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THE CONSTRUCTION OF A MOTOR ROAD ROUND SIMLA

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There is appalling overcrowding in the bazaar areas of Simla, the density of population being stated to be five times as great as anywhere else in the Punjab. This, combined with primitive drainage and poor sanitation, constitutes a constant menace to the health of the station.

Many schemes for the improvement of Simla have been born during the last three decades, but, hitherto, none has reached maturity. The present scheme envisages an enlargement of the sewerage system, provision of an increased and reliable water supply, an experimental scheme of ideal sanitary housing for the migratory coolies with whom Simla is flooded in the summer, and the construction of a motor road round the town.

The first three items are self-evidently highly desirable from a health point of view, but a large percentage of the public are puzzled at the introduction of a motorable road. Mr. K. L. H. Wadley, I.S.E., who was specially deputed by the Government of India to a preliminary investigation of the possibility of improving the conditions in Simla, suggested, *inter alia*, the relief of congestion by indirect means, *i. e.*, by a road similar to that now being described. He expected that the road would reduce the demand for, and therefore the numbers of, coolies, by improving the means of transport available, would cut out the influx of mules and mule-men from the Hindustan-Tibet road by encouraging lorry traffic, and would encourage the development of suburban areas.

The present Simla Improvement Scheme is being financed jointly by the Government of India, the Government of the Punjab, and the Simla Municipality in the ratio 50 per cent, 25 per cent and 25 per cent respectively. At present only the housing for coolies and the motor road are under construction, both through the agency of the Punjab Public Works Department, Buildings and Roads Branch. This paper deals with the construction of the Motor Road.

1. Layout

There have been two suggested routes for a motorable road round Simla familiarly known as the "Wadley" and the

"Dorman" route. Both are illustrated in Plate 1. It will be seen that the Wadley route, proposed by Mr. K. L. H. Wadley, I.S.E., is further away from the centres of population, and might therefore be considered preferable from the point of view of relieving the present overcrowding. The Dorman route, proposed by Mr. W. S. Dorman, I.S.E. (retired and the Founder of the Punjab Engineering Congress), is on the other hand, shorter and more accessible from the principal areas, while the localities it opens up are probably more attractive for prospective development than are the somewhat remote areas traversed by the Wadley route. The decision, made in 1941, to construct the road on the Dorman alignment will have its supporters and its critics.

It will be seen from Plate 1 that the route can briefly be described as follows:—From the existing motor terminus it follows the present Cart Road, past the Veterinary Hospital, to the Municipal Forest Depot. At this point the alignment leaves the Cart Road, forking downhill to the right towards Bemloe, through which estate it passes. A length of completely new construction then follows, joining the old cemetery road near "Delshangie". The existing road below "Hawkesford" is followed to "Newlands", where the new road forks uphill through the forest, rejoining the existing road near "Talland", whence it almost immediately again forks to the left through forest land, through the Park Estate, below "Victoria Place" and "Vincent House", joining the Mall at Chota Simla. From Chota Simla the alignment follows the existing road past "Ellerslie" etc., up to the entrance gates of the Convent of Jesus and Mary, through the grounds of which a short length of new construction is necessary to improve the steep gradient and sharp curve of the existing road. Thenceforward the alignment follows the existing Ladies' Mile to Sanjauli.

From Sanjauli the new road consists of improving the existing mule track below the Mayo School etc., up to a point near Belvedere Tunnel, where it leaves the mule track and skirts the East Slope of Elysium spur, which it crosses near the gates of "Longwood". Thence it returns along the west side of the spur, by the existing road, to a point near the west end of Balvedere Tunnel, whence it follows the mule road to below "Blessington", continues along Lovers' Walk, bridges over the road leading down into Kaithu Bazaar, continues through the "Mythe" estate, etc., and finally, after further stretches of new construction along the North slopes of the main ridge, tunnels under the ridge between Gorton Castle and the Council Chamber to join the existing Kalka—Simla road.

2. General Specifications

The roadway consists of an 18 ft. wide formation, as illustrated typically in Plate 2. On bends this width is increased to 20 ft., the extra 2 feet being provided in the metalled portion. Gradients are not to exceed 1 in 10, with the proviso that short sections of a 1 in 8 gradient would be acceptable. The radius of bends are not to be less than 50 ft. at the centre line of the road. All road bridges and culverts are to be capable of carrying the standard loading speificed by the Indian Roads Congress.

All these requirements were fulfilled, and it was found possible to lay out the road with gradients which nowhere exceeded 1 in 10. This, coupled with the fact that only three small subsidiary buildings have to be demolished; reflects great credit on the surveyors.

3. General Design

The road crust consists of a 3 inch thickness of hard sandstone ballast over 3 inches of local stone soling. The thicknesses given are as laid and are reduced by consolidation. The crust is considered to be adequate for the weight and type of traffic likely to use the road. It will be completed by two coats of tar and chippings as follows :—

1st coat. Road Tar No. 2, 28 lbs. per cent sq. ft. blinded by 3·2 cubic ft. of local stone chippings, graded $\frac{3}{4}''$ to $\frac{1}{4}''$.

2nd coat. Road Tar No. 2, 14 lbs. per cent sq. ft. blinded by 2 cubic ft. of local stone chippings, graded $\frac{3}{8}''$ to $\frac{1}{4}''$.

Retaining walls are built generally to the sections shown in Plate 2, and are of dry-stone masonry. Obviously in dry-stone masonry no tension is permissible and this condition is fulfilled when the angle of repose of the retained earth is not less than 45°, with earth weighing 110 lbs. per cubic foot, and the masonry 140 lbs., and calculations are made by Rankine's formula. The geology of Simla is highly complex, and conditions vary almost from yard to yard. Thus more daring design is out of the question. The standard type of wall does not theoretically permit surcharge, but, where the hillside is sloping and apparently giving a surcharge, it is reasonable to suppose that the angle of repose of the material in question which has withstood the weather for thousands of years, is much more than 45°. Be that as it may, the fact remains that the cross section in question has proved successful in a very high percentage of cases, has been used in the Punjab Hill Stations almost universally with slight modifications, and is a

very cheap type of construction. The somewhat hit-and-miss method of allowing a small percentage of failures and then designing walls specially to cope with the conditions which caused the failure of the standard wall is, in practice, the only method, hill conditions being recognised as almost incalculable. Where space prohibited the standard type of wall with its battered face, the vertical wall illustrated on the same plate was adopted. Its cost per unit of volume was nowhere less than double that of dry-stone masonry, it being built in a 1 : 6 cement-sand mortar.

The waterways of culverts were calculated by the formula :—

$$A = C \cdot a^{\frac{3}{4}}$$

where A = Area of waterway of the culvert in square feet.

a = Catchment area in acres.

C = Co-efficient varying from 0·66 to 1·00.

Plate 3 illustrates a typical culvert, and shows the form of construction. Coursed rubble masonry in cement sand mortar was considered suitable for the abutments and flooring, but in view of the very poor class of masons available in Simla, and the surrounding areas, it was considered inadvisable to expect reliable stone arches to eventualise. Thus, in view also of the extreme difficulty of obtaining steel of any description, brick arches were adopted in all cases where special conditions did not prohibit their use, and except for certain small culverts, over which the cover was ample, which were decked with stone slabs. Our apparent reticence in using brickwork may surprise those who do not realise that no bricks are made in Simla, and that the cheapest imported first class bricks cost from Rs. 60 to Rs. 70 per thousand on site.

All arch rings were checked graphically to ensure that no tension could exist in any part of the ring. This is conservative when viewed in the light of successful modern practice, but the available bricks are poor, and, as mentioned above, workmanship is an inevitable source of anxiety. For some arches, the thickness of ring allowed is very extravagant, as all were made up of the nearest above number of half-brick rings. In no case was the skin compression allowed to exceed 8 tons per square foot. Some criticism is possible that we did not consider for so large a scheme, purpose-made bricks. We did. The manufacturers demanded an extra Rs. 10 per thousand bricks. The reason for this was obscure, as it appeared that, if we supplied the necessary numbered moulds, and if the sizes were the same as that of the standard brick, no extra payment was justified. Actually there is a big local

trade in rejected standard bricks, and, with special bricks, there would be no such sale. So special bricks were to sell at a price to compensate for the loss of this bye-product ! The matter then received the fullest consideration, and it was found cheaper and far more convenient, to be slightly extravagant in the use of the standard bricks.

Superelevation on bends is a highly controversial matter, depending as it obviously must on the probable speed of traffic. The authors go so far as to say that superelevation for hill roads is beyond the reach of theory. Any formula must enjoin steeper superelevation for curves of smaller radius, but every motorist is aware that the sharper the bend the slower he goes. Who can generalise in the matter ? In a climate such as that of Simla an additional complication arises in that, during winter, ice-covered superelevated roads become dangerous for pedestrians and animals, and cause slow moving carts etc. to slide inwards. Some very interesting observations were made in this connection, and collected, by Mr. L. A. Freak, I.S.E., in whose Circle of Superintendence this road was designed and is being built. Mr. Freak finally decided that superelevation steeper than 1 in 12 was undesirable, and, for the road under consideration, the following formula was therefore evolved :—

Radius of bend.	Superelevation.
Under 120 ft.	1 in 12
x ft.	1 in x/10
e.g. :—	
150 ft.	1 in 15
190 ft.	1 in 19

The portions of the road over which motor traffic is as yet possible have been carefully observed for their riding qualities, which have been found to be highly satisfactory.

Transition curves were nowhere introduced, being considered superfluous on what will obviously always be a slow-driving road.

Vertical curves are a vexed problem. In Europe, where more research has taken place in this direction, possibly, than elsewhere, the problem has always been viewed as one of obtaining visibility. In this case visibility is limited by the shape, in plan, of the layout, and this, if it is to be kept within the bounds of financial reason, cannot be much improved. We therefore viewed the question from the point of view of providing easy riding qualities at changes of grade, and have worked to the following formula :—

$$H = 5\ (N - M)$$
$$v = x^2/1000.$$

where :—

H is the horizontal tangent length in feet from the point of intersection of the grades between which the curve is to lie.

N and M are the gradients, expressed as percentages, to be joined. *Note.*—Where an "uphill" joins a "downhill" M must be given a preliminary negative sign, and the formula becomes, in effect :—5 (N+M.)

v is the vertical distance, in feet, of the road surface above or below, as the case may be, the straight lines to be joined by the curve. The reduced levels of any points on these straight lines are, of course, readily determined from the profiles.

x is the distance in feet, from the tangent point (and measured towards the point of intersection) to the point for which v is being calculated. x must be measured horizontally.

Obviously the value of x must never be taken in excess of H.

This formula is derived from the basic expression $y = x^2/1000$, and, when applied as outlined above, no vertical curve will permit a variation in the pressure on the road in excess of about $\frac{1}{2}$ per cent.

4. Principal Structures

These include essentially one tunnel, three single span birdges and four viaducts.

TUNNEL :—The site of the tunnel is shown in Plate 1. The site was selected for two reasons; firstly on account of the conveniently short length (160 ft. only) through the ridge at this point between Gorton Castle and the Council Chamber, and secondly on account of the easy approaches this site makes possible. A geological survey of the site has been made, and certain difficulties were anticipated by the geologist, who reported accordingly to his Government (of India). On the matter being referred back to the authors, they remained strongly of the opinion that this was the best site for the tunnel and did not agree with the geologist that the driving of the tunnel would involve considerable danger to the overlying buildings, *i.e.*, Gorton Castle and the Council Chamber. Our departmental seniors agreed with us, and the Government of India then stated that they had no objection to the

proposed site provided that the Punjab Government, the executing agents, agreed to be wholly responsible for any damage which might occur. The Punjab Government were, on principle, unwilling to agree to this, and, at the time of writing the matter has not been settled, although, with a view to proving the nature of the hillside, the construction of a pilot tunnel is in hand. This pilot tunnel will, provided the site is not changed, form the heading for the construction of the tunnel proper, and thus will all be useful work.

The authors are unaware that any accepted formula exists for earth pressure on a tunnel lining, and their exhaustive search produced a multiplicity of theories. They therefore designed the lining on the following assumptions, which appeared to them reasonable for the stratified sandstone, of which the hill in question was expected to be composed :—

(1) Active inward pressure according to Frühling's formula :—

$$q_1 = w\ (h - 0{\cdot}06\ h^2 + 0{\cdot}0012\ h^3)$$

$$q_2 = \frac{x\ (16{\cdot}5 - h)^2}{269}$$

where :—

q_1 = pressure per square foot on the arch due to the superimposed earth.

q_2 = pressure per square foot on the arch due to live load.

w = weight of earth in pounds per cubic foot. This was assumed at 150 lbs. per cubic foot for the rock in question.

h = depth of cover in feet.

x = intensity of live load in pounds per square foot.

It will be seen that, where h = 16·5 ft. there is a point of inflexion in the parabolic formula for q_2. At this value of h, Frühling asserts that the values of both q_1 and q_2 are maxima. As this value of h is exactly the minimum cover over the tunnel under consideration, it has most conveniently been assumed for all the calculations, which also enables the live load to be ignored.

(2) Passive resistance of the earth back-fill surrounding the lining to be limited to 1 ton per square foot.

(3) It was also considered reasonable to expect a fall of rock such as would leave a natural arch with sides at 45° to the horizontal. For simplicity this was taken as leaving a dead weight of 12 ft. of spoil resting on the arch ring.

The following conditions were each considered separately, and ability of the assumed section to resist them was investigated by Fuller's method :—

(*a*) Whole ring loaded vertically with the weight of a 12 ft. depth of spoil, the resistance of the sides to outward collapse being limited to 1 ton per sq. ft.

(*b*) Pressures on all parts of the arch and abutments (vertically and horizontally) according to Frühling's formula.

(*c*) Earth pressure on one half of the ring according to "a" on the other as "b", with side pressures limited to 1 ton per sq. ft.

Plate 4 shows the standard cross-section of the tunnel, as finally adopted, and also the elevations of the North and South portals. These latter are, as regards thickness, designed to stand as vertical retaining walls; their appearance is intended not to clash with the existing features nearby.

Bridges :—Leaving the South end of the tunnel, and proceeding by the new road towards Chota Simla, the next principal feature is the bridge over Combermere *nala*. On this site there existed a fairly recently-constructed bridge consisting of a reinforced concrete slab, supported on rolled steel beams resting on dry stone masonry abutments. The width of roadway was 14′ – 8″ on a sharp curve in the road.

Preliminary calculations showed that the reinforced concrete slab was unable to withstand the shear specifications of the Indian Roads Congress, and that the beams gave undue deflection. Our inspection of the structure showed that widening was difficult without undermining the existing abutments, which were showing, at that time, some signs of distress, while the alignment of the bridge was such as not to fit in conveniently with our proposed alignment.

It was decided, in view of everything, to scrap the existing structure entirely, and build a new bridge. The design adopted is shown in Plate 5, which requires little explanation as regards its general outline. The design followed the usual methods. The only original feature is the method of construction of the abutments, on which we comment more fully under "Materials used etc."

The bridge was erected without interrupting traffic. Sufficient of the old structure was first demolished to permit the erection of one half of the new bridge; the latter was then opened to traffic, the remaining portion of the old bridge was removed, and the new bridge completed. The settlement of the arch, on easing the centrring, was 0·6″ for each half. On account of this settlement, which was, of course, expected, the

two halves were built independently, with a half-inch space between. This space was finally grouted up with cement mortar. The abutments were each bonded to form continuous structures.

This bridge is illustrated in Photograph No. 1. It is thought to be pleasing in outline. It has carried 10 ton steam rollers, but the most severe load has probably been the largest of the lorries bringing stone from outlying quarries. It is suspected that this lorry has been loaded to about 10 tons gross, and the driver has often given the impression of realising that "time is money"!

No further bridge is encountered by a traveller until he passes Sanjauli, turns back along the North limb, and nears Elysium spur. Here there exists a deep *nala* traversed by a 22 ft. span bridge consisting of a wooden decking carried on rolled steel beams resting on dry stone abutments. This bridge has been christened "Belvedere Bridge." Here again the bridge is manifestly unsafe, and far too narrow, for unrestricted traffic.

The road at this point is necessarily on a very sharp curve. Although the shape and geology of the *nala* at once invites an arched bridge, such a bridge would have to be very wide in order to give a clear and unobstructed road 20 ft. wide on the curve. The rolled steel beams in the old Combermere Bridge were, as stated, too weak for that span, but are, luckily, ideal for 22 ft. span at Belvedere. Considerable reinforcement was recovered from the decking of the old Combermere Bridge. We therefore decided on reconstructing Belvedere Bridge with abutments of brick-faced concrete supporting rolled steel beams carrying a reinforced concrete slab. The design is illustrated in Plate 6. This is interesting, we think, in that the concrete slab is curved in plan to meet the approaches, and is superelevated. The design of the slab is, of course, that of a continuous slab over the five beams, with cantilevers at the ends of varying lengths. The design was obviously tedious but not avoidably so. Unfortunately, at the time of writing, the construction of this bridge has not been started owing to restrictions of cement, but it is thought that the effect of this bridge will be "easy on the eye", being the opposite of some of the kinks in our arterial roads caused by wooden adherence to straight right angle bridges over canals, etc.

The third and last single span bridge can hardly aspire to that title at all, being of only 11 ft. clear span. Here the new road is carried over the existing rickshaw road leading down into Kaithu bazaar. Considerations of head room for equestrians necessitated a simple reinforced concrete slab design.

The length (along the new road) of the bridge being small, it was unnecessary to bother about curving it in plan, but the slab has been suitably superelevated. From the rickshaw road the elevation is unusual in that a culvert has been provided through the structure only a few feet away from the main opening for traffic. The road to Kaithu bazaar is on a gradient of 1 in 4, and the culvert is provided to permit the side drain of this road to continue through in a straight line. The side drain in question is a veritable torrent during the monsoons, and this care was thought not undue if damage by scouring was to be avoided to the road below.

VIADUCTS :—Viaducts are situated at the junction with the new link road to Hawbuck Grange, at Chota Simla, and two on the North side of Elysium spur.

The design of the viaducts was first considered generally, and was based on the assumption that masonry retaining walls above 35 ft. in height were economically a bad proposition, requiring special consideration and treatment, structurally to maintain stability. It was anticipated that the heights of the piers of the viaducts would be a minimum of 30 ft. on the downhill side, and of 10 ft. on the uphill side, *i. e.*, an average of 20 ft. As viaducts are only introduced for short lengths, owing to topographical conditions, the abutments will obviously be less high, and the standard design illustrated in Plate 7 was selected out of some round dozen as being the most economical for these average conditions. It will be appreciated that reinforcing bars for concrete being difficult to obtain, our earlier designs in reinforced concrete found their way automatically into the waste paper basket.

Some criticism is likely of our apparent laziness in not designing each of the four viaducts on their merits, and in hiding behind vague expressions such as "probable height of piers". We therefore draw attention to the fact that the heights of the piers could not be determined until the foundations were opened, as trial borings in Simla are completely unreliable.

All viaducts are identical, as regards materials and methods of design, with Combermere Bridge. The piers are designed to withstand any combination of out-of-balance loading on the several spans.

It will be appreciated that Plate 7 shows a type design only, it being modified to suit local conditions at the individual sites. All the viaducts are curved in plan to varying extent, and are on gradients. The curvature in plan was introduced, were possible, by introducing skew arches (the masonry in brickwork caused some head scratching among our work-charged establishment !),

Where skew arches would not meet the case, the piers were made trapezoidal in plan. The reason why skew arches cannot be introduced, where necessary, everywhere, is obscure until one tries to draw out the result. Skew arches were possible at the junction with the Link Road, and the design for that viaduct is shown in Plate 8. At Chota Simla trapezoidal piers were necessary, and the design is illustrated in Plate 9. This latter is also illustrated photographically in Photograph No. 2. The viaduct at the junction is difficult to photograph in an illustrative manner, but efforts are reproduced in Photographs Nos. 3 and 4.

We think that the finished effects of these viaducts is pleasing, though engineers have expressed their opinions that the arch rings appear heavy, and the abutments on the light side. The arch rings are not heavy with the specified stresses and loading, and cannot be reduced unless tension is permitted in some part of the section. The backs of the abutments are, in due course, covered by the ends of the adjoining retaining walls, and this may possibly have misled observers into thinking them too light.

It will be observed that, for the two cases illustrated, all arches are made rampant to conform with the gradient of the road at the point in question.

5. Materials used and stresses allowed

The most controversial item in this section is likely to be the method of construction of bridge abutments and piers, *i.e.*, a brick facing, with a filling of 1 : 5 : 12 concrete. This construction is a natural development of the normal form of construction of brickwork in 1 : 6 cement mortar.

It is standard Punjab P. W. D. practice to allow stresses up to 4 tons per sq. ft. in brickwork in 1 : 6 mortar, and obviously, with designs based on this stress, there is no point in having a fill composed of a stronger material. Solid brickwork would, of a course, in Simla, be completely prohibitive in cost, while coursed rubble stone masonry was not considered sufficiently reliable for carefully designed structures. Thus some form of concrete became inevitable.

The manner in which we decided to use 1 : 5 : 12 concrete for this filling is as follows. On page 203 of the Military Engineering Services Handbook, Volume 1, the following stresses are permitted :—

1·2·4	Concrete	20 tons	per sq. ft.
1·3·6	do	15	do
1·4·8	do	10	do

Plotting cement-sand ratio horizontally, and stress vertically it is obvious that a straight line is obtained, and this gives a cement-sand ratio of 1 : 5 : 4 for 4 tons per sq. ft. From this we decided to use 1 : 5 : 12 concrete. This method is conservative, as the straight line as plotted allows no stress whatever for 1 : 6 mortar, and everybody knows that excellent results are regularly obtained by its use.

The brick facing serves a two-fold purpose. Firstly it is probably as cheap as any other form of shuttering, and secondly it serves to give a good finish on the work. This was found highly successful in practice, the easiest way being to fill with concrete course by course as the brick facing is laid. The bricks were laid alternate headers and stretchers in each course breaking joint of course, and the finished work has the appearance of Flemish bond brickwork. The average thickness, by this method, of the facing comes to 6". The alternative method of having alternate courses of headers and stretchers, resembling English bond, gives an average thickness of 7½", and is thus more expensive. In the opinion of the authors, moreover, the bond between the face and the fill would not be so good by this method.

This method of working is now being adapted to stone masonry walls, the facing being of stones laid in cement-sand mortar, and the backing being of concrete. For normal walls, where a collapse would be of no great moment, it is intended to try 1 : 6 : 18 concrete for the fill. This mixture has, of course, been consistently successful as foundation concrete, in place of lime concrete, for building work.

If anybody feels that the use of 1 : 5 : 12 concrete in the superstructure of bridges is too daring, the authors would like his opinion on arches made from lime concrete! There are several such on the Kalka-Simla road, and they are all standing perfectly.

Other materials were stressed on the lines of the standard P. W. D. specifications.

6. Carrying out the Work

The authors think it can be said, without fear of contradiction, that there have been few schemes of this size (about Rs. 12 lakhs) which have been executed under conditions of such continuous difficulty from the beginning throughout the work.

In November, 1941, the survey work was complete and the design and estimates under preparation, when orders were received to commence construction immediately. A start was made on the excavation for the formation of the road, and tenders were called for the construction of retaining walls.

Only one tender was received at exorbitant rates, and it was therefore decided to let out the work piecemeal by work orders to petty contractors ; it being realised that contractors were diffident of committing themselves to contracts during a period of fluctuating markets, except at very handsome rates, which rates included an ample margin for possible increases in the prices of labour, etc. We considered it wiser to let a large number of work orders at the then prevailing rates so that the petty contractors would be free to stop work when they so desired. These work orders were therefore let on the then prevailing market rates and not on what these rates might soar to six months later. The scheme was fairly satisfactory in practice, but obviously entailed considerable office work, three sub-Divisional clerks being employed.

Supply of building stone also proved difficult. The Simla Municipal Committee were obviously disinclined to permit quarrying in a manner likely to impair local amenities, and possible quarries were few in number. Local quarries were essential as, of course, there was no road access to sites.

A large building scheme by the Central P. W. D. was shortly to commence, and the labour market took full advantage of the situation.

It was therefore decided, in view of all the difficulties enumerated above, to open up construction only on the southern limb of the road, *i.e.*, from the Municipal Motor Terminus, *via* Chota Simla to Sanjauli. From Chota Simla to Sanjauli the work consisted only, except for a short length of new road through the grounds of the Convent of Jesus and Mary, of rebuilding culverts and widening the existing road, known as Ladies' Mile, strengthening one small reinforced concrete gallery, and replacing a wooden gallery by standard construction. From the Motor Terminus to Chota Simla the bulk of the work is entirely new construction.

The Hindustan-Tibet road from Simla closes down in November for the winter, and all the P. W. D. gangs and Road Inspectors, who normally are given leave without pay during the winter, were offered work in Simla on this scheme. The majority, some 200 in number, duly came. This was a great blessing as all these men are used to routine road work, such as widening, etc., and their presence had a stabilising effect on the labour market.

Contracts by private negotiation were later let for various parcels of work. At the time of writing, the north limb is shortly to be opened, and it is hoped to conclude agreements with suitable contractors, but again we are threatened by

opposition for labour by rumours of a further Central P. W. D. building scheme for the winter of 1942.

Summarising, it may be said that the work has been carried out by a mixture of petty work orders and direct labour, with a few negotiated contracts here and there.

7. Troubles Experienced During Construction

The construction of a scheme of this nature is dependent entirely on transport of stone for retaining walls, as the progress on other items must depend on the construction of retaining walls. The biggest quarries where first-class stone is available nearby, are at Sanjauli (three-quarters of a mile from the nearest point on the road) and the Baraighat quarry (four miles away). As long as petrol coupons for lorries were available these quarries were worked hard, but the leads involved made transport by any other means, other than lorry, very inconvenient and costly.

In the Simla hills there is a marked unofficial Trades Unionism among the various types of transport contractors, *e. g.*, mules are meant to carry potatoes, bullock-carts mangoes, and etc., and it has been found impossible to induce these men to allow other work to interfere with their normal traffic. Thus, now that petrol coupons for lorries are unavailable, we are compelled to work hand to mouth for transport by hand-carts, mules etc., as may be " in season ".

When the Central P. W. D. works started up in December 1941, competition for material and labour arose, creating great difficulties. The price of bricks soared ; sand was the monopoly of a few firms who had formed a pool ; timber had been controlled by Government ; road tar was also controlled ; steam rollers were being withdrawn for military works ; skilled " mistris " were unobtainable.

These are a few of the difficulties under which work proceeded from the commencement until June 1942, when cement supplies were totally suspended without warning. At this stage many culverts were in a partial state of completion, and considerable damage naturally resulted in the then active monsoons.

People with knowledge of hill roads will expect " teething troubles " with a new road of this nature, and we have duly experienced these troubles. Particular mention will be made of the more interesting incidents.

Reference has been made earlier to the manner in which the geology of Simla varies from place to place. This is clearly illustrated below " Ravenswood ". Here there existed out-crops of apparently sound sandstone, and, in view of the

eternal shortage of building stone, the acquisition of this land was awaited with greed. The quality of the stone proved disappointing, but nevertheless we proceeded with the work of rock cutting to form the road. The rock face was expected to stand vertically, and it duly did, except at one place where the strata changed abruptly from horizontal to vertical without any visible sign of a fault. These vertical strata collapsed, and a heavy slip resulted in the closing of a Municipal road further up the hill near the mouth of Bemloe tunnel. This area is illustrated photographically in Photograph No. 5.

In Bemloe Estate a section occurs where, on account of the steep hill side, it was more economical to build a vertical wall in cement-mortar, on account of the greatly increased height necessary for a dry-stone wall with battered face. This wall was completed with a small culvert piercing it at one point. This culvert carried only roof drainage, sullage, etc., from one of the Blocks of Bemloe Estate.

When the monsoons started, it was observed, by our Staff that the water from the compound in question did not apparently all reach the culvert leaking instead into the ground in many places *en route*. The rains this year were exceptionally heavy and continuous, and, at this juncture, leaks were difficult to locate exactly, much less repair them. Very little warning was given before the wall collapsed throughout its length, exposing a completely waterlogged backfill. It is unfortunate to think that a dry-stone wall would have allowed natural drainage, and probably thereby survived. Deep holes had been provided in the *pukka* wall, but, for some reason which will now never be known, they had not proved effective.

In some half dozen places walls of various heights have shown signs of their front faces "blistering" off. The first explanation which comes to mind is that this is due to the imminent collapse of the wall in question, acting as a cantilever, but it is significant that no corresponding horizontal movement at the tops of the walls in question has been observed. The beds of dry-stone masonry are invariably dressed more carefully in the facework than are the stones behind, and we think the explanation of this blistering lies in vertical settlement of the masonry forming the inside of the wall, which the better-dressed stones in the facework try to oppose. Thus the facework, in attempting to adjust its length to correspond to that of the internal masonry, must buckle, and does so in the only direction possible. Photographs Nos. 6 and 7 show this blistering. It has always been the practice in the hills to view such blistering as a sign of imminent collapse, but the

dates of the tell-tales on the Municipal wall in Photograph No. 7 show that the collapse need not necessarily be viewed as imminent. Moreover it has been found possible in some cases to remove and grout in again the separated facework, leaving a wall to all intents and purposes prefect.

Conclusion.

GENERAL REMARKS :—This paper has been written as the project is half way through. Nevertheless it embraces all the salient features, and covers all important design work. Progress has, for the reasons outlined, been slow, but we still entertain hopes that the road will be open to traffic by the summer of 1943.

There is either a let or a hinderance during practically every month of the Simla season, and anybody who knows the station well will realise this; consequently we have endeavoured to organise the works accordingly. We have endeavoured to keep costs down, and in no way to subscribe to any war-time inclination to view high rates as inevitable. Naturally we have not succeeded in working to anywhere near peacetime rates, but we are not yet in a position to give through rates for finished work.

Photograhps Nos. 8 and 9 are randum snapshots of the work, and may prove of interest. No. 8 shows a typical section of work starting up, and illustrates the type of country through which the road runs. No. 9 illustrates the Chota Simla viaduct when half completed.



PHOTOGRAPH NO. 1. THE CONSTRUCTION OF A MOTOR ROAD ROUND SIMLA



PHOTOGRAPH No. 2. CHOTA SIMLA VIADUCT



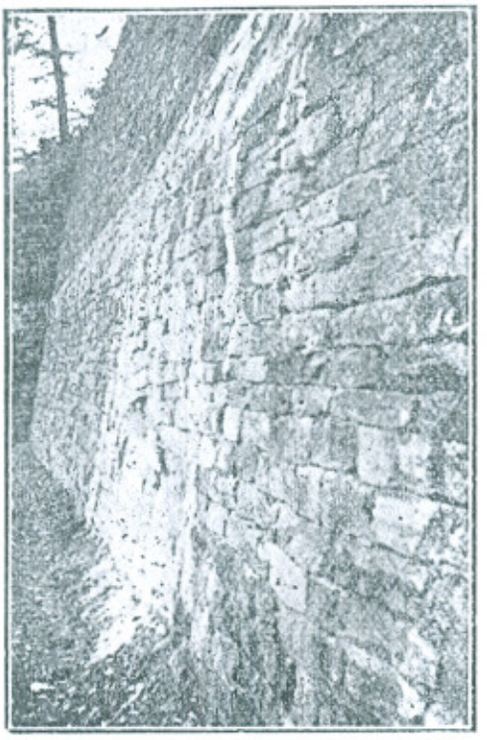
PHOTOGRAPH NO. 3. LINK ROAD VIADUCT



PHOTOGRAPH NO. 4. LINK ROAD VIADUCT AND APPROACHES

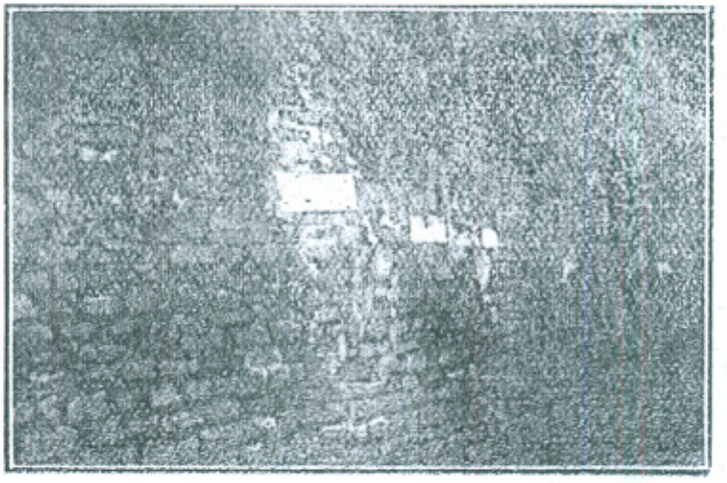


PHOTOGRAPH No. 5. COLLAPSE OF SANDSTONE FACE.



PHOTOGRAPH No. 6.

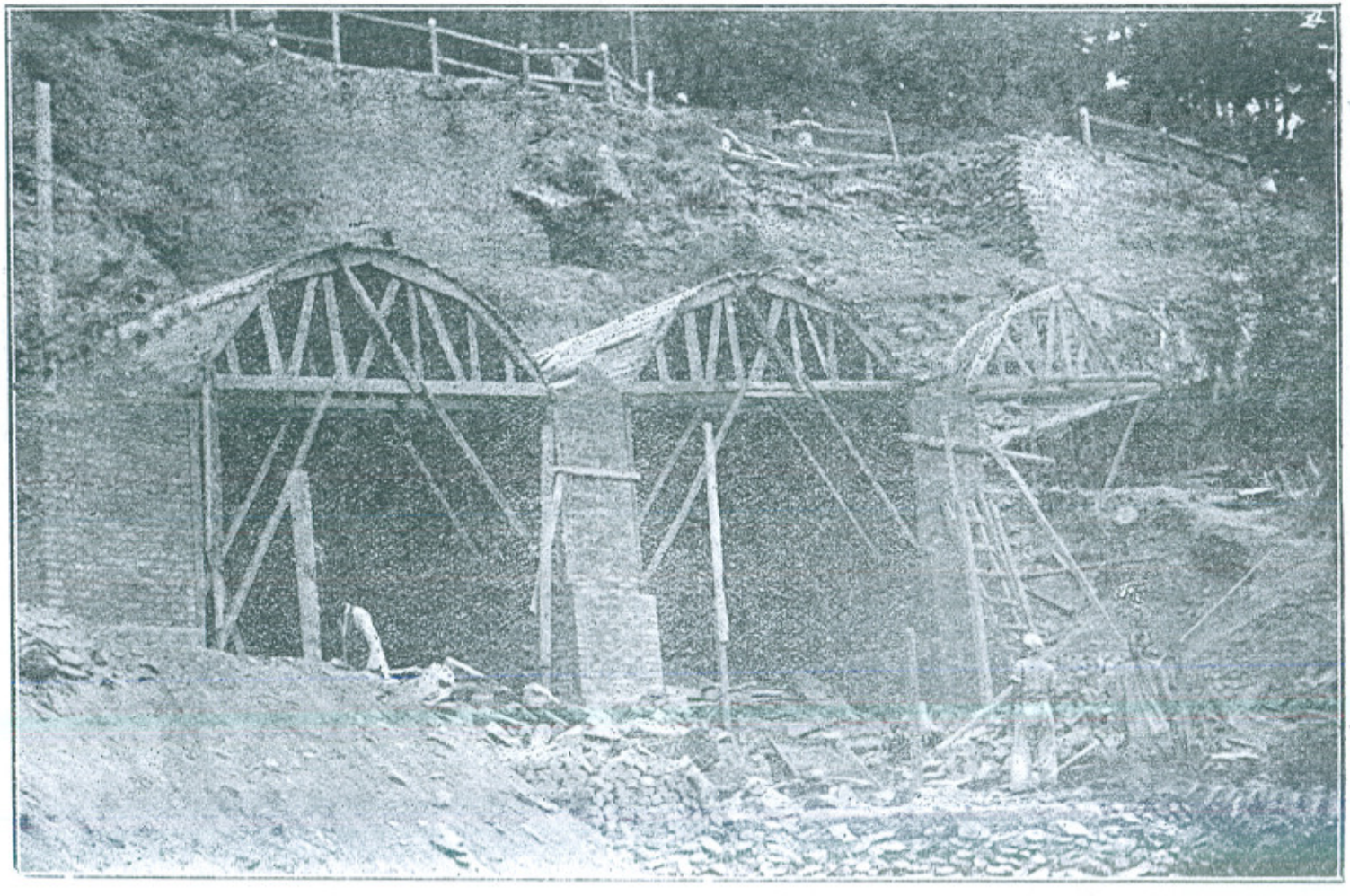
BLISTERING OF FACEWORK.



PHOTOGRAPH No. 7. OLD BLISTERING OF FACEWORK.



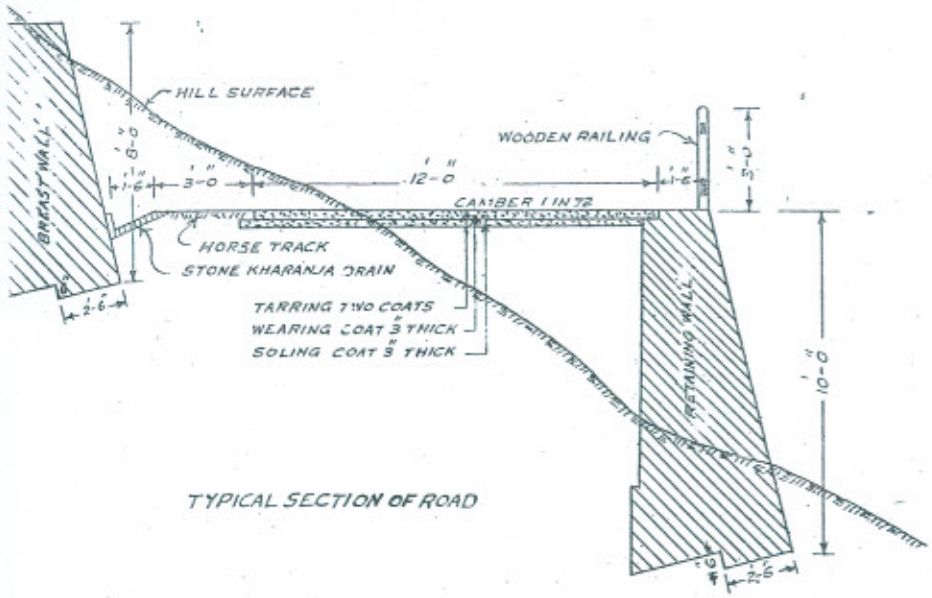
PHOTOGRAPH No. 8. COMMENCEMENT OF WORK



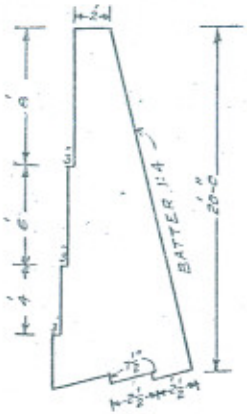
PHOTOGRAPH NO. 9. CHOTA SIMLA VIADUCT UNDER CONSTRUCTION

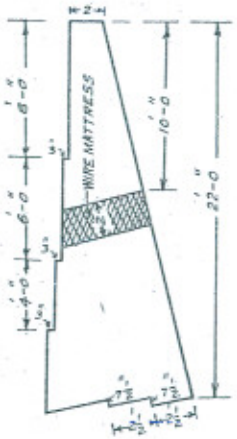
PLATE I
PAPER No 259

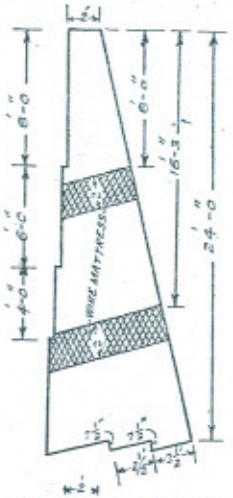
TYPICAL SECTIONS OF RETAINING WALLS

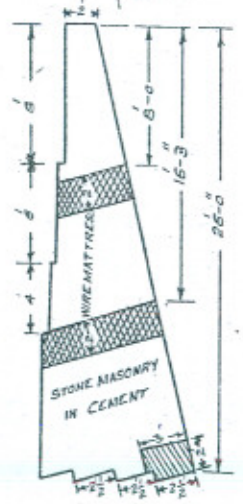


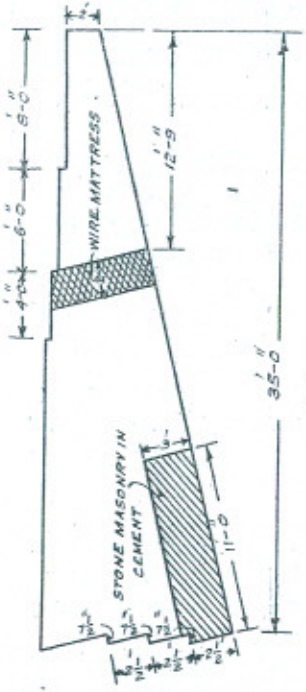
TYPICAL SECTION OF ROAD

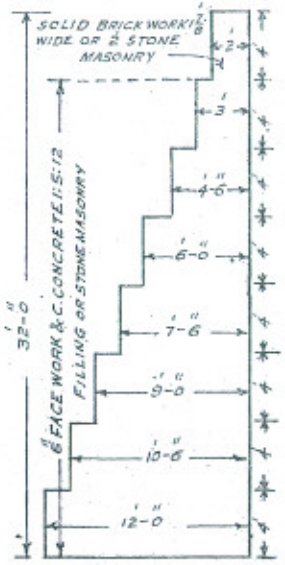








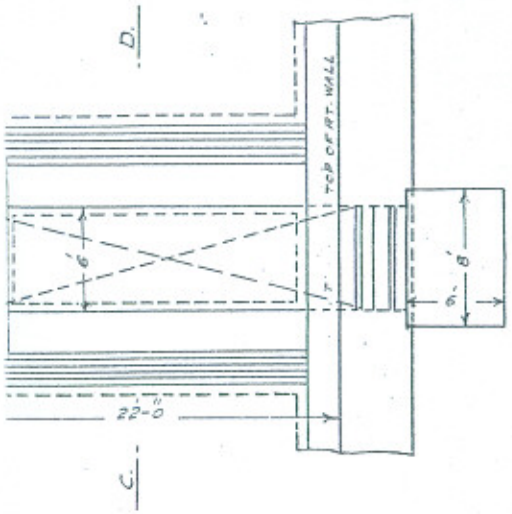




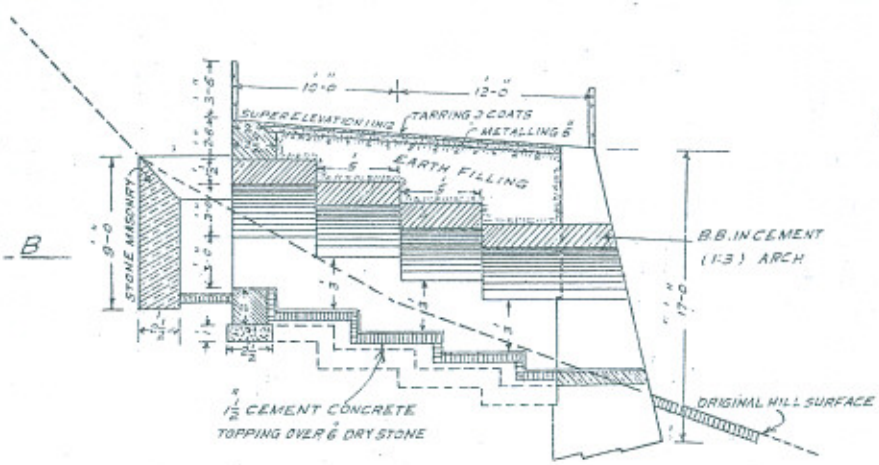
VERTICAL RETAINING WALL

PUNJAB ENGINEERING CONGRESS
1943

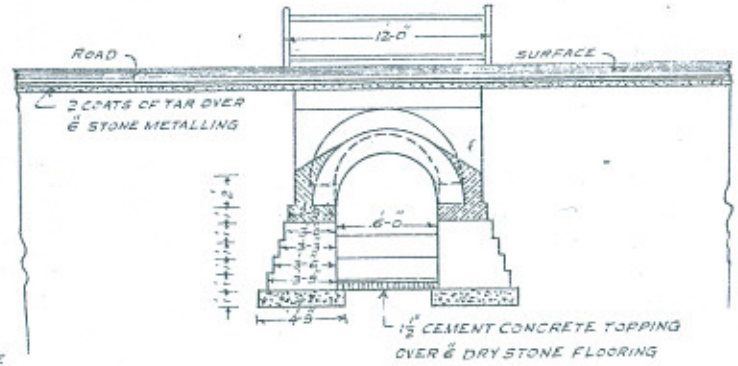
TYPICAL CULVERT



PLAN

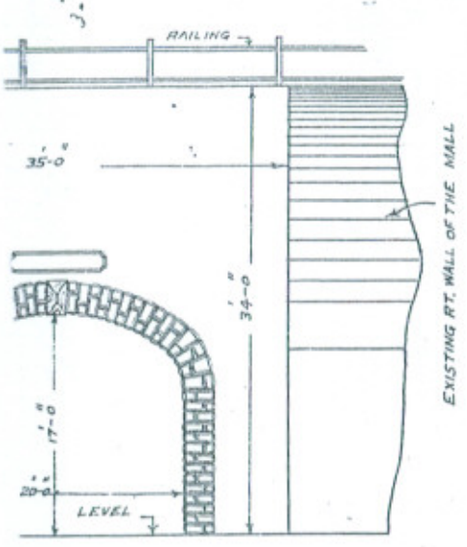


SECTION ON A-B

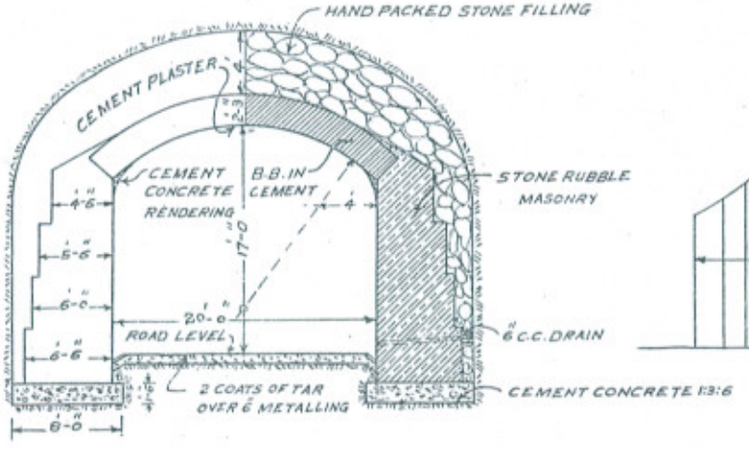


SECTION ON C D

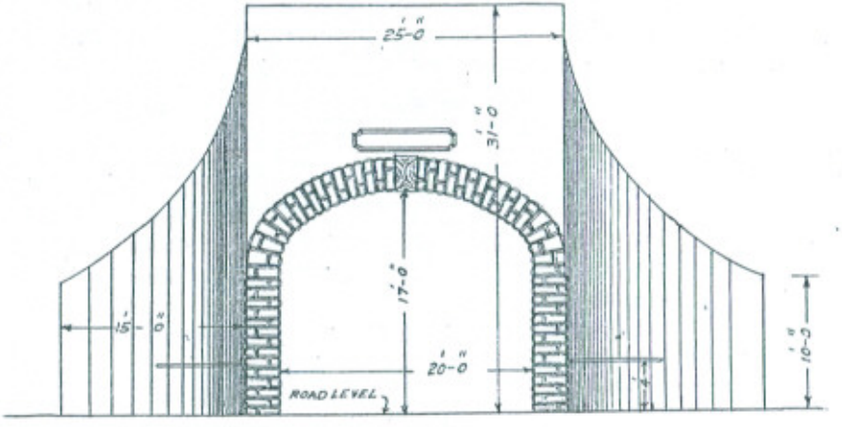
PUNJAB ENGINEERING CONGRESS
1943



I ELEVATION

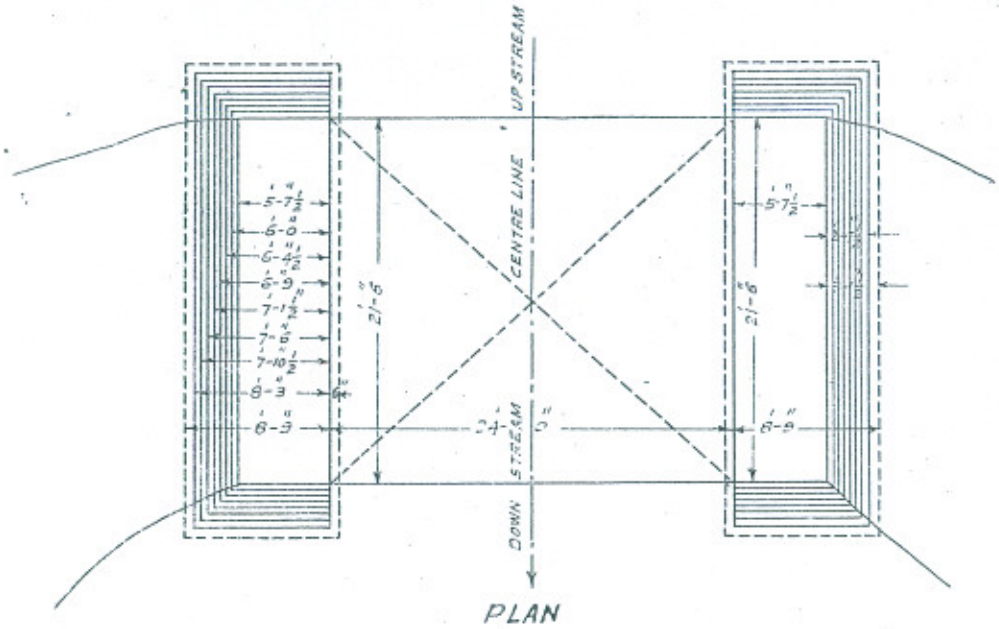


CROSS SECTION OF TUNNEL

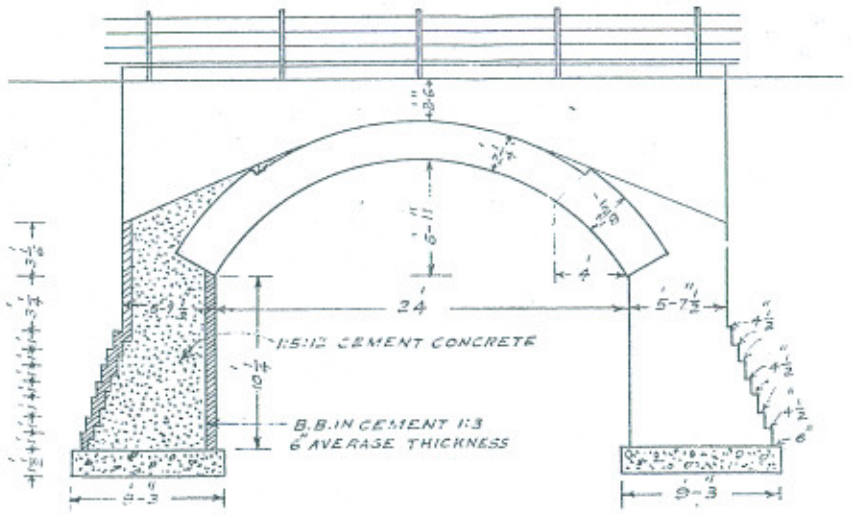


SOUTH ELEVATION

COMBERMERE BRIDGE



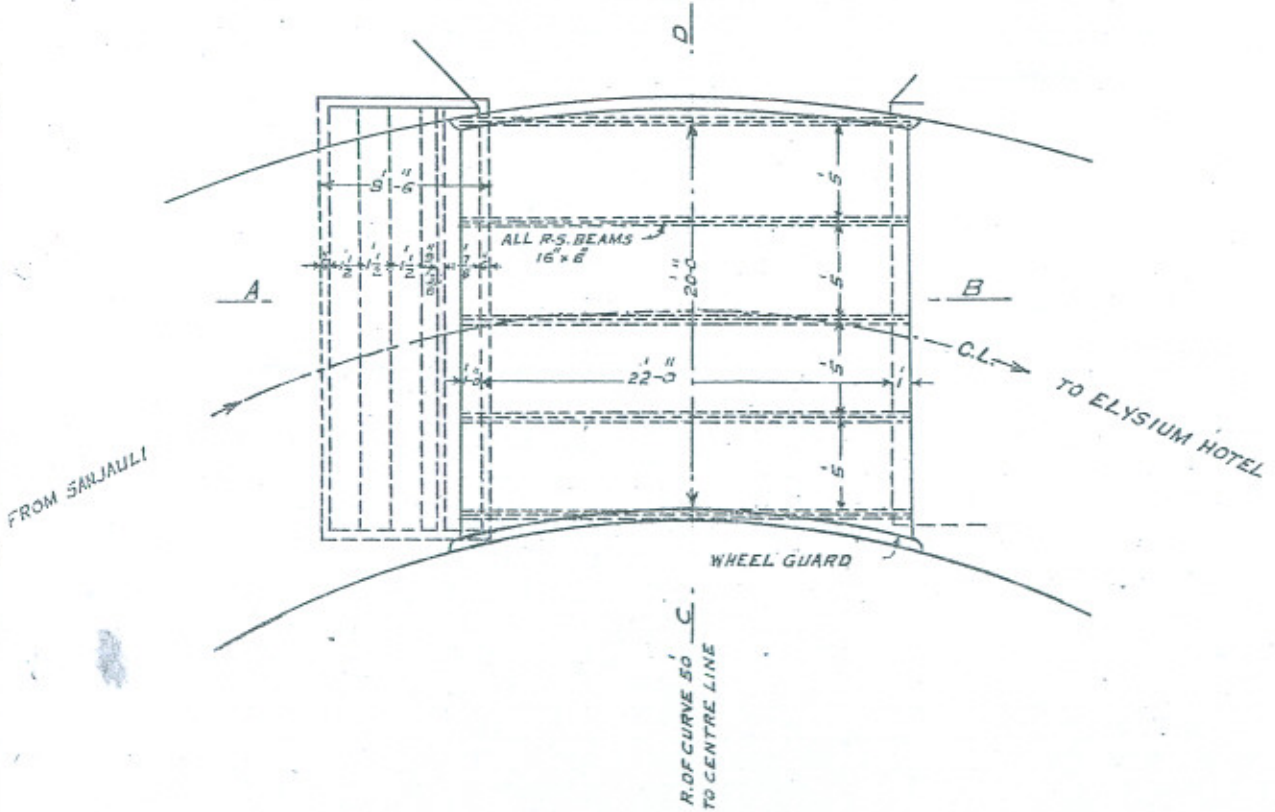
PLAN



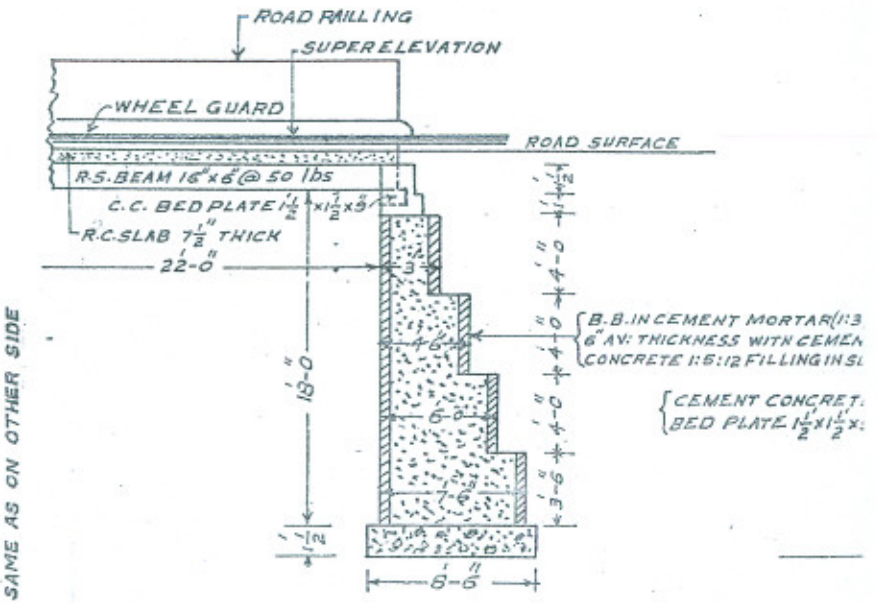
LONGITUDINAL SECTION

BELVEDERE BRIDGE

PLAN



SECTION ON A.B.



SAME AS ON OTHER SIDE