards along the edge of the P.W.D. road itself. It was evident that the whole of this portion of the hill was moving; the direction of movement being at an angle of some 40° to the centre line of the railway.

A retaining wall was at once started and was partly completed. Soon after completion cracks appeared about 10 feet from the end of the completed wall, and it was evident that the whole of this portion down to the bottom of the founds was being pushed out. For two or three days careful measurements were taken and it was found that this movement amounted to about an inch to an inch and a half in 24 hours. It was evident that the only remedy for stopping this movement, was a cut and cover, provided it could be got in in time. Every effort was being made to get centres completed and the work started, when, at about midday on April 8th, the movement suddenly increased, and in the space of an hour the whole hill subsided; the hill above the road sank some 10ft. and the road itself dropped three to four feet, the wall being pushed in, squeezed the track up some two to two and a half feet. An Inspection of the site, immediately afterwards, showed that the whole mass of disintegrated sandstone forming the upper portion of the hill was sliding over the thick band of red clay beneath, and in places where this was exposed it showed a clean polished surface.

By clearing the greater part of the overload away, and taking the foundations down to some 10 feet below the level of railway formation, all further movement was stopped. Before filling in again behind the

retaining wall, care was taken to stop back the clay, to prevent it from once more becoming a sliding surface.

Had the line at the time not been opened to traffic, it would have probably been cheaper to have started founding the wall from the far side (south side) of the railway cutting, this side being in solid sandstone, and by carrying the concrete right across under the formation it would have acted as a buttress. It is in cases such as these that formulae and theories are rather apt to go by the board.

Tunnels.

Neither of the tunnels provided any serious problem. Both were luckily in good ground, Dhundni Tunnel being in hard sandstone and Daulatpur in conglomerate. To avoid possible danger from falling stones both tunnels were lined throughout. The timbering work necessary was fortunately practically negligible, as time was the chief factor of importance. The method of work was the same in each case and was as follows : A top heading was carried through from both ends, these headings being driven in order to check alignment and level, and to explore the strata. As soon as possible the work of opening out to full size was begun.

In order to save expense in the supports for the arch centering for the roof, the upper portion was begun first, and when work had progressed far enough to avoid any danger from blasting, the construction of the crown lining itself was started. This was built in sections eight to ten feet in length, two sets of centres being in use at either end, one supporting the finished arch and the other ready to be carried forward for starting work on a new length.

Behind this again another party was started on the opening out of the lower half of the tunnel, and finally side walls were put in.

It was found that the work of arching and side walling could more than keep pace with the excavation and that it was the latter that really governed the rate of progress.

Compressors were employed on both tunnels and did excellent work. Dhundni tunnel was lined in sandstone masonry and Daulatpur in concrete. The cost per ft. run worked out to 545 rupees in the case of Dhundni and 485 rupees in the case of Daulatpur. Plate IV fig. I shows type of section adopted.

Bridging.

With an annual rainfall of some 120 inches it will be realised that Bridge work proved to be an exceptionally heavy item, see Appendix II, and it was here that most of the difficulties were met with.

It will be convenient to divide the work under three headings : foundations, superstructure, and girder erection.

Foundations.—Broadly speaking the types of subsoil met with may be divided into three groups : Coarse sand and gravel with occasional boulders, compacted boulders, and rock ; the latter presented no problems and may therefore be neglected.

Examples of the first group were met with in both the Chakki and Gaj.

Before work began on the Chakki, every effort was made to get some details of the construction of the P. W. D. road bridge, but none were forthcoming. To be forewarned is to be forearmed, and here was a case where a completion report, or even the scantiest details would have been of extraordinary value.

The bridge, as originally designed, consisted of 39—40 feet spans, the shortness of the spans being accounted for by the fact that a large number of 40′ girders were available from broad gauge lines at a very low cost.

It was hoped at first that it would be possible to sink open foundations, but after trial pits had been made there was found to be a very strong flow of subsoil water, and it was evident that wells would be necessary. These were made of concrete cast *in situ* and proved very satisfactory. As work progressed, the problem of dealing with the water became very serious ; more and more pumps were supplied, but as the wells sank these proved to be inadequate. Finally it was decided to reduce the number of wells by substituting larger spans. This relieved matters considerably, but even so, when work was at its height no less than 40 pumps varying from 3″ up to 8″ diameter were in use. All sinking was done by hand, and work was carried on day and night. Considerable trouble was caused by boulders being met with at the lower depths ; these got wedged under the well curbs, and very careful blasting, using small charges, had to be resorted to, before further sinking occurred. Foundations were sunk to an average depth of some 20 to 25 feet and in nearly all cases the clay strata underlying the sand was reached.

Difficulties at the Gaj proved to be very similar to those met with at the Chakki.

Wells again were sunk, the well curbs being made up of steel sections of the usual type. Sinking was done mechanically, using steam hoists and grabs, and owing to shortage of time, work on this bridge also was carried on day and night. Here again the great difficulty was boulders getting under the well curbs, all efforts with the grab failing to move them. As in the case of the Chakki, small charges placed under the boulders were found to be the only effective means of breaking them up, and as these had to be placed under water, the services of two divers had to be requisitioned, the firing being done electrically.

As pumps became available from the Chakki it was possible to pump the wells dry and the laying of the charges and the removal of the boulders became a comparatively simple matter. Wells were sunk to an average depth of from 20 to 25 feet.

To take the second group, namely those in compacted boulders : the nullah beds being usually very steep and almost invariably wet, and the boulders anything upto 6 or 8 feet in diameter, open founds were adopted, and there was nothing for it but to clear away this enormous

mass of rock. It was soon realised that founding in this sort of ground was going to prove extremely expensive, and it was also evident that water was again going to be a trouble; wherever possible spans were increased so as to avoid as far as possible having to found in the bed of the nullah itself.

In order to fix the depths of founds efforts were made to find out by observation, and by taking soundings, the depth to which the beds of these nullahs moved. As a result on the information gained, a minimum figure of 12 feet was eventually decided upon for the bigger nullahs and correspondingly less for the smaller. These founds stood the test of an exceptionally heavy flood in 1927, so the figure may be considered adequate.

Superstructure.

Plate IV, figs. 4 and 5 shows two type designs adopted for arched bridges and culverts. There were a certain number of failures with the type in figure 4 using the straight return. These occurred where the arch supported a high bank, thus bringing a very heavy surcharge on the parapet wall, the effect of this surcharge being usually increased by the fact that the bank had been tipped and not built up in layers. Failure generally took place by the parapet wall itself collapsing, but in many cases the first few feet of arching was also pushed out. Wherever splay wing walls were adopted no signs of movement took place even under the worst conditions, the wing walls not only acting as a buttress to the arch but also considerably reducing the unsupported length of the parapet walls; the conclusions to be drawn from the above are fairly obvious.

Wherever the slope of the nullah exceeded one in eight it was found that pucca flooring throughout was necessary, but in other cases hand packed stone, with curtain walls as shown in the diagram, proved successful.

In the case of piers of girder bridges, a design using either mass concrete, or a masonry skin with concrete hearting was adopted. It may reasonably be asked why in view of the danger from earthquakes, reinforced concrete was not utilised as giving greater flexibility. It will, however, be admitted that especially in this country, reinforced concrete work requires extremely careful supervision, and with works spread over a length of over 100 miles it was not possible to give the detailed supervision necessary, except by a very great increase in the number of staff. In the first place staff, skilled in this type of work, were not available, and secondly, the extra expense involved did not appear justifiable.

Before designs were started catchment areas were taken out for all important nullahs and such factors as shape, slope, and vegetation were taken careful note of. From this data, and using the method described by Col. Hearn,* the size of waterways required was calculated. The results obtained have proved satisfactory.

* Minutes of Proceedings Inst. C.E., Vol. ccxvii. p. 267.

Girder Erection.

The total weight of steelwork involved was approximately 5633 tons, and with the exception of the design and fabrication only of the 180 feet steel arch span at the Reond, and a few10 feet rolled steel joist spans, these were all designed, fabricated and erected by the Bridge Department of the N. W. Railway. This work entailed the selection of suitable material, the allotting of a portion of the Jhelum Workshop exclusively for the fabrication of girders, recruiting of additional staff, working out detailed schemes for erection, collecting plant, and the maintenance of a regular and adequate supply of finished work.

For the erection of spans upto and including 40 feet a portable derrick mounted on a truck was used; this was capable of lifting and swinging into position a complete girder. In the case of 60 feet spans a steel lattice derrick was found necessary in the final stages. In the case of spans 60 feet and over, these were with the exception of the Banganga and the Reond Arch, taken to site either by road or rail, erected in the nullah bed, and lifted into position by steel lattice derricks; the latter were built up in sections, extremely light, and capable of lifting upto a height of 100 feet.

This carrying up of the larger spans by road, in order to have them erected and ready by the time railhead reached the site, proved an extremely costly operation, and somewhat detracted from the advantage gained in foundation work, by their use.

The erection of both the Banganga and the Reond steel arch deserve special mention.

The Banganga consists of 1 span of 250 feet and 4 spans of 60 feet. For the erection of the 250 feet span, two service girders of 120 feet each, supported on temporary staging were utilized.

The temporary piers, on which the staging was to be erected, were completed on June 9th, 1927, and the erection of the staging and service girders was begun immediately. During the ensuing three weeks, work was carried on day and night in an effort to complete erection from the river bed before any floods occurred. Unfortunately the monsoons broke early, and on the morning of 6th July heavy rain fell, and did such serious damage to the cuttings and embankments, between the dumps for the steel work, which were seven miles in rear, and the bridge site, that all further work was for the time being impossible.

On 25th July the river rose 20 feet and scoured and tilted the temporary piers, damaging the superstructure. After careful inspection it was decided to dismantle all the erected work, and save as much material as possible, before more floods could cause further damage. When about 50 per cent. of the floor system of the 250 feet span had been salvaged, the river rose 40 feet and carried everything before it. This was on August 1st, 1927.

Finally, the work of rebuilding was started in October 1927 and completed on January 12th, 1928.

The Reond steel arch, of a span of 180 feet with two approach spans each of 40 feet, was unique, in that it was the first of its type to be either erected or manufactured in the country.

The bridge was designed by the Consulting Engineers Messrs. Rendel Palmer and Tritton and fabricated by Messrs. Braithwaite and Co., Bombay.

It is impossible with the space available to give a detailed description of the erection work, as this supplies sufficient material for a technical paper in itself. In brief, the erection was done by cantilevering out from the two abutments, the steel work being handled by means of an overhead ropeway supported on steel towers, constructed so as not to interfere with the running of trains when the bridge was completed. Although as previously stated, the construction of a bridge of this type had never previously been attempted in India, the work was carried out so accurately, that when the two halves of the arch came to be joined up at the centre there was an error of less than 1-16 inch.

In order to save time the whole of the steel work of the arch, weighing in all some 300 tons, was taken to the site by road and was erected before railhead reached the bridge. Plates V, VI and VII show the portable derrick in action and erection work in progress on the Banganga, Bathu and Reond steel arch. Appendix III gives details of the progress of erection work on the Chakki and Gaj.

In point of view of both speed and efficiency the programme of girder erection carried out by the Bridge Department on the K. V. Railway will undoubtedly rank as one of the greatest achievements in the history of railway construction in India.

In order to emphasize the importance given to the time factor, a reference may be made to the section between Palampur and Baijnath Paprola. In this length of some 9 miles there are some 23 nullah crossings ; it was at first proposed to design all these as girder bridges but calculations showed that even under the most favourable conditions the time required for girder erection alone was three months. As a result all the crossings except the five major ones, were converted to arched bridges and a period of some two months was thus saved.

Had the completion of the work not been of such extreme urgency, it is a question whether for piers of girder bridges, some form of standardized steel trestling would not have been cheaper than the heavy masonry and concrete structures actually built. These could have been brought up by train as railhead reached the bridge site, thus eliminating to a great extent the excessive amounts paid on lead. Another important factor is the suitability of a flexible steel structure to withstand earthquakes.

Materials and Transport.

During the period of survey, very careful notes were taken of what building materials were likely to be available from local resources.

Unlike a construction in the plains where a temporary line can be quickly run through and materials brought up by train, the conditions imposed in a hill railway necessitate the work being completed before railhead can advance, and diversions or works of a temporary nature are out of the question. These facts, combined with, in many cases, the complete lack of roads of any sort, and the enormous leads involved, made it of the utmost importance to utilize such materials as were available at site.

That this principle was actually adhered to is evidenced by the variety of materials used. Brickwork cement concrete, sandstone and a rather poor type of granite boulder were all utilised in the various sections in which they were to be found.

There was considerable doubt at first over the advisability of using the granite boulder stone. It was found to contain a fairly large percentage of mica, and when broken up into small pieces and exposed to moisture, it tended to crumble. Samples were sent for test and as far as compression figures were concerned the results were entirely favourable. As for its weathering properties, a study of the stone in its natural state showed that it developed a hard black skin, much harder than the inner portion of the stone itself. The decision arrived at was to allow of its use in large blocks, but to rule it out entirely an aggregate for concrete work.

Good sand was on the whole fairly plentiful, although in certain sections it had to be led for considerable distances.

One item of interest was the using of a cement and lime mortar. Although the idea cannot be claimed to be an original one, as it is advocated in many modern text books, the use of cement and lime together may be new to some, and may also lead to a certain amount of criticism.

Good lime was to be obtained in large quantities in various parts of the line, and although tests proved it to be satisfactory, it was found to be very slow setting. As there was little time available for allowing work to set, something was needed to speed up the setting time, and it was found that the addition of a small proportion of cement produced the desired result, and the economy effected was considerable.

It should be added that its use was limited to bulk work. In the more important works, and in places where work had to be carried out in damp or wet localities cement mortar was used, the proportions following normal engineering practice. The actual proportions used for the lime cement mortar were 3 c.ft. cement 10 c.ft. lime 27 c.ft. sand.

The problems of transport is often one which is apt to be overlooked or underestimated, but nevertheless it is of vital importance in the successful and rapid completion of a work of this magnitude, and especially so where time was of such value.

From a study of the key plan Plate I it will be seen that although certain sections of the line were well served by roads fit for wheeled transport there were many portions of the alignment, where not only did no

such roads exist, but it was impossible owing to the nature of the country to build them except at enormous expenditure which could in no way be justified.

The two District Board roads, namely from Nurpur to Jawanwala Shahr and from Kangra to Jawalamukhi Road were only fit for wheeled traffic during dry weather, both being unmetalled, and even then a great deal of maintenance work was necessary to keep them open.

From Jawanwala Shahr, where the District Board road leaves the alignment, it was found feasible to make a fair weather service road alongside the alignment fit for wheeled traffic up to the crossing of the Guj, otherwise a service footpath fit for pack transport was all that could be done.

Lorries, bullock carts, donkeys and camels were all utilized in their particular spheres of usefulness. The principle adopted was to cart materials from Pathankot to the main dumps situated in the various sub-divisions, and from these they were led by the contractors actually doing the work.

APPENDIX I.

Organisation.

		Remarks.
Head Quarters.	Superintendent of Works	.. From October 1925 to December 1926 responsible for K. V. Railway only. From December 1926 until completion, Superintendent of Works becomes Superintendent of Works, Northern Circle, including rebuilding Khyber Tunnels, Ravi Bridge and parent lines.
	Personal Assistant to Superintendent of Works.	To assist Superintendent of Works owing to extra work involved on formation of Northern Circle. February 1927 to completion.
No. 3 Division.	Executive Engineer	.. Responsible for receipt and issue of all stores and running of all plant and also incharge of section from Mile 0—20.
	One Assistant Executive Engineer.	Mile 0—20.
No. 1 Division.	Executive Engineer	.. Incharge of Section. Mile 20—60.
	Three Assistant Executive Engineers.	Mile 20—41.
		Mile 41—51.
		Mile 51—60.
No 2 Division.	Executive Engineer	.. Incharge of Section. Mile 60—103.
	Three Assistant Executive Engineers	Mile 60—74.
		Mile 74—89.
		Mile 89—103.

Actually only 5 Assistant Executive Engineers were allowed in Divisions I and II. One of the Assistant Executive Engineers therefore had to first complete the Section from Mile 41—51 in Division No. I and was afterwards transferred to the Section Mile 89—103 in Division No. II, a Sub Engineer acting as Sub Divisional Officer until he arrived.

The whole organisation was under the control of the Chief Engineer, Surveys and Constructions, Lahore.

Suggested Alternative Organisation.

Head Quarters.	Chief Engineer	..	Responsible for the construction of the Kangra Valley Railway only and with full powers.
	P. A. to Chief Engineer.		
Stores & Mechanical Division.	Executive Engineer	..	Incharge of receipt and issue of all stores and running and maintenance of all plant.
No. 1 Division.	Executive Engineer	..	Mile 0—40.
	Two Assistant Executive Engineers.		Mile 0—20. Mile 20—40.
No. 2. Division.	Executive Engineer	..	Mile 40—Mile 64.
	Three Assistant Executive Engineers.		Mile 40—Mile 48. Mile 48—Mile 56. Mile 56—Mile 64.
No. 3 Division.	Executive Engineer	..	Mile 64—Mile 103.
	Three Assistant Executive Engineers.		Mile 64—Mile 76. Mile 76—Mile 89. Mile 89—Mile 103.

APPENDIX II.

List of Bridges.

Mileage.	Name.	Spans. No.	Spans. Length.	Girder Bridges Skew or Square.	Straight or Curve.
6·66	Baghar ..	3	30′	Square	Straight.
7·30	Chakki ..	17	40′	do.	do.
,,		2	80′	do.	do.
,,		6	130′	do.	do.
12·64	Garelli I ..	7	30′	do.	do.
16·03	Garelli II ..	4	40′	do.	do.
26·10	Bhul ..	4	40′	do.	do.
35·18	Gajh ..	10	100′	do.	do.
39·74	Minnu ..	5	40′	do.	do.
43·48	Sukhad I ..	5	40′	do.	do.
45·95		2	40′	do.	do.
		1	60′	do.	do.
46·16		4	40′	do.	5 Transition Curve.
46·36		4	40′	do.	14 Transition Curve.
46·70		5	40′	30 R Skew	14 Transition Curv.
47·85		1	80′	Square	Transition Curve.
47·96	Banganga ..	4	60′	do.	11 & 14 Transition Curve.
		1	250′		
48·40		3	40′	do.	6 Transiton Curve.
50·60	Nagni ..	3	40′	do.	Straight.
53·02	Bathu ..	7	40′	do.	do.
		3	60′	do.	14 Curve.
56·14	Daulatpur III ..	3	40′	do.	14 Transition Curve.
58·67	Jamni ..	3	40′	1—40′ Span 30 R. Skew.	14 Curve.
		1	60′		

Mileage.	Name.	Spans.		Girder Bridges Skew or Square	Straight or Curve.
		No.	Length.		
59·23	Reond ..	2 1	40′ 180′	Square	Straight.
59·89	Sukhad II ..	4	40′	do.	do.
61·79	Jugal I ..	3 1	40′ 100′	do.	14 TransitionCurve.
74·58	Neogal ..	5 1	40′ 100′	do.	Straight.
77·99	Soon II ..	3	40′	do.	do.
79·97	Moul ..	4 1	40′ 60′	do.	14 Curve.
82·24	Dharam Dai ..	3	60′	do.	Straight.
84·57	Awa ..	6	40′	do.	do.
86·39	Bithi ..	5	40′	do.	do.
86·93	Poon ..	3 1	40′ 100′	do.	14 Curve.
88·50	Binwan ..	4 1	40′ 100′	do.	14 Curve.
92·10	Bhir ..	1	100′	do.	Straight.
97·90	Bachgar ..	2	40′	do.	do.
101·50	Googli	2	40′	do.	24 Curve.

In addition to the above there are :—

		No. Span.	Length.
9 Girder bridges of	..	1	40′
1 do. do.	..	3	30′
4 do. do.	..	2	30′
6 do. do.	..	1	30′
4 Girder bridges of	..	3	20′
2 do. do.	..	2	20′
8 do. do.	..	1	20′
2 do do.	..	2	10′
26 do. do.	..	1	10′
6 Arches of	..	1	20′
9 do.	..	1	15′
18 do.	..	1	12′
1 do.	..	1	12′
		and	
		1	6′
10 Arches of	..	1	10′
2 do.	..	1	9′
14 do.	..	1	8′
6 Culverts of	..	2	6′
38 do.	..	2	6′
21 do.	..	1	4′
2 do.	..	1	3′
1 do.	..	1	2′
3 Barrels of	..	1	3′

404 Rail openings of 2′ & 3′ Spans.
57 Syphons of 2′ & 3′ diam.
256 Armco pipes of 2′ & 3′ diam.
44 Armco flumes of 2′ & 3′ diam.
3 Over bridges

APPENDIX III.

Progress of Girder Erection of Chakki Bridge.

25-4-1927	.. Arrival of first consignment of steel work at site.
20-5-1927	.. 1st span 133 ft. erected on piers.
26-5-1927	.. 1st span 88 ft. ,, ,,
31-5-1927	.. 2nd span 133 ft. ,, ,,
3-6-1927	.. 3rd span 133 ft. ,, ,,
6-6-1927	.. 4th span 133 ft. ,, ,,
11/12-6-1927	.. 5th span 133 ft. ,, ,,
15-6-1927	.. 6th span 133 ft. ,, ,,
18-6-1927	.. 2nd span 88 ft. ,, ,,
22-6-1927	.. 1st and 2nd spans 44 ft. ,,
23-6-1927	.. 3rd and 4th spans 44 ft. ,,
24-6-1927	.. 5th span 44 ft. ,,
25th to 30th June 1927	.. Work held up owing to floods in river.
1-7-1927	.. 6th span 44′ erected on piers.
2-7-1927	.. 7th span 44′ erected on piers.
3-7-1927	.. 8th span 44′ erected on piers.
4th to 23rd July 1927	.. Work held up owing to damage to embankments by monsoons.
24-7-1927	.. 9th and 10th spans 44 ft. erected on piers.
25-7-1927	.. 11th and 12th spans 44 ft. erected on piers.
26-7-1927	.. 13th, 14th and 15th spans 44 ft. erected on piers.
28-7-1927	.. 16th span 44 ft. erected on piers.
29-7-1927	.. 17th and last span 44 ft. erected on piers.

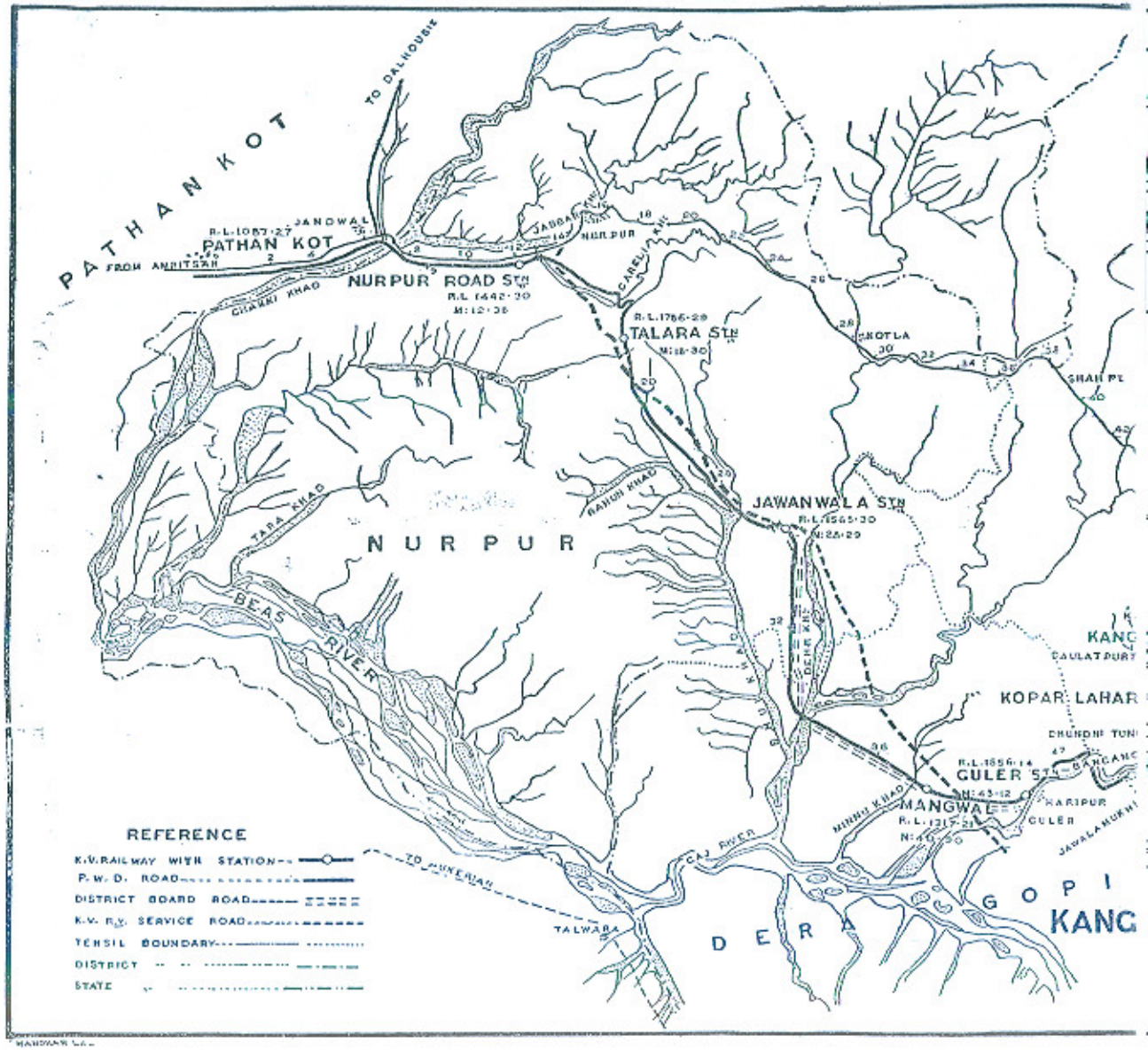
Progress of Girder Erection on Gaj Bridge.

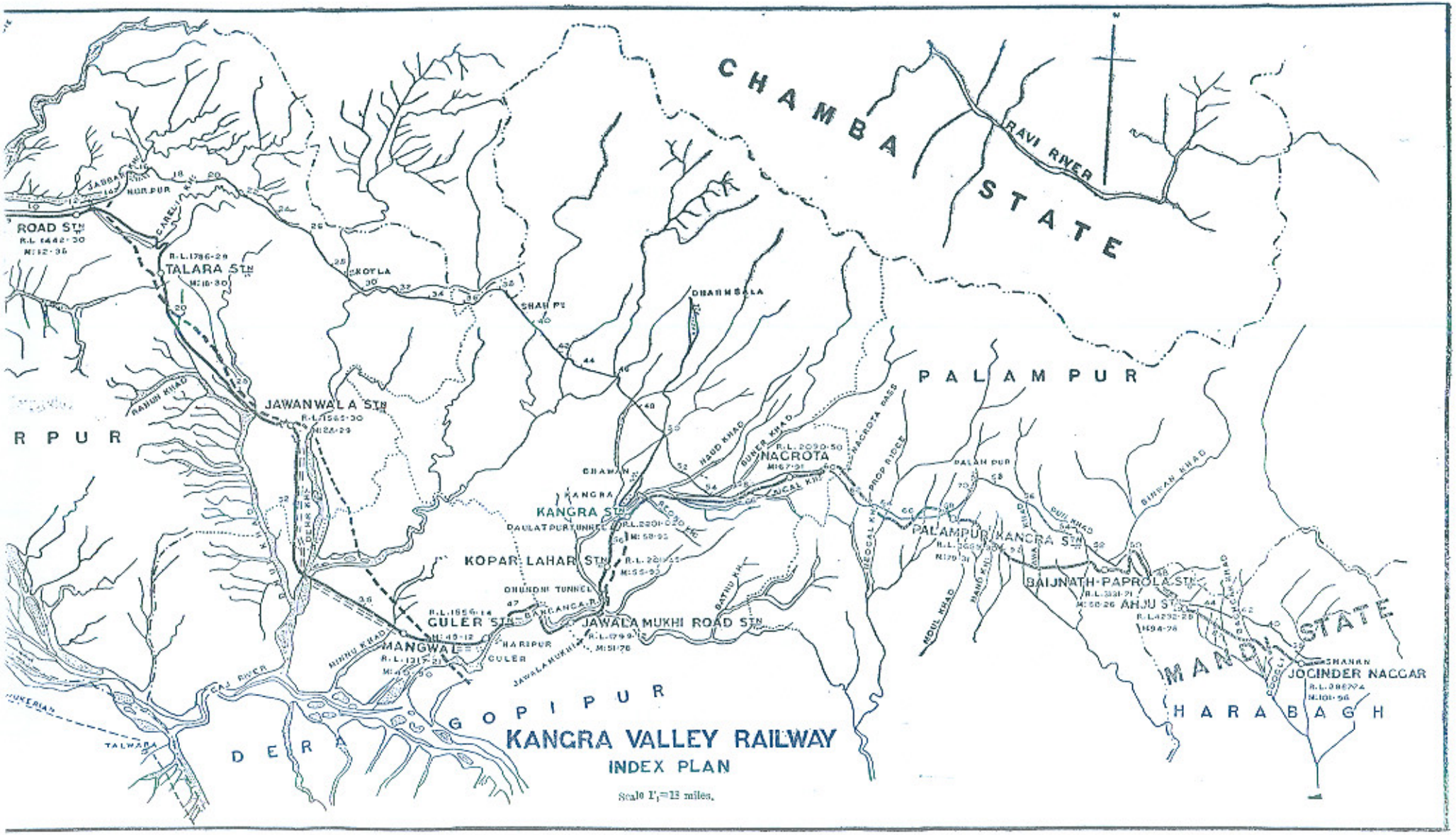
16-6-1927	.. 1st Girder	erected on piers.
17-6-1927	.. 2nd	do.
19-6-1927	.. 3rd	do.
20-6-1928	.. 4th	do.
21-6-1927	.. 5th	do.
22-6-1927	.. 6th	do.
23-6-1927	.. 7th	do.
24-6-1927	.. 8th	do.
25-6-1927	.. 9th	do.
26-6-1927	.. 10th	do.
27-6-1927	.. 11th	do.
28-6-1927	.. 12th	do.
30-6-1927	.. 13th & 14th	do.
2-7-1927	.. 15th & 16th	do.
3-7-1927	.. 17th & 18th	do.

On 4-7-1927 a flood came down the Gaj and submerged and damaged the Service Track.

On 5-7-1927 although the track was still partly submerged the 19th and 20th girders were taken to site and erected.

Before the girders could be lifted into the piers they had to be carried fully assembled, on trollies over a service track for a distance of $^1/_4$ mile. The first serious flood occurred on the morning of the 6th, and completely washed out the 2'-6" gauge diversion and B. G. Service Track.


PATHAN KOT
TO DALHOUSIE
FROM AMRITSAR
PATHAN KOT
R.L. 1087·27
JANDWAL
NURPUR ROAD STN
R.L. 1442·20
M: 12·38
CHAKKI KHAD
JABBAR KHAD
NURPUR
CHARELI KHD
TALARA STN
R.L. 1756·29
M: 18·30
KOTLA
SHAH PU
RAHUN KHAD
JAWANWALA STN
R.L. 1565·30
M: 28·29
TARA KHAD
NURPUR
BEAS RIVER
DERA KHD
KOPAR LAHAR
CHUNDNI TUN
R.L. 1856·14
GULER STN
M: 43·12
BANGANG
NIKKI KHAD
MANGWAL
R.L. 1315·21
N: 4·50
GULER
JAWALA MUKHI
KANG
GAJ RIVER
TO JHANDIAN
TALWARA
D E R A
GOPI
KANG
REFERENCE
K.V. RAILWAY WITH STATION
P. W. D. ROAD
DISTRICT BOARD ROAD
K.V. R.Y. SERVICE ROAD
TEHSIL BOUNDARY
DISTRICT
STATE


CHAMBA STATE
RAVI RIVER
PALAMPUR
ROAD STN
R.L. 1442·30
M 52·36
TALARA STN
R.L. 1786·29
M 18·30
JAWANWALA STN
R.L. 1565·30
M 22·29
KOTLA
CHAK PI
DHARMSALA
NAGROTA
R.L. 2090·50
M 67·21
KANGRA STN
DAULATPUR JUNCTION
R.L. 2201·00
M 58·93
KOPAR LAHAR STN
R.L. 2215·55
M 55·93
GULER STN
R.L. 1856·14
M 45·12
MANGWAL
R.L. 1315·21
M 4·50
JAWALAMUKHI ROAD STN
R.L. 1799·
M 51·76
PALAMPUR KANGRA STN
R.L. 2669·
M 129·31
BAIJNATH-PAPROLA STN
R.L. 3331·21
M 50·26
AHJU STN
R.L. 4232·28
M 94·26
JOGINDER NAGGAR
R.L. 3867·4
M 101·56
HARABAGH
MANDI STATE
GOPIPUR
DERA
KANGRA VALLEY RAILWAY
INDEX PLAN
Scale 1"=13 miles.

ELEVATION

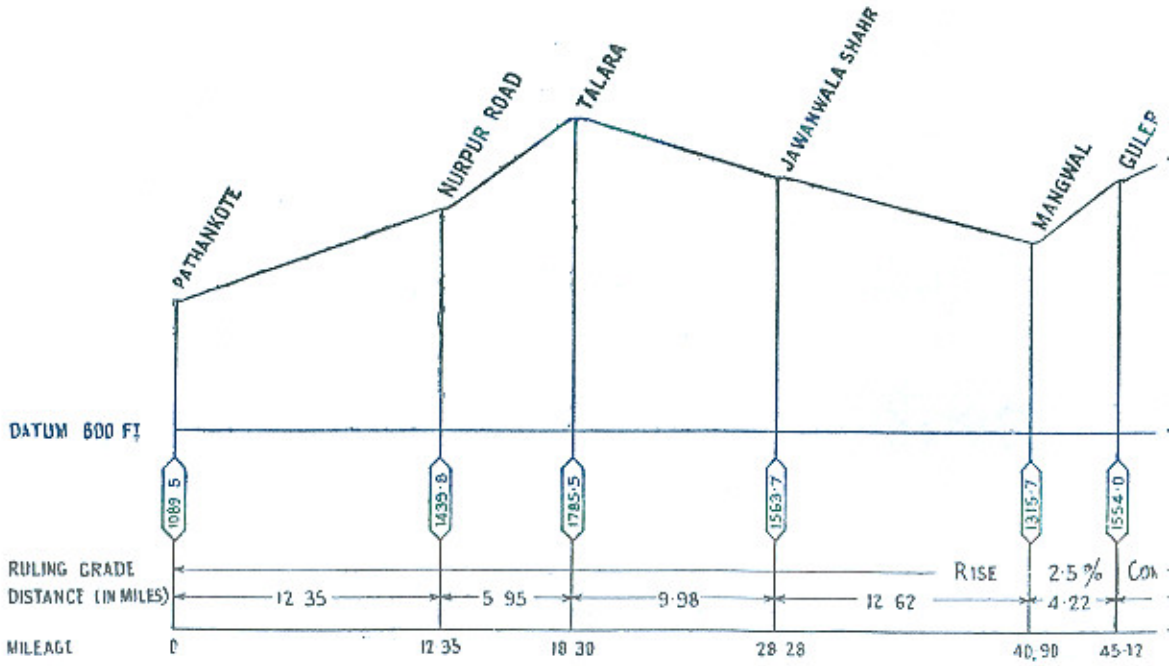
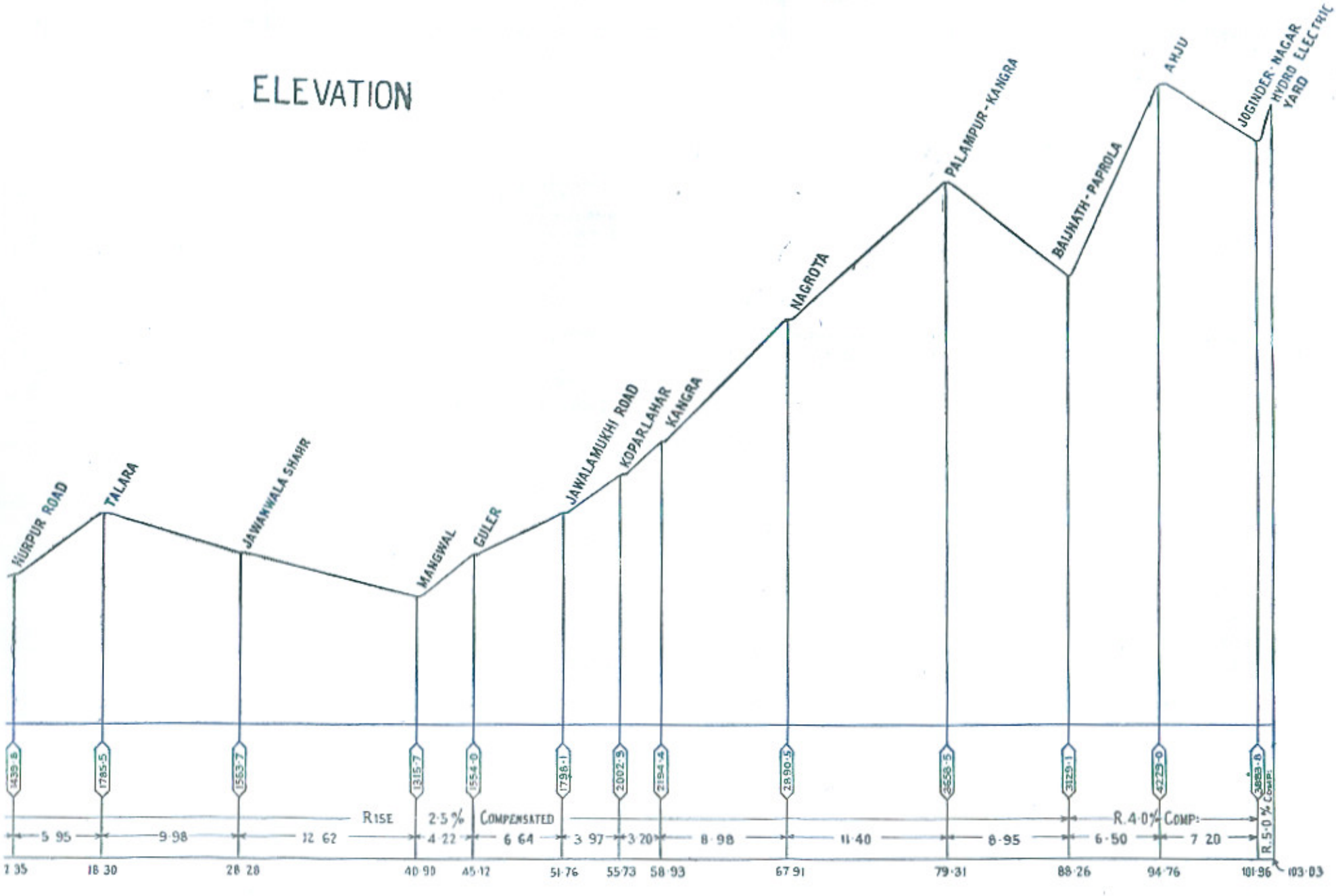
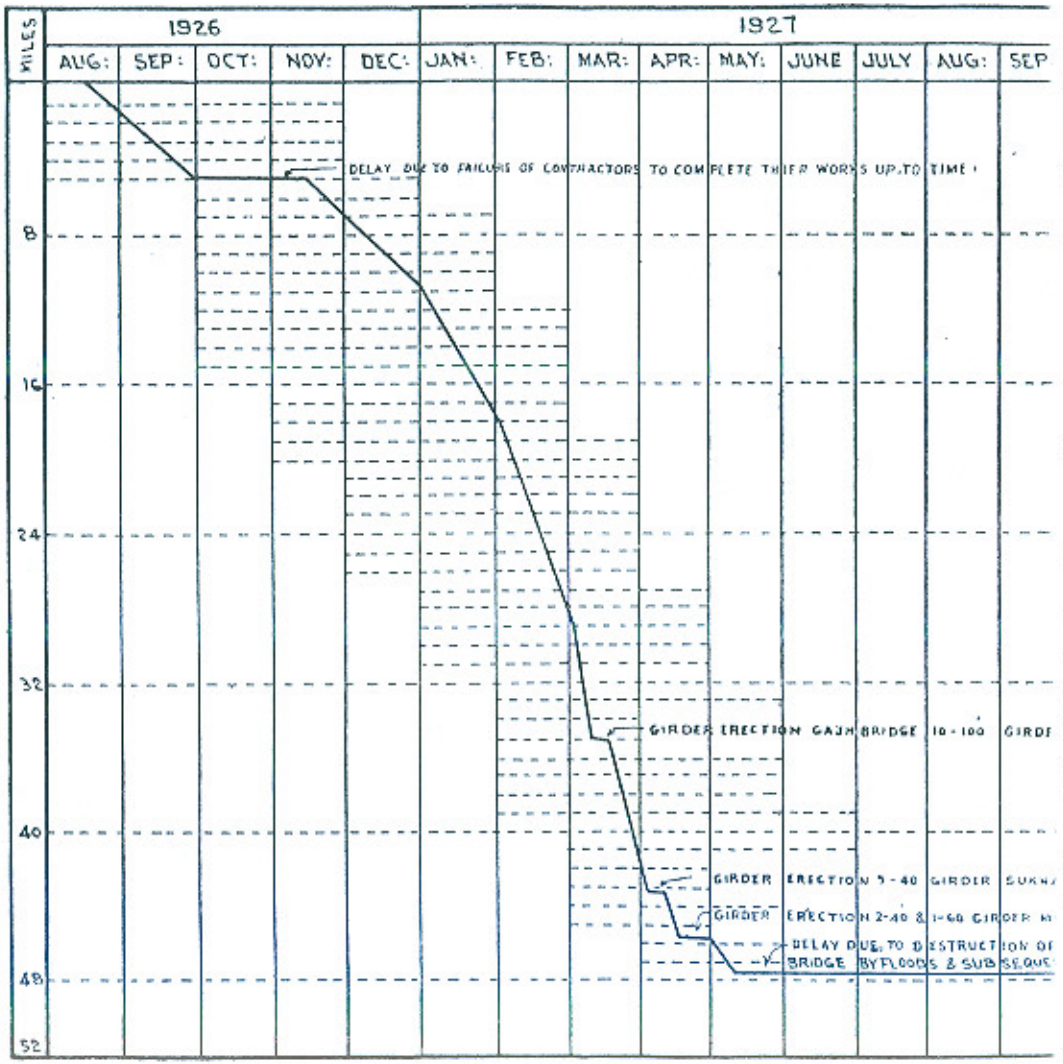

PATHANKOTE
NURPUR ROAD
TALARA
JAWANWALA SHAHR
MANGWAL
GULEP
DATUM 600 FT
1089·5
1439·8
1785·5
1563·7
1315·7
1554·0
RULING GRADE
DISTANCE (IN MILES)
12 35
5 95
9·98
12 62
RISE
2·5 %
4·22
MILEAGE
0
12 35
18 30
28 28
40, 90
45·12

PLATE No. II.

ELEVATION



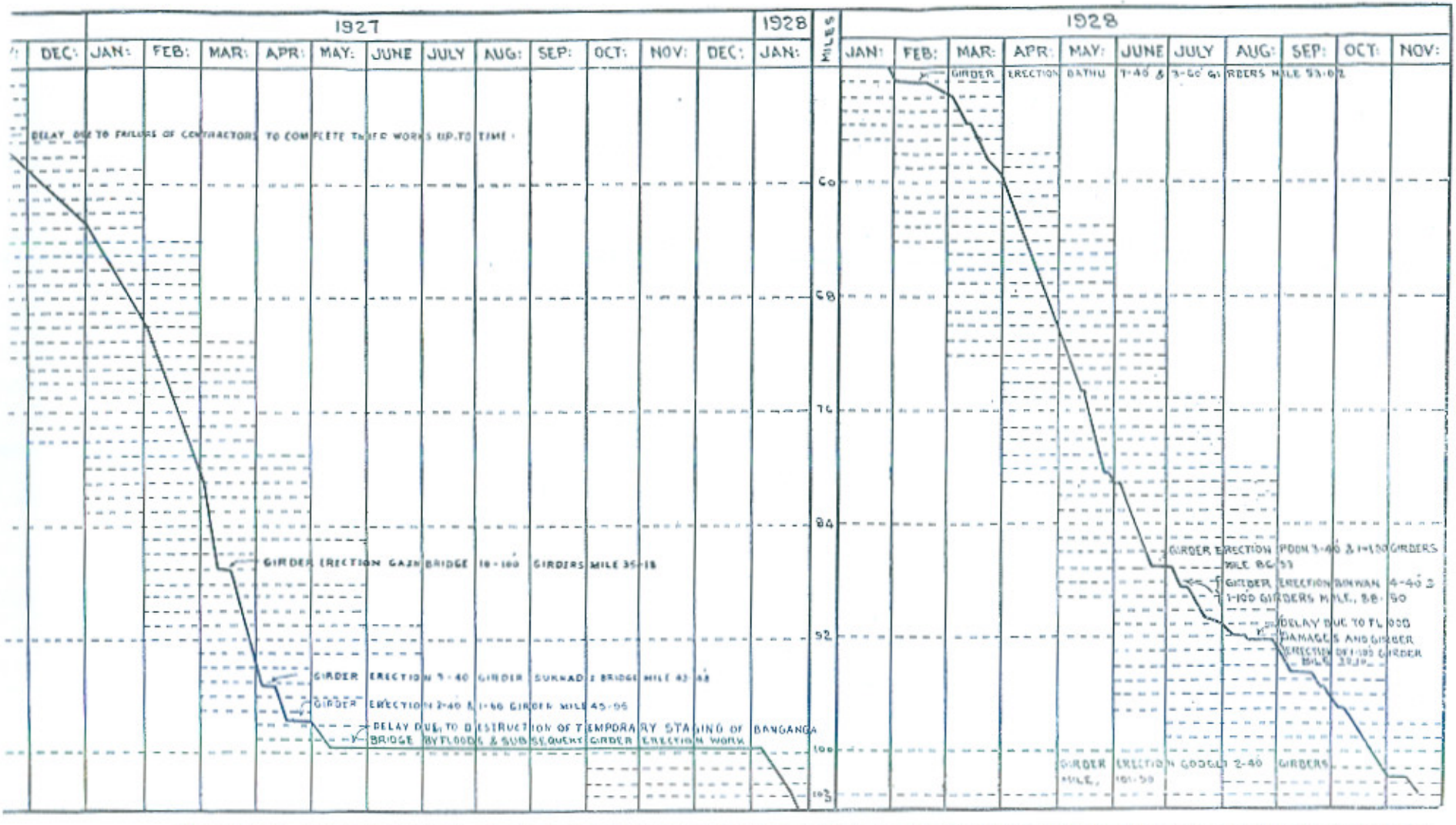
LINKING PF



NOTE:-DURING RAINS OF 1927 &1928 CERTAIN DEL

PLATE No. III.

LINKING PROGRESS DIAGRAM



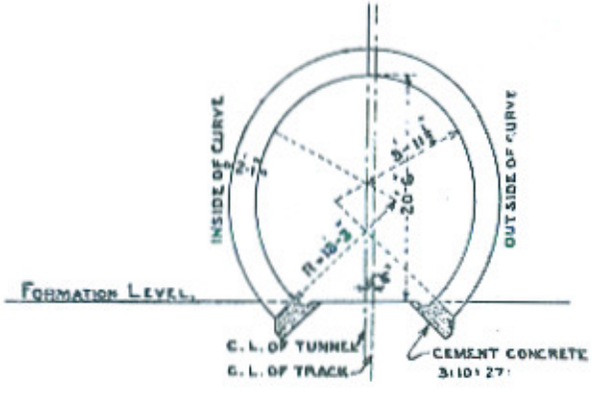
NOTE:-DURING RAINS OF 1927 &1928 CERTAIN DELAYS WERE CAUSED OWING TO DAMAGES TO BANK & CUTTINGS, BUT THESE ARE TOO SMALL TO SHOW IN THE ABOVE DIAGRAM

TYPE OF TUNNEL.

FIG. I

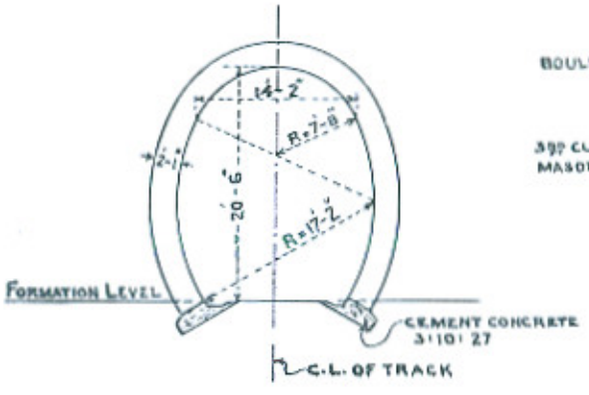
TUNNEL SECTION ON 11¼° CURVE.

SCALE 15 = 1"

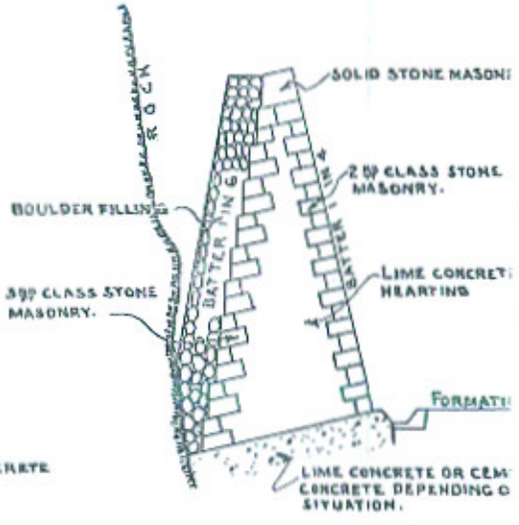


TUNNEL SECTION ON STRAIGHT.

SCALE 15 = 1"



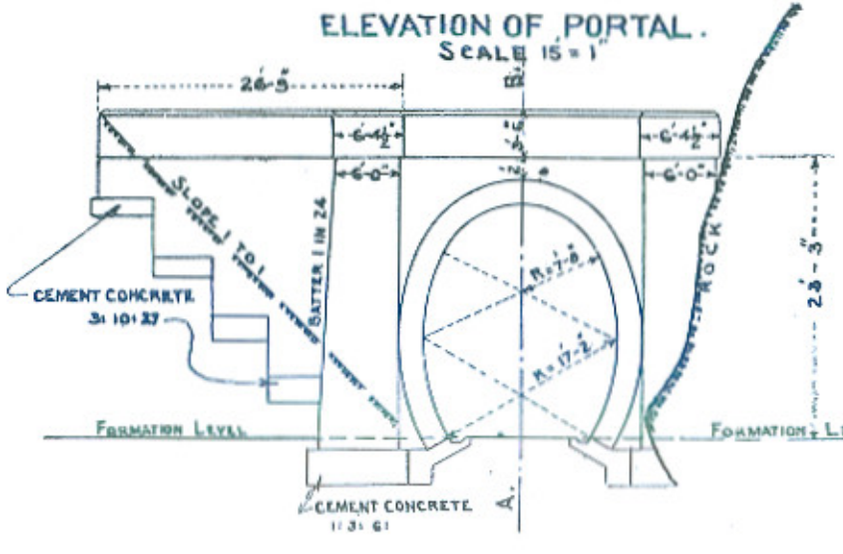
TYPE OF B



TYPE OF F

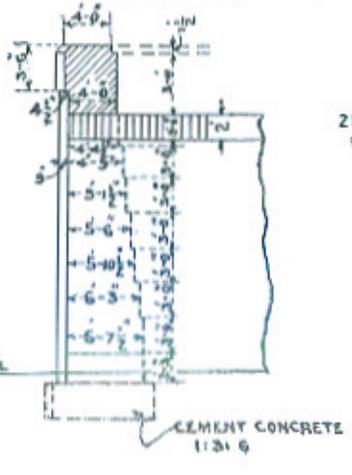
ELEVATION OF PORTAL.

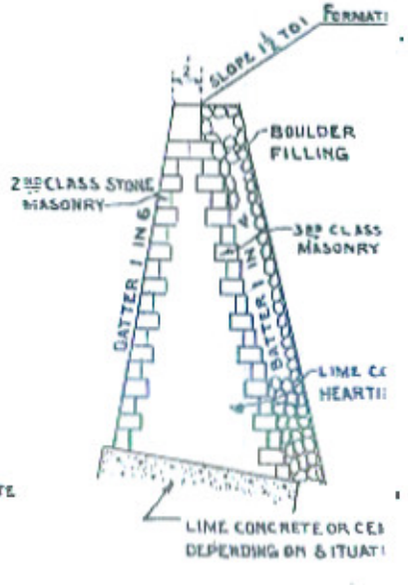
SCALE 15 = 1"



SECTION ON A.B.

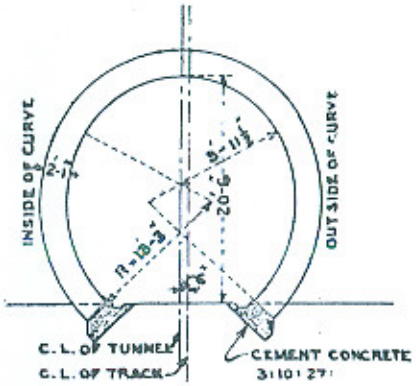
SCALE 15 = 1"



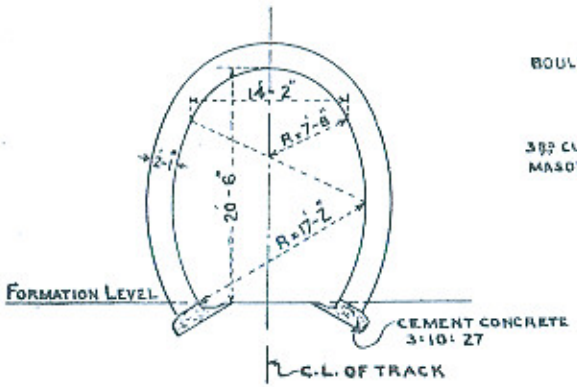


TYPE OF TUNNEL.
FIG.1

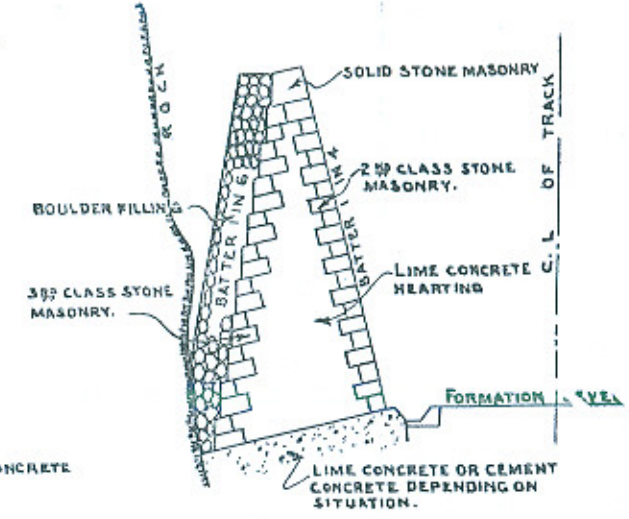
NEL SECTION ON 11¼° CURVE.
SCALE 15 = 1"



TUNNEL SECTION ON STRAIGHT.
SCALE 15 = 1"

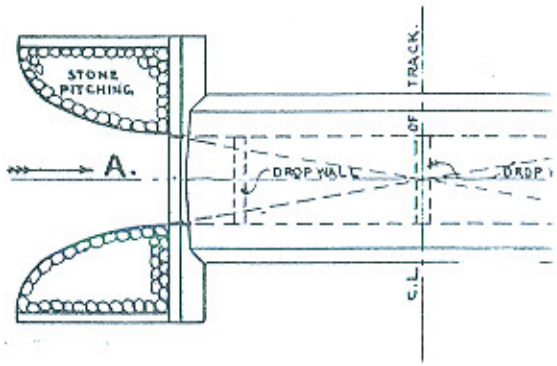


TYPE OF BREAST WALL.
FIG.2

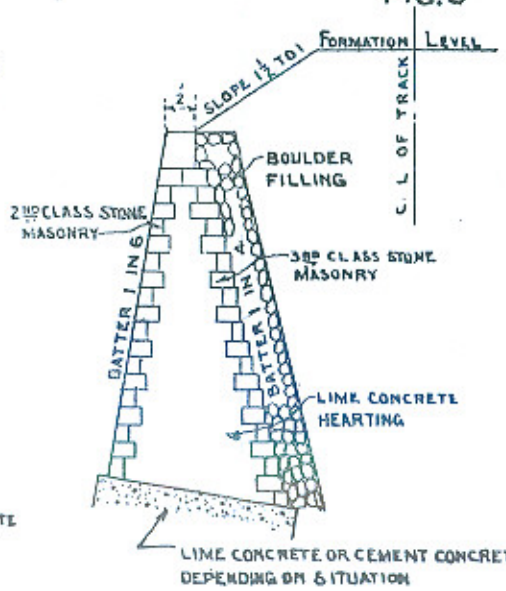


TYPE OF ARCH
FIG.4

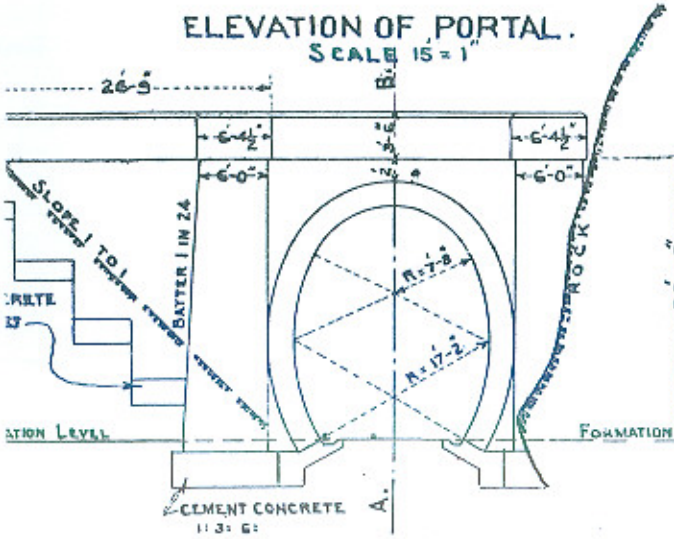
PLAN.



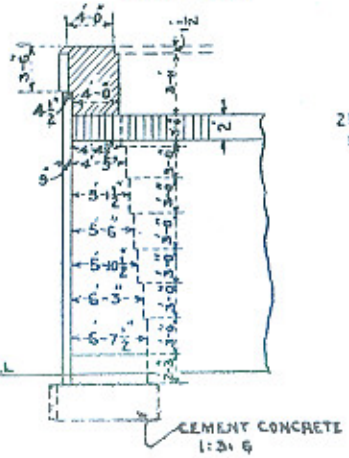
TYPE OF RETAINING WALL.
FIG.3

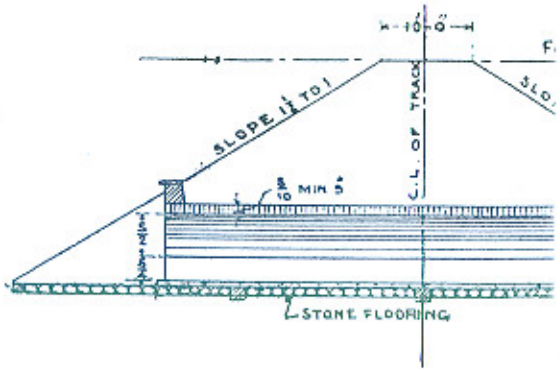


ELEVATION OF PORTAL.
SCALE 15 = 1"



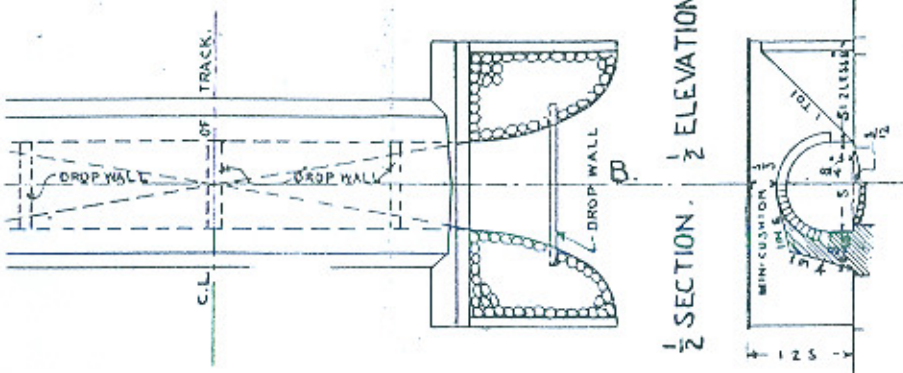
SECTION ON A.B.
SCALE 15 = 1"



SECTION ON A.


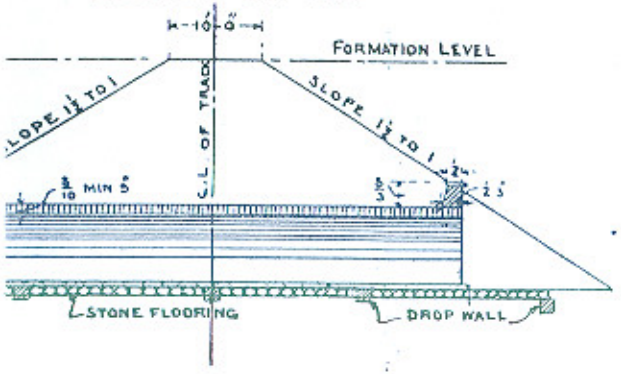
TYPE OF ARCH.
FIG.4

PLAN.



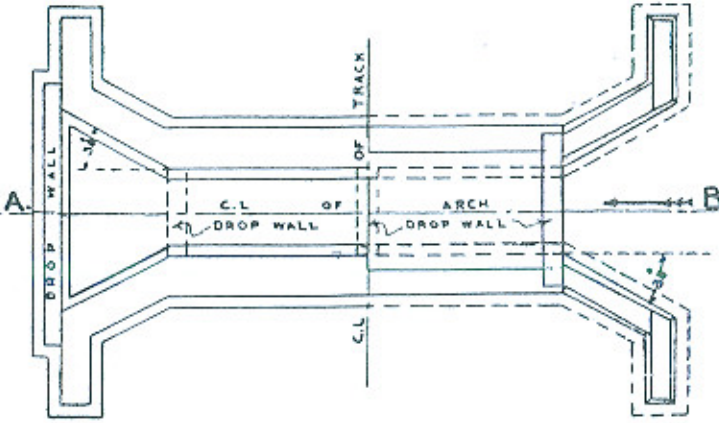
½ SECTION. ½ ELEVATION

SECTION ON A.B

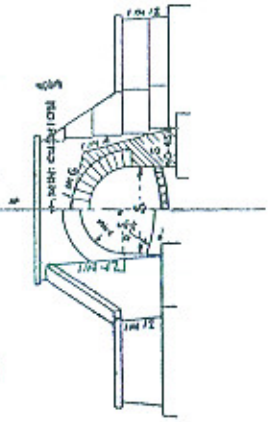


TYPE OF ARCH.
FIG.5

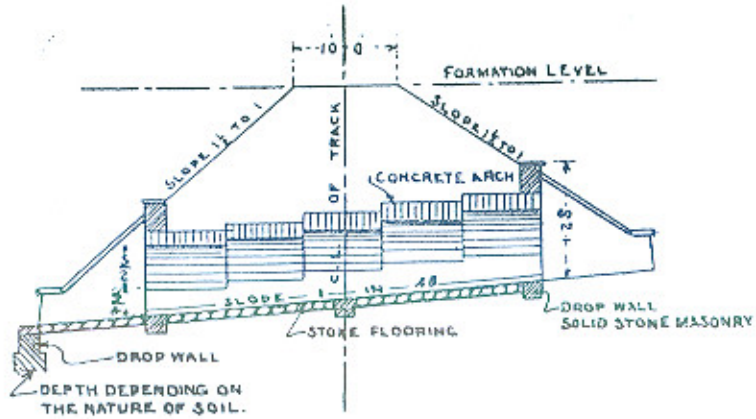
PLAN.



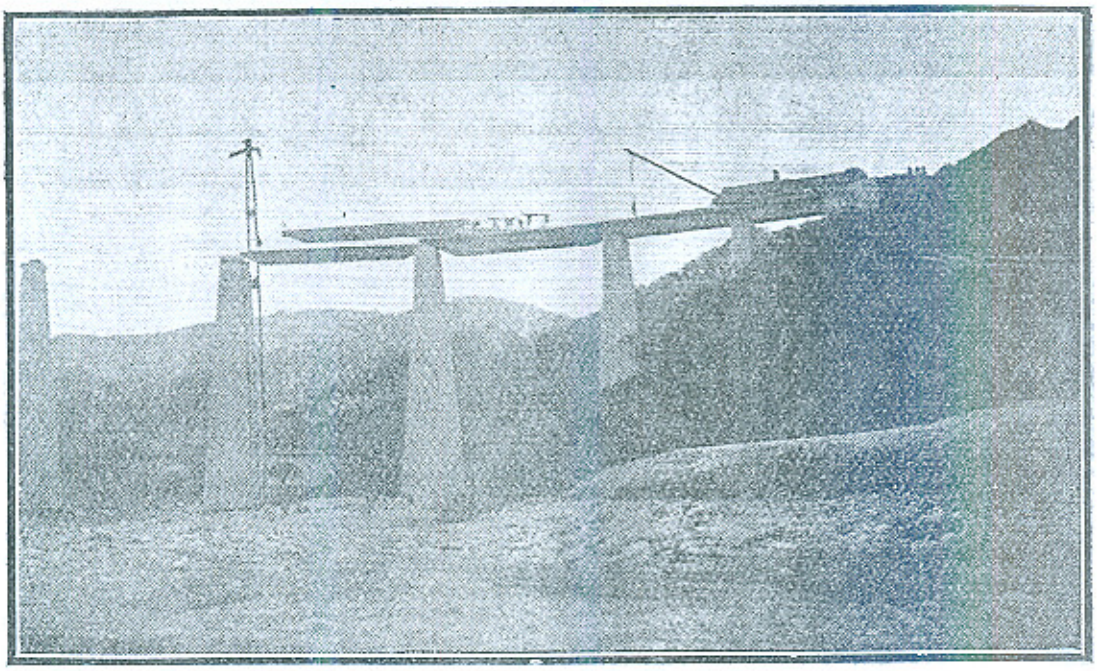
½ ELEVATION. ½ SECTION.



SECTION ON A.B.

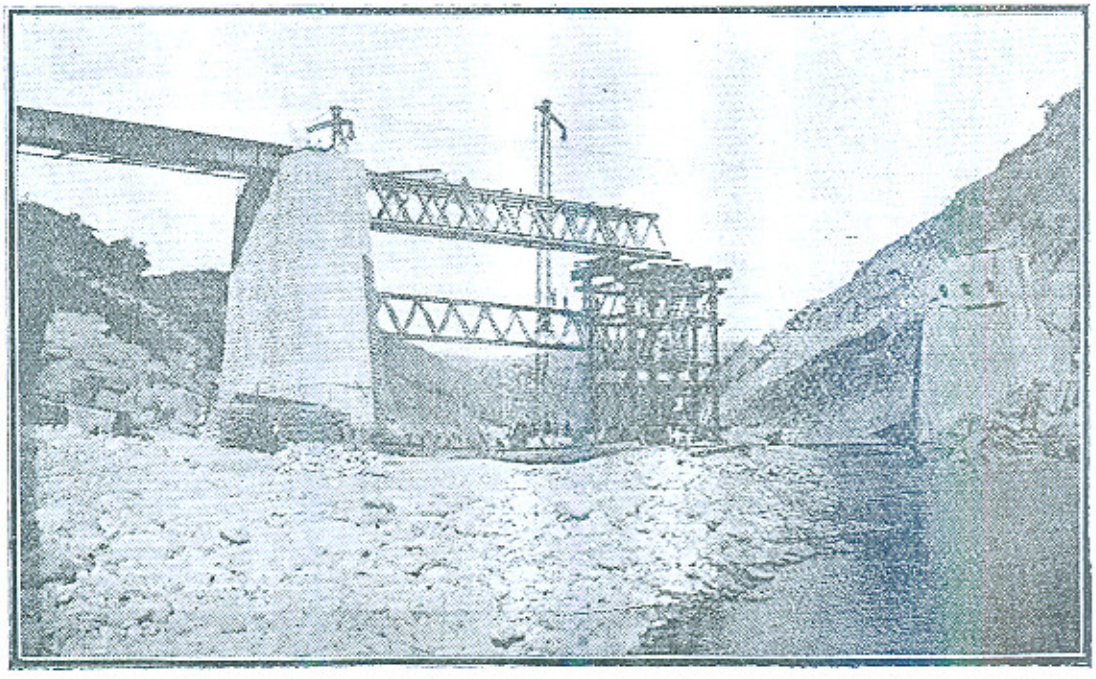


BATHU BRIDGE. Plate No. V.



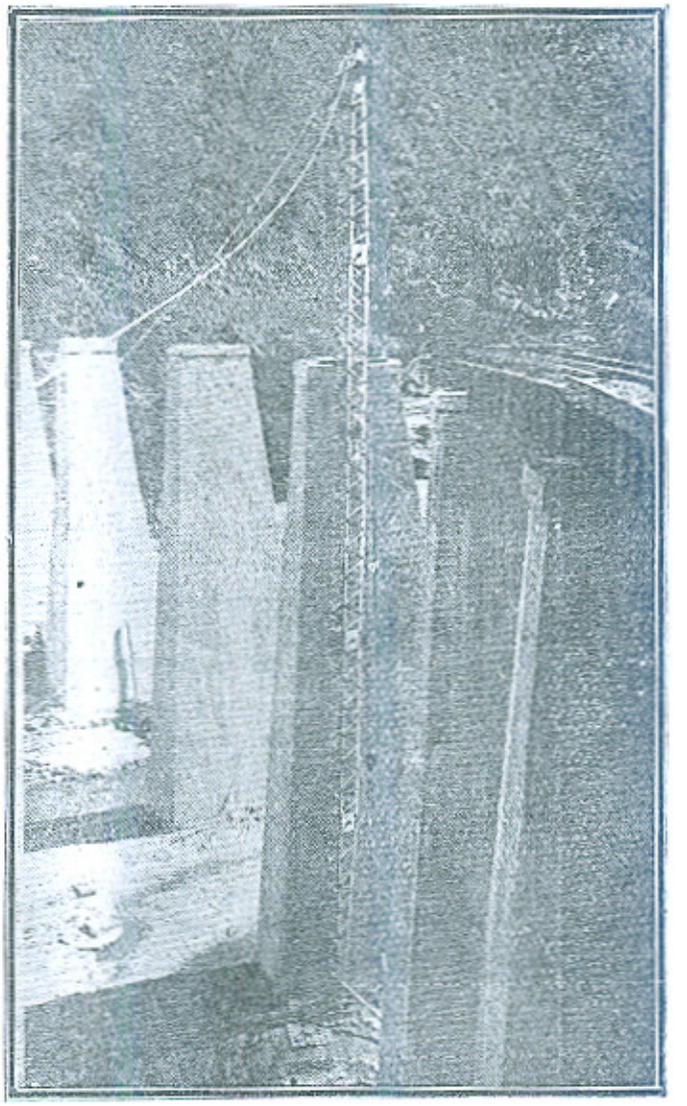
Portable Derrick being brought into position to assist in the final stages of the launching of 60 ft. Girder.

BANGANGA BRIDGE. Plate No. VI.



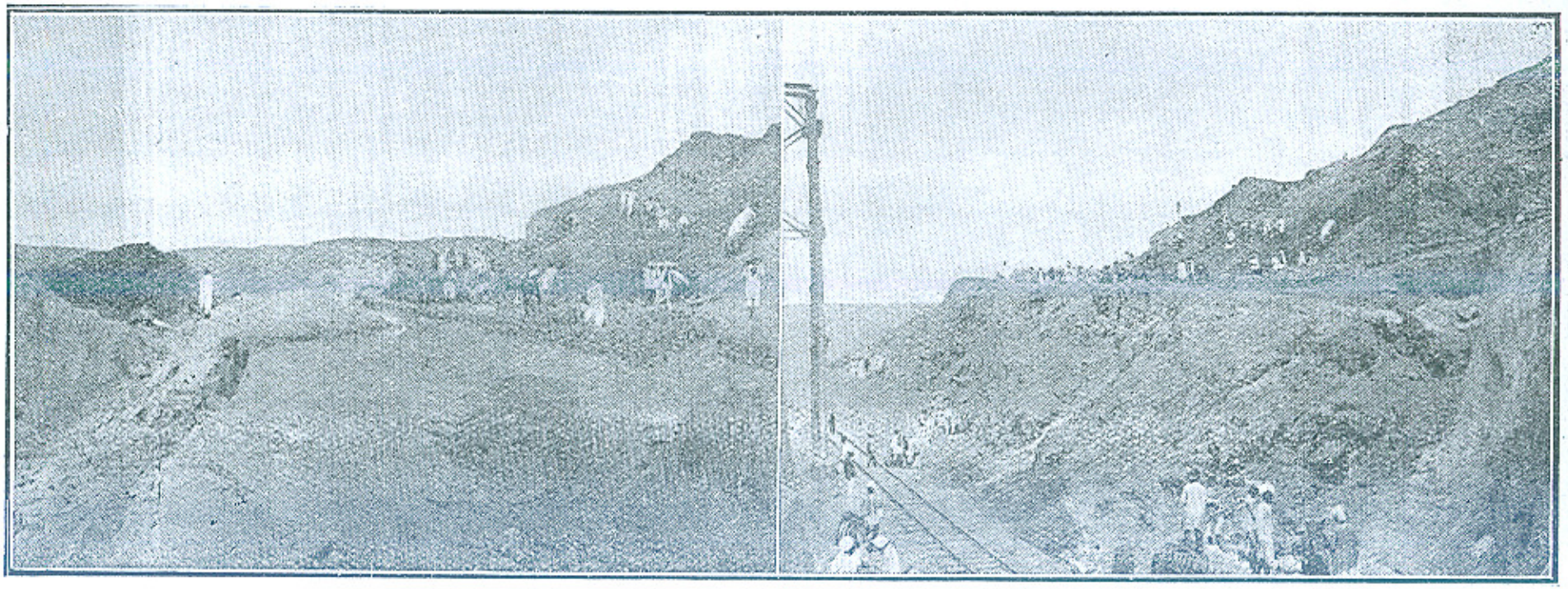
Erection of the Service Girders.

BATHU BRIDGE Plate No. VII.

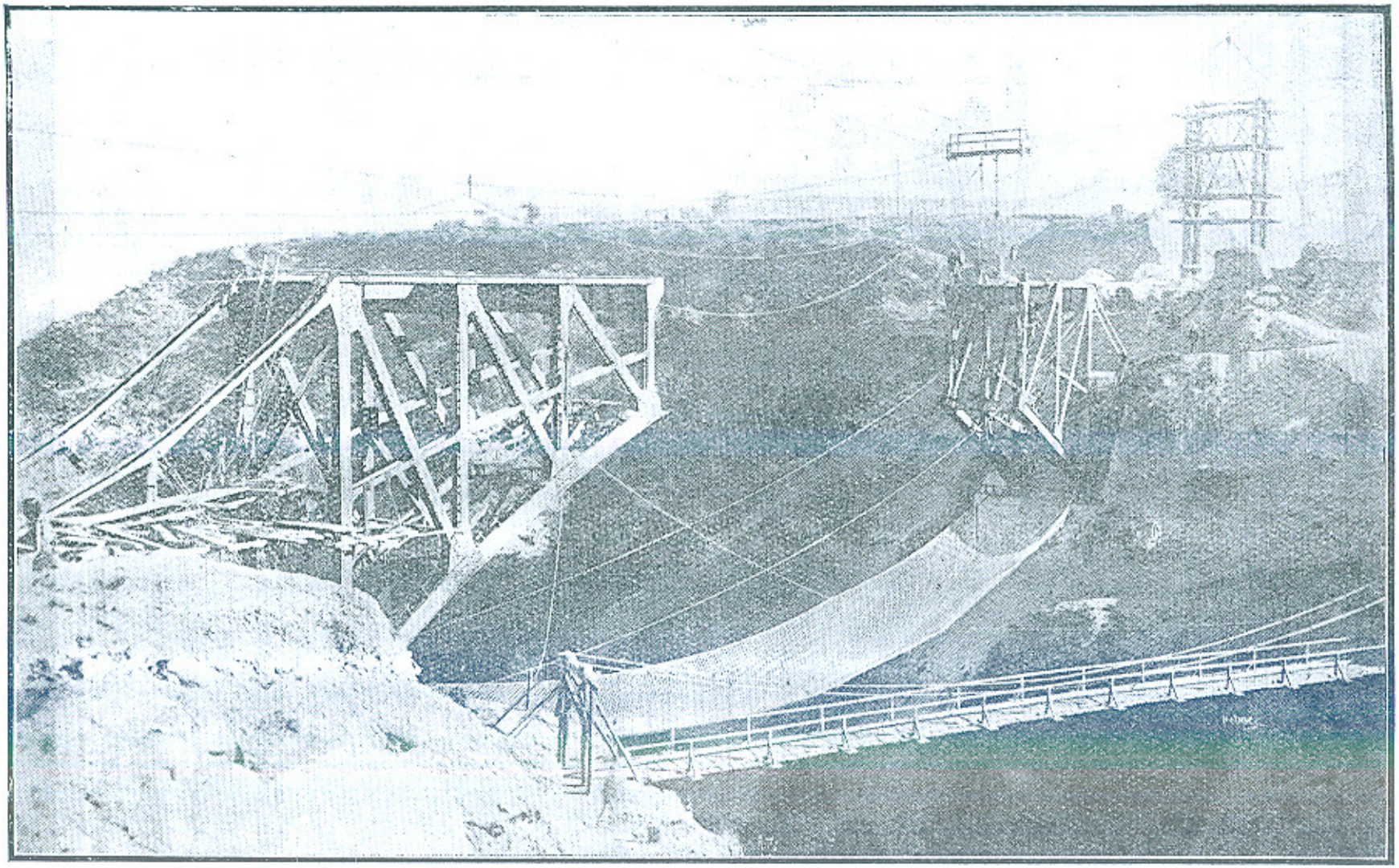


130 ft. Derrick for launching 60 ft. Girders.

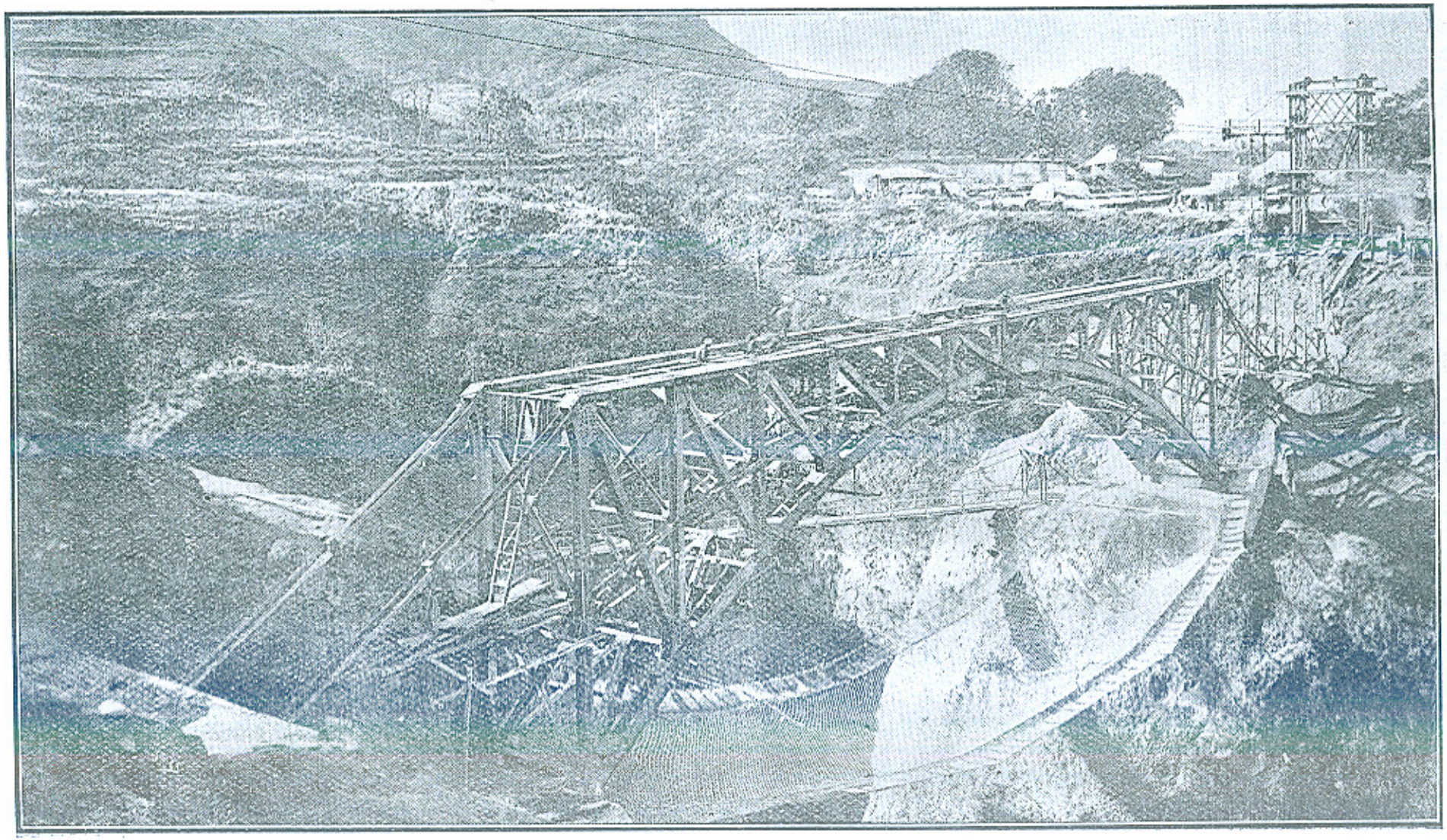
PAROR RIDGE. Plate No. VIII.



Cutting showing both Railway and P. W. D. road.



Erection in progress.



Erection completed.

DISCUSSION.

Major Waghorn, in introducing the paper gave a brief summary of its contents. The paper he stated may be divided into three parts.

The first part is in the nature of an introduction and deals with such items of general interest as the history and topography of the line; the second deals with the technical problems met with both during Survey and Construction and the methods adopted to overcome these; the third deals briefly with a few interesting problems met with under the heading "Materials and Transport."

The paper commences with a history of the various projects which have been under consideration since 1900 and which have led up to the present construction and explains how the necessity for railway connection with the headworks of the Punjab Hydro-Electric Project was one of the main factors which influenced the undertaking of the project.

This is followed by a brief description of the topography of the country and a short general description of the line; reference is made to the extreme instability of the country in general and its liability to earthquakes, both factors which were to influence the alignment and design of works.

The surveys and location work is dealt with section by section. The fixing of the alignment was a matter of primary importance, but to have adopted the first alignment that suggested itself without investigating other possibilities might have meant a great deal of unnecessary expenditure, while on the other hand there was the danger of overdoing the investigation of alternative routes and a consequent loss of valuable time. The problem was not an easy one and a mean had to be struck.

The portion of the paper dealing with the construction of the various works is dealt with under separate heads, paragraphs being devoted to earthwork, walling, tunnels and bridging. Of these four there is nothing of outstanding interest in the first three, and although many minor problems had to be tackled, the methods adopted followed normal practice. Bridging proved by far the greatest problem. The Kangra Valley is one of the wettest districts in the Punjab and bridgework proved to be an exceptionally heavy item.

Foundations proved extremely troublesome, the majority of these were either in sand mixed with boulders or in compacted boulders up to 8 feet in diameter; most of the nullah beds were wet and in almost every case there was a very strong flow of subsoil water necessitating the maintenance of a very large amount of pumping machinery. These difficulties were to a great extent overcome by the adoption of larger spans but these proved almost equally expensive owing to their having to be taken up by road and erected in front of rail-head in order to avoid delay.

The total weight of steelwork involved was approximately 5,633 tons practically all of which, with the exception of the Reond Steel Arch, and a few minor spans, was designed and fabricated by the Bridge Department of the North Western Railway in the Jhelum Workshop.

The Reond Steel Arch is unique in being the first steel arch of its kind to be either erected or constructed in this country. In point of view of both speed and efficiency the programme of girder erection carried out by the Bridge Department will undoubtedly rank as one of the greatest achievements in the history of railway construction in India.

Emphasis is repeatedly laid on the influence which time played in the solving of the many problems met with; this was always the first consideration, involving in many cases methods which otherwise would have been ruled out on the score of cost.

The paper concludes with a brief note on materials and transport. The transport problems proved much more formidable than at first anticipated. Although certain sections of the line were well served by roads fit for wheeled transport, there were many sections where no such roads existed and pack transport had to be resorted to.

Major Waghorn apologised for the lack of figures. This he stated was due to the fact that in December 1928 a fire occurred at Palampur in which the records of two out of three divisions were completely destroyed.

Questions and Replies.

Colonel Battye, stated that there were a few points to which he wished to draw attention. He said that Major Waghorn's paper was particularly interesting to him because it dealt with the problem of trying to locate a surface line at the cheapest possible cost over rough country; he thought the Congress would agree that this was one of the most fascinating problems that an engineer could ever be faced with.

The principle the Hydro-Electric Department adopted in locating their tramway was to endeavour to work to the steepest grade they could get, combined with curves up to 40 degree and to stick at all costs to the water shed.

The N.-W. Railway took over the construction of the line and their estimates for traffic were much higher. The N.-W. Railway adopted 2·5 per cent. grades and 14 degree curves up to Baijnath and beyond that 4 per cent. grades and 30 degree curves, the result being that they adopted an entirely new route. Going over the Kangra Valley Railway with Colonel. E. P. Anderson, R.E. and comparing the two alignments he conceded that the reducing of the curvature to 14 degree on the section up to Baijnath and thence to 30 degrees was sound; it would reduce working expenses and wear and tear on rails and there would be none of the discomfort which is experienced on the Kalka-Simla line.

There, however, was no question of discomfort in going for a 5 per cent. grade.

When the original survey was being carried out by the Hydro-Electric Department it was intended that the line would be eventually electrified at some later date and he maintained that had the steeper gradient been adopted, money would have been available for the cost of plant and

rolling stock required to convert from steam to electric traction when the time came.

He was very interested in the alignment up the Bhir Khud near Ghatta.

The original location adopted by the Hydro-Electric Department crossed right at the bottom of the Nullah and got on to the other side of the hill and he was glad to say that his own judgment of geology had proved to be right. He also wanted to ask whether the reorganization resulting in the Superintendent of Works being made responsible for the works in the Khyber, the construction of new lines at Narowal and a bridge over the Ravi as well as the Kangra Valley Railway, was due to financial stringency or possibly to direct orders from the Railway Board.

He was under the impression that these changes must have made things very difficult for the Engineer responsible and probably cost more than the financial people hoped to save.

The shifting of control of accounts on to the unfortunate Divisional Officers and making them responsible for accounting as well as design work must have resulted in terrible congestion of work, and that always costs money.

He felt that it was time that engineers in the Province got together and made a firm stand regarding the extent to which they as Engineers were being converted into Accountants.

He stated that his Engineers on the Punjab Hydro-Electric Project who were all first class men, keen and enthusiastic, were unable to function as Engineers for at least half their time, as it was taken up in performing non-productive and non-technical functions which had been thrust upon them. He would also like to know whether it would not have been better to have centralised design work in the Superintendent of Works office instead of its being done in the Divisional offices. He said that he had tried to relieve Executive Engineers of the fundamental design work leaving them free to concentrate on the practical work of construction.

He wished to ask Major Waghorn whether the prices for tunnels at Rs. 545 and 485 per foot run, included overhead establishment cost of plant, fuel, etc., used for plant and to what extent interest during construction was included, or if it was merely a net figure.

He was very interested to find out how the depth was fixed for foundations; this was a point over which he had had very long discussions and he would like to ask how Major Waghorn arrived at the figure of 12 feet.

He endorsed everything that the author said about girder erection.

He also wished to endorse what the author had said about the granite boulders; they also found that they were quite suitable for stone masonry if carefully selected and used in large enough block; strict orders, however, were issued against its being used as aggregate for concrete work.

In regard to the use of cement and lime mortar mentioned by the author, they had also used it but for a rather different reason and in different proportions. A proportion of $\frac{1}{4}$ lime was added to 1 of cement and they found that by adding this lime they were enabled to work the mortar with a much drier mixture.

Colonel Walton heartily congratulated the author for writing such a valuable paper on the work carried out on the Kangra Valley Railway.

He wished to emphasise one or two things in regard to survey work. He did not know whether the Railway Surveyors still used Wellington's "Economic Theory of Railway Location" as they did in the old days.

The important point in the location of hill railways was to see that they concentrated the heavy work.

Not only was it a good thing to concentrate heavy work in comparatively short sections but it was also sound to concentrate their heavy grades also in short sections. This had been done on the Kangra-Valley Railway in that a 1 in 40 grade had been adopted up to Baijnath and beyond that a 4 per cent. These two points were really useful and should always be remembered when faced with a hill railway location.

In regard to the question of grades referred to by Col. Battye he said there was something to be said on the side of capital cost for heavier grades. It was seen, however, that electric power would not be available for three or four years after the line was first opened and that even then it would probably be difficult to justify electric as against steam traction, taking into account the extra capital required for conversion. That was one of the reasons why they adopted the comparatively easy gradients; the other factor being that they wanted to have speed and a steep gradient was a restricting factor because it not only restricts speed up hill but also down, as one has to be careful on account of brakage. Speed he thought was an important factor these days on account of motor competition.

In regard to the Bhir Khud referred to by Col. Battye; he agreed with him that the alignment from the geological point of view was unsound. The alternative alignment suggested by Col. Battye was not only thought of, but a trial line was run; it was found, however, that this necessitated a very expensive and lofty crossing of the Bhir Khud and it is very doubtful which of the two alignments would have been cheaper in the long run.

Referring to the heavy work that was put on to the Superintendent of Works, he agreed with Col. Battye and he thought that Mr. E. B. N. Taylor, Superintendent of Works, was to be heartily congratulated for the extraordinary way in which he had carried through the work. He wished to mention one or two points in connection with the foundations of the Gaj and Chakki; he thought that there was a very natural tendency for engineers to get their foundations down to such a depth that there would be no possibility of failure due to floods. On the other hand there was the financial side of the question to consider and the tendency appeared very often to err on the side of safety; it really seemed to him very largely

to come to a matter of judgment based on experience as to what depth foundations should be taken.

It was extremely difficult in cases of rivers like the Chakki and Gaj.

In the case of the Chakki efforts were made to get drawings of the P. W. D. road bridge but these were unfortunately unsuccessful and he thought that in this case foundations were taken down rather deeper than necessary.

In the Gaj, however, time was short and matters got to a stage where further sinking was becoming very difficult; this was likely to lead to extra cost owing to another season being required, and he took the responsibility on himself (and then the Chief Engineer agreed) in stopping the wells where they were. He was glad to say that so far the bridge showed no signs of failure, but he admitted that it might take many years for his decision to be justified.

Mr. Brij Mohan Lal said that the reconnaissance, survey and construction of a hill railway over 103 miles long in the Kangra District, having 1,000 openings including 53 major bridges over 40 feet span in a period of three years and a half, is certainly an achievement which the construction branch of the North Western Railway may well be proud of, and on which the officers responsible for the work deserve to be congratulated.

The speaker having spent some years in charge of the roads in Kangra District, wished to be allowed to make a few observations on the paper mainly on the points where the railway as well as road interests were concerned.

Carriage of the very heavy plant and machinery required for the Uhl Hydro-electric project was not possible along the Kangra Valley Road, nearly all the bridges on this road were built between the years 1865 and 1900, when such heavy traffic could not be foreseen. The gradients on this road are as steep as 1 in 17, and the width is narrow. The road was stressed to its limit during the years 1926 and 1927 when all the materials for construction of major bridges on the Kangra Valley Railway and plant and machinery for the electric plant at Dhelu were carried over it. The only alternative was to construct a railway up to Jogindarnagar.

The author has discussed on pages 83 and 84 the different alternatives, but has not given any reasons for building the line from Pathankot in preference to Mukerian. One distinct advantage in building the line from Mukerian would have been the shorter distance from Mukerian to Jogindarnagar.

On pages 87 to 90, the alignment finally chosen is briefly described. It will be seen that the railway has not followed the Kangra Valley Road between Nurpur and Kangra, and has avoided the more populated portion of the Valley. Dharmsala, the headquarters of the district, is left 18 miles away from the railway. But from an engineering point of view the alignment adopted appears to be the most economical. By avoiding

Kotla and Shahpur a number of big bridges have been saved, and the whole drainage of the valley has been crossed at Gajh by a big bridge with 10 spans of 100 ft. each. Another advantage of this alignment is that it goes through a part of the country hitherto unserved by any roads worthy of the name, and brings Deragopipur and Hamirpur Tahsils much nearer railhead.

The alignment brings the famous Hindu shrine Jwalajee within fifteen miles of Jwalamukhi Road Station. I understand there is a project under consideration for connecting Jawalamukhi Road with Jawalajee and if completed the railway will prove a great convenience to the pilgrims.

Though there is not much to criticise in the alignment, the siting of the railway stations is not very convenient for travellers. No station has been constructed between Pathankot and Nurpur, and one near Chakki bridge would have proved useful. Nurpur Road station is about three miles away from Nurpur—the headquarters of a tahsil and an important town. Kangra Station is about three miles from the town. At Kangra, also, there is very important Hindu shrine, which attracts thousands of pilgrims in the months of April and October. The station being so far from the shrine is not much used by pilgrims, consequently the railway loses revenue. The site of the present station would have been improved by locating it between the Daulatpur tunnel and the point where the railway crosses the Jullundur-Dharmsala Road. If the Station had been sited as suggested, the approach road would have cost little, and the distance from Kangra town would have been practically the same.

As the station yard is laid out at present, every passenger has to cross the line before he can reach the platform. This is not a very satisfactory arrangement.

At Jawalamukhi, Koparlahar and Kangra Stations the goods sheds have not been sited on the same side of the line as the passenger platforms and station buildings. Thus, while at Kangra the approach road serves the goods-shed, at Koparlahar and Jawalamukhi Roads the approach roads only serve the passenger platforms, and the carriage of heavy goods from the goods-sheds to carts on the approach road is very inconvenient.

The Jwalamukhi Road and Koparlahar Station buildings are at a much lower level than the ground behind, and the approach roads are at a higher level than the platform. When deciding the sites of stations the building of approach roads should also have been considered more fully.

It is admitted that to construct a station site at Palampur would have meant an unnecessary rise and fall of about 400 feet; and an increased length of about three miles, raising the cost of construction by several lakhs, but in view of the fact that the Punjab Government is shortly building a model town at Palampur, and the town itself is likely to prosper, it is considered that such an expenditure would have been justifiable.

On page 94, Major Waghorn has described the difficulties that he had to cope with at Paror ridge. At this point the road had been diverted, the road and railway passing through the same cutting with the railway at a much lower level. It would have been better to have provided either retaining walls in the first instance, or provided a 'cut and cover' at this big cutting.

On page 96, Major Waghorn has said that he could not obtain details of the foundations of the P. W. D. road bridge over the Chakki. The speaker wished to inform him that the details of construction of the Chakki bridge were printed in the P. W. D. proceedings of July 1892, September and October 1899 and those of December 1890 and a P. W. D, paper No. 28 had also been written by Mr. Bagley, Executive Engineer in charge of the work. These printed papers give full details of the construction of the Chakki bridge.

For the road bridge, open foundations to a level of 1255·00 about 13 feet below river bed proved sufficient, and no wells were sunk, though pumping had to be resorted to for keeping them drained.

As regards the lime cement mortar, Cement 3 : Lime 10 : Sand 27, the speaker would enquire whether any tests of strength were carried out, and what was the result.

Lastly, though the paper has only dealt with survey and construction, he considered that the cost of construction should also have been mentioned. It was specially necessary in this case, as the difficulties of correct estimating are very great in all hill projects. In the Buildings and Roads Branch, in the same district, there have seldom been any hill road projects which have been completed without a great excess over the original estimates. Going as far back as 1865, the construction of the Kangra Valley Cart Road from Chakki to Palampur was started with an estimate of about 3 lacs of rupees, but up to 1874, Rs. 8 lacs had been spent and the work was still incomplete. Uncompleted portions were then taken piece by piece in accordance with funds available, and the work dragged on till about 1900, when the total expenditure incurred was well above Rs. 15 lacs. Coming to recent times, the Larji Mandi Road project was started with preliminary estimates of about Rs. 3 lacs in 1913 ending with an expenditure of about Rs. 15 lacs by 1923, and in the case of the Kangra Valley Railway it is believed that the final cost has also been greatly above that of the original estimate.

Major Waghorn, in replying stated as follows :—

As regards the details of cost of tunnel work asked for by Col. Battye, the figures given included contractors bills, *i.e.*, cost of labour and material actually put into the work cost of works charged establishment (Junior subordinate staff, Mistries, etc.) and the cost of fuel required for running of plant. It did not include " general charges " such as pay of Officers and Senior Subordinates and expenses incurred in administration such as clerical and medical staff, office expenses ; it also did not include the cost of plant. He considered that to get at a total figure of

cost 7 per cent. should be added on account of " general charges " (this was the percentage figure of " general charges " taking the whole construction into account) and a further figure of 7 per cent. would more than cover the cost of plant used ; this would bring the foot run costs up to approx. Rs. 620 and Rs. 553 respectively.

The second point raised by Col. Battye was in regard to depth of foundations ; Col. Walton had already dealt with the subject but he would like to add a few remarks also ; when referring to the figures of 12 feet which he stated had been adopted, the author had in mind the series of girder bridges between the Negal and Baijnath ; he admitted that the figure of 12 feet was a somewhat arbitrary one ; before the monsoon, however, boulders of varying sizes were selected and marked and their relative positions in relation to some fixed object was noted, after the monsoon a further series of observations were taken to ascertain which, if any, had moved ; during the monsoon soundings, where possible, were taken to try and find out the amount of scour taking place (not a very satisfactory job in a river bed full of boulders) and certain results, chiefly negative. were obtained ; this data combined with a careful inspection of the foundations of the many road bridges adjacent to the work gave this figure of 12 feet but as Col. Walton had said a problem of this nature very largely resolves itself into a matter of judgment based on experience.

The author referred to a question by Col. Battye regarding the centralisation of design work in the Superintendent of Works office ; he agreed to the extent that a great deal of assistance could be given to Divisional Officers by the preparation of standard or type designs being done in the Superintendent of Works office, but when it came to the preparation of working drawings especially those for the smaller openings and arched bridges he considered that it was almost essential that these should be prepared by the Divisional Officers themselves ; the method which the author adopted, and which proved very satisfactory, was to go out to the site with his Head Draughtsman and then and there settle all details ; he considered that there were many factors in the preparation of a design which could not be properly appreciated by an Officer who simply had a site plan to work on.

The method also proved a very quick one and the author found he could deal with 8 or 10 bridges in a day ; in the case of the larger girder bridges the design work was actually done in the Superintendent of Works office chiefly due to the fact that reference has to be continually made to the Bridge Engineer regarding details of girders, etc., and by centralisation considerable saving of time was effected.

Regarding the points raised by Mr. Brij Mohan Lal he said that the alignment from Mukerian was ruled out chiefly on account of the very expensive crossing of the Beas ; the river has to be crossed very soon after reaching Mukerian and it would naturally have been impossible to carry on with the linking until this had been completed ; a difficult and lengthy piece of work occurring at the lower end of a hill construction

tion such as the Kangra Valley Railway was bound to have delayed the work further up, and consequently postpone the final date of completion.

The author admitted that the station sites of Jawalamukhi, Koparlahar and Kangra were open to criticism but he thought that if Mr. Brij Mohan Lal were to study the question more closely taking into account the actual facts which had to be faced when settling these station sites he would realise that there really was no alternative. There was very little room available and the siting of goods platforms on the opposite side to passenger platforms was done to close up the station yards as much as possible.

He admitted that at Paror ridge it would probably have been cheaper to have put in a "cut and cover" or a heavy section retaining wall before movement had started, but that was rather a case of being "being wise after the event."

Exhaustive tests were made regarding the strength of the lime and cement mortar but the author regretted that he was unable to give any definite figures; he can remember, however, that the results obtained were surprisingly good.