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Recent Road Construction and Proposed Future Development in the Punjab

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PART I.--RECENT ROAD CONSTRUCTION

Soon after the war broke out in 1939 it was realised that there were some gaps in the Arterial Road System of the Punjab which needed filling up to meet the requirements of military transport. Most of the missing links were in the North-western part of the province between the Indus and the Jhelum and though many unmetalled roads had been constructed in this part of the country long ago as far back as in the middle of the nineteenth century, only a few had been bridged and metalled due to financial reasons, and also because demands of traffic had not been heavy. Early in 1941 development of these roads was considered urgent, and the Government of India offered to pay in full for the construction of some of them and give substantial financial assistance in the case of others. The proposed work was to cost about seventy lakhs of rupees and was to be completed as quickly as possible.

The roads proposed to be constructed were the following :—

(1) From Bhai Pheru on Lahore-Multan Road Arterial Road No. 4 to mile 41 of Lahore-Lyallpur Road Arterial No. 3 over the Balloki Weir.

(2) From Kathwai to Chakwal.

(3) From Chakwal to Sohawa.

(4) From Chakwal to Pindigheb *via* Tallagang.

(5) The remaining 15 miles of Rawalpindi-Khushalgarh-Kohat Road.

(6) From Tallagang to Musakhel (15 miles from Mianwali).

(7) Tarbela-Hazro-Campbellpur-Basal-Pindi Sultani :—

providing portions not already metalled and tarred.

(8) Mianwali-Kalabagh-Isakhel-Kurrum.

(9) Jhang-Bhakkar-Darya Khan Road.

(10) Widening to 20 feet the metalled and tarred surface of the Grand Trunk Road from Lahore to Attock Bridge.

Besides the above the following were already under construction out of the Punjab share of the Central Road Fund :—

(11) Sirsa-Dabwali portion of Delhi-Multan Road.

(12) Muzaffargarh-Alipur-Panjnad Road.

(13) Khushab-Mianwali Road.

(14) Tobatek Singh-Kamalia Road.

(15) Sargodha-Mari-Lak-Jhawarian-Dhak-Katha Road.

Items (1) to (6) were considered to be of the first urgency which had to be commenced immediately in anticipation of preparation of detailed estimates, and the cost was to be met from Central Revenues.

While the construction of some of the above roads was commenced through the existing Provincial Divisions, a Special Road Construction Division with headquarters at Mianwali had to be formed for building the bulk of these roads (about 300 miles) lying in Mianwali, Attock, Shahpur and Jhelum Districts.

The following standard was laid down for development of these roads :—

" The roads are to be developed for all-weather mechanical transport with bridges of capacity not less than the Indian Roads Congress Standard loading, and without serious interruption at Irish bridges or causeways. " Serious interruption " is defined as stoppage of traffic for periods exceeding 12 hours or more than six days in the year or frequent stoppages of traffic for shorter periods.

The roads should be metalled and tarred, or of such equally or more durable specification, as may, in any particular locality, be found to be more economical or susceptible of more rapid construction without substantial increase of cost.

The width of metalled surfaces should be 10 feet where the soil is such that good berms can be maintained and elsewhere 12 feet. The width of bridges and culverts should be 20 feet clear for bridges and formation width for culverts up to 8 feet span.

Curves should be of not less than 600 feet radius where this is possible at reasonable expense. The minimum level length over humped culverts should be not less than 50 feet. Gradients on approaches to bridges and culverts should be not steeper than 1 in 30 Vertical curves should be provided and visibility over changes of gradient should be not less than 500 feet at 3 feet 6 inches above road level."

Alignment. The existing unmetalled roads followed circuitous routes, and were full of sharp and serpentine curves and steep gradients, and it was essential to realign them to bring them to the standard laid down by the Government of India. Detailed surveys were, therefore, undertaken to prepare land plans showing the existing land width so that the final alignment could be decided. The proposed improvements and

diversions were marked on the pencil plans as soon as they were ready and the same were examined at site to see that they fitted in correctly in the field. When finally fixed, they were passed on to the Drawing Branch for checking, tracing and taking out working ferros and preparing notifications for the purpose of land acquisition. In order to expedite the demarcation of the existing road land in accordance with the revenue record, a few patwari mistries were employed who kept demarcating the correct land width and ascertained village boundaries, etc. through the Civil Patwaris and kept ahead of the Surveyors.

The main realignments which have resulted in saving of long lengths of road, thus reducing initially cost of construction and eventually saving time in travelling and costs of motor transport are the following :— (See Plate I).

(*a*) *Khushab-Chakwal.* The original alignment for Khushab-Chakwal road was to go first along the existing metalled road from Khushab to Kathwai, and then along the unmetalled road *via* Naushera, Khabbaki, Pail, Munara, Nurpur and Kallar Kahar to Chakwal. As the zemindars near Naushera refused to part with their lands for a bye-pass at Naushera, a new alignment straight from Khushab to Pail was proposed *via* Katha Saghal, reducing the distance between Khushab and Pail from 57 miles to 29 miles, and thus saving a length of 28 miles. While there existed an unmetalled road from Khushab to Katha Saghral there was not even a foot track in the hills between Katha Saghral and Pail and altogether a new hill road had to be surveyed, marked and cut along the slopes of a steep hill range in a length of about ten miles. This now forms one of the best scientifically designed hill roads in the province.

(*b*) The Mianwali-Tallagang road after crossing the Dhak Range by a narrow, winding and steep route followed a circuitous track through Lawa village. A straight road has now been constructed from the foot of the Dhak Hills to the village Danda Shah Bilawal, resulting in a saving of a distance of about eight miles.

(*c*) Mianwali-Kalabagh-Hazro-Gurgashti and Campbellpur-Basal roads have been built on practically a new alignment altogether, as the existing tracks were not capable of improvement.

Land Acquisition. As practically all the existing alignments of the roads had to be modified and improved, and the existing inadequate road width widened, no actual work at site could be taken in hand without first acquiring the land. As the usual land acquisition proceedings conducted through the Deputy Commissioners take months to mature, it was considered necessary to requisition the services of an officer of the Provincial Civil Service experienced in revenue work to work as a Special Land Acquisition Collector for the various districts involved. He proved to be most useful in getting possession of land through formal "Razinamas" (letters of consent) before the actual notifications could be published, and awards accounted and paid for. The land plans were prepared and forwarded to him and land demarcated at site by the

P. W. D. staff and the Land Acquisition Officer then arranged to take in writing from the owners that they had no objection to the sale of the land to Government. After this, work on the road could proceed without any hindrance from the owners of land. It may be of interest here to note, that the cost of land so far acquired by him has been Rs.7,21,000, and the expenditure on his pay and travelling allowance, and that of his office and staff Rs.1,33,000, which is about 18 per cent of the former.

Tenders. Side by side with the survey work, no time was lost in collecting data for analysis of rates of collection of metal, bajri, etc., and preparing notices inviting tenders for works, dividing each road into small sections varying from 5 to 10 miles in length for each contract. Tenders were thus called for, before any detailed estimate for any road could be ready. Time required for completion of each work was fixed in the tender notices as seven to eight months and conditions about completion of proportionate work in proportionate time definitely laid down. As contractors generally have difficulty in obtaining land for borrow pits by direct negotiations with zamindars, it was decided after consultation with the Deputy Commissioners of the various districts, that compensation for temporary acquisition of land for borrow pits will be paid direct by the department at a rate of Rs.10 per acre in good land and Rs.5 per acre in inferior land, borrow pits not being deeper than one foot. The rate for compensation of earth works out to -/4/- and -/2/- per thousand cubic feet. Though the rates of commodities and labour were rising rapidly in 1941, it was possible to give out the various works at an average premium of only 17 per cent above the sanctioned schedule rates.

Formation. The formation width of the roads was kept 32 feet in plains and 24 feet in hilly areas. In the hilly and semi-hilly areas, the formation levels were controlled according to available gradients, but in the plains, the finished formation level was kept only about 9 inches above the surrounding ground except where there was a local depression and the bank had to be raised. The embankment for the road was not made in the centre of the acquired land width of 110 feet, but to one side, so as to leave space for collection of materials for soling and wearing coats, and service roads for contractors' vehicles and officers' cars *vide* Figure I, Plate II.

The low embankment has the following advantages :—

(1) The soling coat is laid nearly directly on a firm sub-grade. The ponding and compaction of a high bank required to make it fit to receive soling coat was very doubtful, as availability of water in such large quantities was considered to be very difficult and not possible without exhorbitant expense and unreasonable delay.

(2) Saving in time due to less quantity of earthwork having to be done ; and

(3) Comparative ease and less expenditure with which a low bank can be given flat side slopes, so as to minimise the danger to traffic even if

a motor vehicle goes off the road; also the psychological advantage which one gets when driving on a low formation.

To expedite work, the central 20 feet of formation embankment was laid first in some cases, leaving six feet on each side to be done later on, when completing the side berms.

Curves. Attempts were made to keep to the standards laid down, but while it was possible to do so in the plains, it was found necessary to use curves to a minimum radius of 50 feet on Katha Pail Road, and 30 feet on Campbellpur-Basal Road. Transition curves were laid in the form of a lemniscate according to Dawson's method. Super-elevation on curves was provided according to P. W. D. specifications restricting it to a maximum of 1 in 12.

Gradients. The ruling gradient on the roads in hilly portions was kept as 1 in 20, but maximum grade up to 1 in 13 in short lengths of 200 feet had to be allowed in places.

Vertical Curves. At junctions of differing grades, and on humps of culverts, vertical curves were laid so as to ensure a minimum visibility of 550 feet. For this purpose detailed instructions for providing parabolic curves *vide* Plate 3 were framed and issued to subordinates. These curves have provided quite comfortable riding surfaces at junctions of gradients.

Cuttings. On Musakhel-Tallagang Road, the nature of the ground was found deceitful, as what appeared to be ordinary clay or sand and shingle on the surface proved to be cemented clay or hard sand stone. Some of the cuttings in such ground had to be made as deep as 30 feet.

The magnitude of the work may be gauged from the fact that in the Mianwali Division alone the following quantities of work had to be carried out in a length of 280 miles for the formation :—

1. Ordinary earth work in filling ... $6\frac{2}{3}$ crores cft.
2. Pick, jumper, and blasting work in cutting ... $3\frac{1}{3}$ crores cft.

Road Structures. Practically every type of road construction work in every type of country has been undertaken and roads have been constructed through plains and hills, fertile lands and sandy deserts. Numerous culverts, bridges—low and submersible, and causeways have had to be built, and it is not possible in this short paper to describe them.

For the purpose of deciding the waterway to be allowed in major bridges, flood discharges were worked out from hydraulic data regarding slope, bed width, etc., and the same compared with discharge obtained from catchment area of the Nullahs. A table is attached in Appendix I giving the calculations made for waterway for some of the bridges to serve as a guidance.

Soling Coat. In the construction of these roads the following thickness and types of soling coat have been used according to considerations of availability of materials, nature of soil, cost and saving in time :—

(1) $4\frac{1}{2}$ inches brick on edge laid diagonally as well as laid at right angles to the road.

The diagonally laid soling coat *vide* Figure 3 (*a*) gives better results than the one laid at right angles as in Figure 3 (*b*) because the load is distributed more uniformly in the former case. In diagonal laying there is a waste due to cutting of full sized bricks for the end pieces, and it takes more time to execute. Square laying was, therefore, mostly adopted. Specially moulded bricks, as shown in Figure 4, can, however, be burnt when there is time to do so to eliminate waste.

(2) 3 inches flat brick soling coat where the soil was considered good and sub-grade firm.

(3) 6 inches thick broken stone.

(4) $4\frac{1}{2}$ inches thick broken stone.

When stone is used for soling coat, it is always advisible to get stone broken to the maximum possible gauge and hand packing it when laying instead of using pieces of smaller thickness.

The leaner specifications (2) and (4) were adopted primarily :—

(*a*) for speed in construction as lesser quantity of material was required to be collected and carried, and

(*b*) for economy in cost where the bricks or stone had to be carried long distances, but they were used only when soil was considered comparatively firm, and the embankment was low.

Consolidation of Soling Coat. Consolidation in sandy tracts proved difficult, as a heavy 10 ton roller sank badly if used directly on the soling from the beginning. A light 6 ton roller was, therefore, first used to do the primary consolidation first dry and then with water. When it became fairly firm, consolidation was completed with a heavy roller.

Wearing Coat and Surfacing. The usual specifications in the past had been to consolidate $4\frac{1}{2}$ inches thickness of 2 inches gauge stone metal as waterbound macadam, allow traffic for about a month, and then apply two coats of tar at intervals after brushing the road surface with steel and fibre brushes for removing the earth blinding from top. This method requires a considerable quantity of water in consolidation and takes a long time in execution. Most of the roads to be constructed passed through sandy deserts and waterless tracts, where water was scarce even for drinking purposes. Specifications for wearing coat and surfacing had, therefore, to be carefully selected from the point of speed in construction, availability and cost of stone metal and brick ballast as well as of water.

In the case of Sirsa-Dabwali Road in Hissar District which passed through a sandy waterless desert, but where speed was not a great consideration, it was decided to lay premixed tar macadam of $3\frac{3}{16}$ inches unconsolidated and $2\frac{1}{4}$ inches consolidated thickness, detailed specifications of which are given in Appendix 2 (item 1). The cost of this turned

out to be Rs.19 per hundred per square feet which was not any more than that of 3 inches consolidated thickness of surfaced water-bound macadam. In the absence of mechanical mixers, the premixing of metal and bajri has to be carried out in hand operated tar-drum mixers of a small capacity and the progress of work is too slow, and a large number of labourers is required. It was, therefore, considered unsuitable to use these specifications on the roads to be constructed for strategic purposes, where speed was the main consideration as well as water was scarce. Though some motor lorries had been purchased for transport of water, it was considered too costly and unpractical to carry the large quantities of water required for water-bound macadam.

It was, therefore, decided to use built-up-spray-grout specifications, the main feature of which is that tar is sprayed or grouted in with a mechanical sprayer over partially dry consolidated metal. This method is a great improvement over the orthodox consolidation and subsequent surfacing not only because it requires less quantity of water but also because it provides for much quicker and more homogenous type of construction and gives a fairly close proximation to a tar-grout at a very much reduced cost. Specifications for semi-grout with 4 inches metalling are given in Appendix 2 (item 2).

As these specifications did require a certain amount of water, and in some lengths of the road water could be had only at exhorbitant costs, it was decided to omit the use of water entirely and to alter and increase suitably the quantities of binder and grit in various spray coats *vide* item 3 of Appendix 2.

The average cost of wearing coat laid on the above specifications amounted to the following figures :—

(1)	Built up spray grout dry	4 inches thickness	Rs.14- 6-0 per 100 sft.
(2)	Built up spray grout dry	3 inches thickness	Rs.12-13-0 per 100 sft.
(3)	Semi grout	4 inches thickness	Rs.13- 8-0 per 100 sft.
(4)	Semi grout	3 inches thickness	Rs.11-12-0 per 100 sft.

Mr. Abdul Aziz, M. B. E., Executive Engineer has discussed the evolution and development of these specifications in detail in his Paper " Revised specifications for bituminous roads in the Punjab " read before the Indian Roads Congress 1943, and a perusal of that Paper may be made for detailed information regarding these methods.

Use of Brick Ballast for Wearing Coat. The metalling of Jhang-Bhakkar-Daryakhan Road presented problems of its own kind. The road lay beyond Trimmu for a length of about 70 miles through the Thal desert and the nearest railheads were Trimmu and Bhakkar—72 miles apart. The longest lead for carriage of stone was therefore 36 miles. Though there were wells along the road in the Mianwali district about two miles apart, they were very deep with very little yield. The soil along the road was too sandy, and not quite suitable for brick burning. About fifty miles length of the road in Mianwali district metalled with small

bricks removed from the walls of Hyderabad and Mankera forts in 1875-80 still existed though not in a good condition. The thirty five miles lying in the Jhang District were laid with a soling coat of bricks, and a wearing coat of stone metal brought from the Irrigation Branch quarry at Sikhanwala and spray-grouted with tar. In the Mianwali district, the existing brick metalled surface was treated as soling coat and repaired by straightening the outside edges, and filling the ruts first with a thin layer or clay and then with brick ballast. As the carriage of stone metal involved leads of more than 20 miles over sandy tracks or the brick metalled surface, which could not bear heavy traffic, it was decided to lay a three inches thick wearing coat of 1½ inch gauge brick-ballast except for a few miles near Bhakkar, where stone metal could be cheaply used. The manufacture of brick-ballast proved a difficult affair, as the local sandy soil did not prove quite suitable for brick burning and consumed too much coal dust, and the bricks turned out were far from satisfactory. Efforts were made to overburn them to the extent that quite hard brick-ballast be obtained without its becoming vitreous. The brick-ballast was consolidated on water-bound macadam without using any earth for blinding, and was immediately surfaced using 50 lbs of tar and 4 cft Mari Indus bajri ¼" to ¾" gauge per hundred square feet in the first coat and 17 lbs of tar and 2½ cft bajri ⅛" to ⅜" gauge in the second coat. This specification has proved quite satisfactory.

Brick ballast for wearing coat had also to be used on Muzaffargarh-Alipur-Panjnad Road, as it was too expensive to carry stone for a distance of over 23 miles. 4½" thickness of brick ballast was consolidated over a soling coat of brick-on-edge, and surfaced with tar using 50 lbs in the first coat and 25 lbs in the second coat. The surface, however, began to loosen under traffic, and a third coat of surfacing using about 30 lbs of tar per hundred square feet had to be given within a year to strengthen the road surface. Since then the road is behaving satisfactorily. The use of brick-ballast in wearing coat is however not free from dangers of failure, as its toughness and hardness is much less than that of stone and moreover it is difficult to avoid altogether "pila" stuff. Therefore where stone metal is too costly, safe specifications would be to graft 1½" thickness of stone metal over a layer of 3" thick ballast. The extra expense of stone would be balanced by the saving in the cost of surfacing.

Trackways. In the last few years experiments have been made in the Punjab on laying trackways on roads carrying light traffic, a detailed description of which has been given by Sir Kenneth Mitchell in his Paper on "Trackways" read before the Indian Roads Congress 1941. They, however, do not solve the problem of constructing cheap roads in rural areas, because the concrete trackways are as costly as an ordinary water-bound macadam road, and brick trackways do not last long and are too expensive to maintain. Moreover, great difficulty is experienced in overtaking slower traffic, or crossing the vehicles approaching from the opposite direction, as one of the vehicles must go off the tracks, and run the risk of getting stuck in the mud or deep sand. The strain due to

driving for continuous long lengths along narrow tracks is also a disadvantage. On a length of 12 miles on Muzaffargarh-Alipur Road, brick trackways consisting of 3 feet wide 4½ inches thick brick pavements, 5½ feet centre to centre have been laid, and attempts have been made to break the monotony of driving by providing 11 feet wide brick pavements one mile long after every three miles of brick trackways. This has, however, not proved successful, as the bricks got badly worn out and rutted with traffic within a year, and costly repairs are necessary to maintain them. Moreover in fair weather traffic prefers to go over the berms instead of on the brick trackways. Naked bricks cannot be hard enough to take the abrasion due to steel tyred bullock carts, and the sub-grade gets uneven due to heavy motor lorries. To envolve some other specifications for cheap road construction, experiments are now being made on Batala-Sri Gobindpur road in a long length of 18 miles to test the practical and economical aspects of building stabilised earth roads on the lines of the methods, discussed by Mr. S. R. Mehra in this Paper "Soil Stabilisation as applied to roads in India" read before the Punjab Engineering Congress 1942.

Tools and Plant. While the ordinary tools for carrying out the work were provided by contractors, the department had to arrange the plant required for consolidation and surfacing. As a large number of miles had to be metalled within a short time, the number of rollers and Bitumen boilers and sprayers with the P. W. D. in the Punjab was not sufficient to carry out the programme. Besides collecting all the plant of the Ambala and Lahore Circles which could be spared, the various District Boards and Municipal Committees in the Province were requested to loan whatever they could, and the balance was taken on hire from some Lahore firms. A number of boilers were newly purchased. At one time, there were one hundred steam road rollers, eighty boilers and twenty Harris Trolly Sprayers on work in the Rawalpindi Circle in 1942. A fortnightly report of the work done by each machine was introduced by the Superintending Engineer to watch that no plant was kept out of active service.

Cement Concrete Roads. While cement concrete road construction has proceeded much ahead in other provinces, the Punjab has not adopted this form of construction as it is too expensive in its initial cost, though cheap in maintenance. It could not have been possible to surface the total mileage of the metalled roads in this Province, had cement concrete been used for building even the main roads. However, where traffic is very heavy, say more than 2,000 tons a day, cement concrete is the only specification which can give satisfactory and economical results. An experiment was, therefore, made in this province in 1934, and seven feet width of the Lahore-Multan Road on the side of the incoming heavy bullock-cart traffic was made in cement concrete near Chauburji for a length of about two miles. Similarly the incoming lane of traffic on Amritsar-Lahore Road just beyond the Shalimar and near Goods Shed of the Lahore Railway Station was made of cement concrete in 1938, but the width

was increased from 7 feet to 10 feet. In both cases the outer end of the concrete slab was made a bit thicker, *viz.* 6″ than the other portion which was only 4″. Both these experiments have proved a great success. This experience has been utilised in constructing some bazar roads within the Amritsar City where the traffic was unusually heavy in cement concrete for the whole width. The total length of such roads reduced to a width of 12 feet is 3·27 miles. The thickness of slab laid is $4\frac{1}{2}$″ for the whole width without any thickening at edges. Expansion joints $\frac{3}{8}$″ wide filled with "Flexcell" and grouted with bitumen and sand have been provided at every forty feet with dummy joints at 20 feet. These dummy joints are only one inch deep in the top surface and help in localising cracks. Longitudinal joints in the centre of the road have been used where the width is more than 20 feet. Cost amounted to Rs. 60 per hundred square feet.

The mixture for cement concrete used in this construction consists of 90 lbs cement, 2 cubic feet Pathankot sand and 4 cubic feet of Pathankot stone graded from $1\frac{1}{2}$″ to $\frac{1}{4}$″. To achieve the latter 40 per cent of river gravel (bajri) $\frac{1}{4}$″ to $\frac{3}{4}$″ size was mixed with 60 per cent of $1\frac{1}{2}$″ gauge broken stone metal. The roads were laid in 1942 and are behaving admirably.

In Lahore the approaches to the Ravi bridge have been similarly treated for the full width of 30 feet, thickness of cement concrete being 5″ and expansion joints having been laid every 30 feet apart without any dummy joints but with centre longitudinal joints and they have stood up perfectly to the very heavy traffic at the place.

Chakki-Dalhousie Road. A difficult problem that had to be contended in recent years is the maintenance of Chakki-Dalhousie Road. The road was not initially built as a cart road, but has gradually developed from a bridle road in 1860 and is now required to carry heavy motor vehicles at a fast speed. When the portion from Dunera to Dalhousie was constructed about sixty years ago, it was anticipated, that the hillside was unstable, and unfit for constructing a road at a number of places and specially in miles 42 and 45 but as there was no other safer alignment, the road was constructed along the present route. Such places frequently used to give trouble by slipping during monsoons every year, but in the years 1942 and 1943, the rains were unusually heavy breaking all previous records, and slips were so numerous and immense, that the roadway got blocked in many places, and was carried away altogether at certain points. Traffic was dislocated for long periods causing unspeakable discomfort to travellers. After the road had been restored by removing the slips and filling up the gaps, it became essential to take effective steps to prevent such breakdowns in future.

The primary thing to do was to investigate the existing drainage of the hill side and to so improve it that all the rain water falling on it was carried along defined channels on the slopes of the hill and through culverts under the road to the khud below. For this purpose a detailed survey was made of all the important affected sites and proposals were

made to provide catchwater drains along the hill at various heights, and to connect them with pucca drains running down the hill into culverts under the road. Treatment of one of the sites is shown in Figure I of Plate IV.

A large number of retaining walls had to be re-built or newly constructed to hold the slipping roadway and numerous breast walls were necessary to be provided to support the slipping hillside. The tendency in the department has been to build such structures cheaply in dry stone, and though theorectically they are as strong as those built in cement or lime mortar the standard of their construction is inferior and unreliable and most of them bulge out and fall down within a few years. This is partly due to the low rate of Rs.10 per hundred cubic feet allowed for this type of work, and it would be of interest to know that even in the last century the same rate used to be paid for dry stone walling. It is idle to expect that strong and stable retaining walls in coursed rubble masonry can be built at Rs.10 per hundred cubic feet, and it was, therefore, proposed to build the bottom of all high retaining walls below 12 feet in cement mortar (1 cement : 6 sand), and wherever good building stone was not available to substitute it by lean cement concrete 1 : 9 : 18, 1 : 6 : 18, or 1 : 6 : 12 according to situation and necessity, the front facing remaining in stone. The lean cement concrete was used on account of cheapness, sometimes even in places where stone could be available. The design of the retaining walls is shown in Fig. 2, Plate IV. For breast walls the design shown in Fig. No. 3 Plate IV was adopted. The back of the wall being at a slope of 1 in 3, very little cutting is required to be done in the hillside thereby avoiding any local disturbance. A pucca V shaped drain is provided at the foot of the breast wall to prevent water flowing across the road. Pucca drains of this type were also constructed along the hillside elsewhere too where found necessary.

Some of the steep nullahs have been stabilised by building a series of low retaining walls about eight to twelve feet high across the width. The bed of the nullah between these walls gradually gets filled up and erosion is reduced. Treatment of one of the nullahs is shown in Figure 4 on Plate IV.

Another cause of the trouble on this road is the absence of vegetation on the hills caused by uncontrolled grazing. The question of introducing such a control has been taken up with the Chamba State authorities, as most of the road passes through the State Territory and it is hoped that some satisfactory solution towards protection of the hillside would be arrived at.

Though it is too early to state whether these measures have proved effective, the damages to the road in the year 1944 in spite of quite a heavy monsoon were slight and all the newly built structures stood up splendidly. About two lakhs of rupees have already been spent on these works, and about the same amount is still required to treat other dangerous sites. The building of these structures in cement mortar

might be considered extravagent by some persons, but it may be stated that the U. P. Building and Roads Branch have used these specifications and designs on their hill roads for a long time, and have considerably reduced the damages in the monsoons. The North Western Railway too have abandoned the use of dry stone walling and in the author's opinion the pucca structures would prove cheaper in the long run.

Costs. A statement is enclosed as Appendix III giving the cost of each road separately under the following sub-heads:—

1. Formation.
2. Soling coat.
3. Wearing coat.
4. Road structures other than major bridges.
5. Major bridges.
6. Acquisition of land.
7. Miscellaneous.

Roads in plains have been separated from those in partly hilly areas; a combined total has, however, been also made for the sake of comparison. This table would be of a great use in estimating rough costs of roads proposed under Post War Planning Schemes. On an average the cost of roads in the plans has been Rs.14,000 per mile and that in semi-hilly areas Rs.28,000, the difference being mainly due to additional cost of cutting in formation, and a large number of culverts, bridges and retaining walls. The total length of roads constructed was 547 miles at a cost of about a crore of rupees at an average cost of about Rs.19,000 per mile. Most of the work was commenced in June 1941 and completed by March, 1943, and the rate of progress of construction works out to about one mile per day.

PART II.—POST WAR DEVELOPMENT OF ROADS IN THE PUNJAB

Existing Road System. The total length of our existing non-urban metalled roads in the Punjab is 6067 miles. The bulk of these, *i.e.*, 4574 miles are maintained by the P. W. D. Out of the remaining, 891 are maintained by the local Boards and 602 by the States. In addition to these, there are 21704 miles of unmetalled classified roads, also maintained by Government Departments. This system of roads has earned for the province the reputation for possessing the best roads in India.

While, this system of roads with an incidence of .05 mile of metalled road per square mile of the area, served the needs of this province quite successfully in the past, yet as early as 1940, during the first year of the war, it was realised that it was far from sufficient, and was already proving inadequate for defence as well as the social and economic needs of the country.

Problem of Future Road Communications. It was, therefore, decided that the problem of the future road communications of the province should be carefully studied and examined, and a comprehensive scheme of road development, which would take into account the needs of our economy in another couple of decades in the post-war period, should be worked out.

In this country, the basis of our economy so far has been mostly agrarian : 86 per cent of our population live on the land. While this may have worked successfully in the past with a low standard of living, lesser density of population and comparative isolation, with a general rise in the standard of living of the rest of the world and an increase in the density of population in this country, we have passed the optimum for a total agricultural base for our economy. India must, therefore, industrialise and take people off the land giving them employment in industries and other social services. While industrialisation is essential for solving the economic problem of the country, it is well to remember that for a long time to come agriculture will still occupy an important position in our economy.

In working out any social services for this country, therefore, more so of roads, it is necessary that we should take into account our needs with regard both to our future industries and agriculture. This has been done, as far as possible, in working out the future road system for this province. A survey of the future industrial and agricultural needs of the country, during the next couple of decades, has been carried out and the roads planned to cater for their needs.

Proposed Road System for the Punjab. The future road system for this province, as envisaged in the Post-war Development Scheme for the Punjab, falls under the following two heads depending upon the service each is to render to the community.

(*a*) An Arterial Road System.

(*b*) A Rural Road System.

They are by no means two entirely independent systems, but are supplementary to each other. Yet both of them have distinct functions to perform and are in the main responsible for meeting a particular need of the community.

The Arterial Road System, for instance, is meant to cater for the needs of the urban population. It will look after the future needs of our trade and industry in addition to our social and administrative needs, including, defence.

The Rural Road System, on the other hand, in conjunction with the Arterial Road System, will look after the agricultural needs of the country, and help the villagers to collect their agricultural produce from the land and take it to the nearest market town for disposal, and enable them to bring back with them manufactured goods and agricultural necessities for their every day life.

It is proposed, that the roads in the future road system for the province, should be divided into the following categories according to their functions. These proposals are in accordance with the recommendations of the " Nagpur " conference and accepted by the Government of India.

1. **National Highways.** They would be the primary routes of communications, in India, forming the frame-work on which the system of road communications of the country will be based. They would be inter-provincial roads running throughout the length and breadth of the country, connecting capitals of provinces and larger states, ports, large towns and foreign highways.

2. **Provincial Highways.** These would be the other main arteries of trade and commerce traversing the length and breadth of the province. They, with the National Highways, will form the main system of road communications within the province, connecting the District Headquarters and other important towns, and providing the necessary connection with the highway system of the adjoining territories.

3. **District Major Roads.** They would be roads of district importance, connecting towns and mandis with each other, and providing links between the National and Provincial Highways.

4. **District Minor Roads.** These would be roads of rural importance taking traffic into the heart of the country and connecting rural areas to their market towns, and connecting these with each other and the highways and railways.

5. **Village Roads.** These would be roads connecting individual villages or a group of villages, to each other, and giving access to the nearest rural or arterial road.

Roads in the first three categories, will form the Arterial Road System for the province, and will look after its urban needs.

Arterial Road System. There are 374 towns in the Punjab with a population of 5,000 and over, including the States, in the following population groups, with a total population of 5,827,612 :—

Towns between	5000	to	10000	255	...	1,667,541
,, ,,	10000	to	20000	64	...	876,335
,, ,,	20000	to	50000	42	...	1,279,679
,, ,,	50000	to	100000	6	...	385,095
,, ,,	100000	and	over	7	...	1,618,962
				374		5,827,612

All the District Headquarters, the capitals of larger states, trade and industrial centres as well as the majority of mandi towns are included amongst these. The first and the foremost requisite of an efficient arterial road system should be to provide an easy and efficient means of communication between all these towns. This is necessary from Administrative, Trade and Industrial points of views.

We have at present 6067 miles of metalled roads in the Punjab giving us an incidence of ·05 mile per sq. mile of the area only. With this incidence we still have large areas of land unopened and at least 158 of our towns are without any means of access completely isolated from the main life arteries of trade and commerce in the country. How unsatisfactory this state of affairs is, judged from modern standards, would be realized, when we compare this incidence of roads with that obtained in some of the leading countries of the world. The following table provides the comparison :—

France	...	1·84
England	...	2·01
America	...	0·99
Germany	...	0·72
Italy	...	1·05
Japan	...	4·02
India	...	0·33 and ·073 excluding unmetalled roads.

It would be impossible to expect an undeveloped country like India to have an incidence of roads anywhere near what for instance obtains in England or America. Our economic level, nor the state of development of this country, could justify that at this stage, or in another quarter of a century to come. The most, we could hope for, was to raise this incidence of ·05 miles per sq. mile to some thing like ·1 mile per sq. mile of the area of the land as far as the arterial roads are concerned and to ·25 miles per sq. mile with regard to the total road system including the arterial and the rural roads.

Even that would mean the construction of another 6800 miles of new roads in the arterial system giving the following distribution amongst the three different categories.

		Existing.	Proposed.	Total.
National Highways	...	1680	496	2176
Provincial Highways	...	1809	2700	4509
District Major Roads	...	1411	3604	5015
				11700

It is anticipated, that roads included in the arterial road system, will be such, which would carry traffic in both directions. They would, therefore, be of suitable specifications for two lane traffic. They would in most cases be metalled and surfaced roads, and in some cases even of better specifications such as concrete both asphaltic and cement, depending upon the intensity of traffic carried by them.

Vehicular traffic upon the roads in the Punjab, just before the war, varied from about 500 tons to 5000 tons per day. The normal specification of the majority of our roads consists of brick or stone soling, varying

from about 3" to 6" thickness, and 4½" of stone metal on top, except where the thickness of the road crust has become greater with constant renewal in the era prior to tar painting, with surface treatment. While this specification functioned fairly satisfactorily with moderate traffic up to about a thousand tons, cutting down our maintenance costs to almost half and bringing it from about Rs.2,000 per mile in the pre-tar era to about Rs.1,000 per annum per mile now. With an increase in the traffic, the maintenance of these roads carrying traffic above a 1000 tons per day, is tending to rise again. Question of maintenance cost is indeed a very important one, particularly, when the length of our road system increases as is being proposed in the Post-War Scheme. At the present rate of maintenance, the total cost of maintaining roads both in the arterial and the rural road systems, consisting of 11700 miles of Arterial and 16730 miles of Rural roads, will be 1·6 crores per year. This every one will agree is a fairly heavy bill.

Cement concrete has already been suggested and used in many places, particularly, in the U. P., by their Public Works Department, with a view to bringing down costs. With judicious use of cement concrete, they were able to reduce the average cost of maintenance of the roads in their province to Rs.754 per mile in 1939-40. This has been further reduced to Rs.635 per mile in 1942-43 in terms of normal times costs. It is, therefore, being proposed that at least about 222 miles of our existing roads, where the traffic is more than 2000 tons per day, should be treated with this specification.

In the post-war period, with increase in the tempo of life and rise in the economic level of the country as a whole, we may expect to see abnormal increase in traffic upon our roads. Some of our roads are already too narrow for the traffic being carried by them now. They would, no doubt, be much too narrow for the traffic to be anticipated upon them in the post war era. It is, therefore, being suggested that all such roads that carry traffic above a thousand tons per day should be widened to two lane traffic.

Some of the railway level crossings on our existing roads will have to be improved and provided with over or under bridges. At least 25 towns in the Punjab such as Lahore-Amritsar, etc., where congestion on the through arteries passing through these towns causes the traffic to lose considerable time, will have to be provided with bye-passes.

It would, perhaps, be too ambitious to aim, at providing such roads as the "Autostrasse" in Germany and the "Parkways" in America, in this country, exclusively for motor traffic, with all other traffic excluded from them, with no intersection point and controlled points of ingress and egress. Motor traffic to be anticipated in this country in the next quarter of a century would not justify them. Nevertheless, it would be as well to look ahead, and in designing our arterial roads for the future, the main principles involved in their design should be kept in view. This is being done, in designing the future National and Provincial arteries

of the country and sufficient land widths are being provided for making it possible for the eventual switch over to be effected, when the time comes.

Land widths proposed to be provided for different category roads in the arterial and rural road system along with their proposed sections are shown in Plates Nos. 5 and 6.

Rural Road System. We are essentially an agricultural country and out of a total population of 34,308,861 souls including the States 29,269,090 of our men and women or approximately 86 per cent of the total population live in the villages, in this province. We have an agricultural area of 58971 sq. miles. We produce 6 2 million tons of Agricultural produce out of which 3·03 million tons, after accounting for the needs of the rural population, has to be transported every year from the villages to their nearest mandi towns, for being finally disposed.

How vital roads are to the needs of the rural population, will be appreciated, when it is remembered that the average farmer depends for all his necessities of every day life upon his being able to transport his surplus agricultural produce to the nearest market town for being able to exchange it for manufactured goods and other commodities to meet his agricultural needs and every day necessities of life.

Problem of Rural Transport. We have 35148 villages in the Punjab in the following population groups, excluding the States :—

Under 500	...	19161
500-1000	...	9069
1000-2000	...	5167
2000-5000	...	1751

There are 375 mandi towns in the province, including the scheduled and the non-scheduled mandis. Almost all these towns in the province will be situated on the arterial road system. This gives roughly a mandi per 94 villages in the province and 132 sq. miles of agricultural land per each mandi town. The agricultural produce from this area commanded by each mandi town will have to be transported to the mandi before its final dispersal is effected by the arterial road system to the consuming centres.

The problem of the rural transport therefore, resolves itself into the transport of the agricultural produce from the villages situated within the arterial grid which roughly works out to 16 to 20 miles in the arterial road system to the nearest mandi town situated on the grid and reduce its sufficiently to enable each village within the grid to be not more than a couple of miles at the outset from the nearest all weather road.

This is proposed to be effected by reducing the grid, first to something like 8 to 10 miles by providing what will be known as the District Minor Roads, and then connecting all the villages within the reduced grid with a population above 1000 souls with each other and to the nearest

district minor or arterial road by a village road. These roads will not be through roads. They will only serve the local rural interests of the area. When this is done it is hoped that no village within that area will be more than a couple of miles from the nearest all weather road.

A Formula for Rural Roads. The incidence of these roads in any particular area is governed by a number of factors and is a function of the density of rural population, the incidence of villages in the particular area, and the size of the average village. It stands to reason, for instance, that in an area in which there is intensive cultivation, and the density of rural population and the incidence of villages is consequently greater, will need more rural roads to serve its rural needs, than an area in which half of the land is lying waste, and the density of rural population and the incidence of villages, as a result of that, is comparatively much less.

A formula for rural roads required in an area, taking into account all these factors, has been worked out. It gives fairly consistent results, as far as conditions with regard to agriculture as obtained in this province, are concerned. The length of the roads worked out by this formula fits in with the actual length of the rural roads designed by us from other considerations, keeping in view the target set to overselves for providing this Public Service to the community.

The formula is as follows:—

$$L = \frac{A}{4} + \frac{R}{5500}$$

L. Length of road.
A. Agricultural area.
R. Rural population.

These rural roads belonging to categories 4 and 5 included in the Rural Road System will be such as would carry seasonal traffic in one direction, generally, both with regard to the time of the year and the time of the day, depending upon whether the agricultural produce from the areas is being carried to the market town, or the villagers are on their way out for the day's work, or returning home in the evening. The traffic on these roads, therefore, would be mostly in one direction. It is being suggested that these roads should be of such widths and specifications as would accommodate one lane of traffic with occasional crossing in the opposite direction. They would be of lower specifications such as trackways or stabilized soil roads depending upon the intensity of traffic and the importance of the road.

Target kept in view. In designing the future road system for the province the target kept in view has been that all towns with a population of more than 5000 souls and over will be connected by a metalled road and that there will be no village in the province which will be more than a mile to couple of miles from an all weather road. In order to achieve this object it will be necessary to construct 6800 miles of arterial and 16730 miles of new rural roads.

It would be a programme of construction capable of being executed within 15 years of the cessation of hostilities. It will roughly cost the

community Rs.45 crores to build and it is hoped that it will give to the province a system of roads which will be capable of meeting all future needs of our trade, industry, agriculture and social and economic development to be anticipated in the immediate post-war period.

Road Finance. It is obvious that such a comprehensive scheme of road development like all other schemes of Public utility such as large irrigation projects, town improvement schemes, national housing etc., cannot be financed from revenues. The history of roads will show that so far, in no country in the world a comprehensive scheme of road development like this has ever been financed except by loans. In view of the fact that roads add to the national wealth of the country and form a permanent asset, the principle that all future road development should be financed from loans on the assets of the country needs to be recognised.

The way in which the road financing has been viewed in the past has been prejudicial to its case. The roads in India even with the poor and undeveloped conditions of transport in this country have been yielding anything up to 12·0 crores of rupees, out of which no more than 6 crores has ever gone back on the roads in the form of their maintenance and improvements. The rest of the money has been contributed to the general revenues. If the financial aspect of the road has to be viewed in its correct perspective it is only fair to claim for it the total return from the road in working out its financial aspect. It will be seen that when the total return from the road irrespective of the source to which it is contributed is taken into account, the roads can be shown to be as paying a proposition as any other commercial scheme.

Direct Return from the Road. The direct return from the roads for instance as far as Punjab is concerned in 1940-41 was 24 lakhs. Out of this 15·06 lakhs were for receipts under the Motor Vehicles Taxation Act of 1935 and 8·9 lakhs under the Sales Tax on petrol and lubricants. If we add to this amount the revenue of the Central Government from these roads under receipts on account of import duty on vehicles and parts, and excise and import duty on petrol consumed in the Punjab which comes to 89·53 lakhs, the total return from the roads in this province amounts to Rs.113·5 lakhs.

This return is from an investment of approximately 12·9 crores which is the estimated cost of 5465 miles of our roads in the province at an average cost of Rs.20,000 per mile and the existing bridges which are evaluated at Rs.2 crores. After deducting the maintenance cost of these roads which in that year was 41 lakhs, the total net return from the road was 72·5 lakhs. This works out to a rate of interest of 5·6 per cent on the total capital invested after paying for their maintenance. This return under the existing conditions of traffic, which are far from what they should be, cannot be considered as meagre.

The question, as to how schemes of future road development can be made into a practical reality, is the one which is being asked in almost all quarters. It is often said that this country cannot afford to finance

these schemes of future road development, as they are financially not a paying proposition.

Roads financially a paying Proposition. In the Punjab the number of motor vehicles in 1936 on the road was 10,435. This increased to 13,334 by 1939 which roughly gives a rate of increase of about a thousand vehicles per year with very little increase in the mileage of the roads. If we take into account the increase in the mileage of arterial road only, assuming that the sphere of the bullock cart, as the basic means of rural transport up to the mandi towns, will not be violated by the motor vehicles, and work on the same rate of increase of motor vehicles as in the pre-war period which is quite a modest assumption, for the end of the war is bound to bring an added impetus to the transport trade, the number of motor vehicles on the roads in 1965 will be about 60,000.

Petrol Tax, Import Duty on Vehicles and Spares. Our consumption of petrol in the Punjab in the year 1939-40 was of the order of 11·3 million gallons. This gives an average consumption of 847·6 gallons per vehicle per annum. On this basis we would get a consumption of 31 million gallons per year of petrol in this province. If we assume the same rate of taxation on petrol as in 1939-40, the revenue derived from this source alone will be approximately 246 lakhs per year.

Motor Vehicles Taxation Act of 1935. The present rate of taxation in the Punjab under the Motor Vehicles Taxation Act of 1935 is the lightest in India. As compared to Madras for instance it is only one-third. Our total return from this source and the Sales Tax on petrol and lubricants is approximately 24 lakhs a year. If this taxation was brought in line with the other provinces and taking into account the increased, number of motor vehicles and the petrol anticipated to be consumed, we could expect to get almost 132 lakhs from this source, if the rate of taxation was increased to double its present value.

Road Cess. So far it is the urban population only which has been paying for the maintenance and construction of roads. This has been, however, fair enough as the existing motor transport facilities have not catered for the rural population. The conditions with regard to rural communications in this country have so far been poor and have not received the attention they deserve. In the post-war scheme, however, it is proposed to provide them with a complete system of rural roads which should be capable of meeting all the needs of the rural areas. If this service is to be provided, it is only fair that they should be expected to pay towards the cost of maintenance and construction of these roads.

The only feasible method of taxation of the rural population is in the form of a Road Cess on the basis of the land revenue. The total land revenue receipts of the Punjab are about 9 to 10 crores. If we assume a modest figure of 5 per cent as the road cess, we would draw from this source anything up to 50 lakhs. This is by no means an excessive figure when we consider the saving on the transport costs alone to the

community of the agricultural produce which has to be transported to the markets each year. This saving at ·6 pies per maund per mile which is the difference in carriage costs over pacca and katcha roads of agricultural produce will amount to something like 50-60 lakhs per year when the total agricultural produce to be transported is something like 840 lakh maunds per year based on existing agricultural yields. It is, however, hoped that in the post-war period these are increased by at least another 50 per cent. To this, we must add the increase in land revenue due to land in Thal being brought under irrigation with the completion of the Thal irrigation project which is likely to be of the order of another 80 lakhs per year. The road communications of this area with regard to arterial and rural requirements are already included in this scheme.

Total Return from the Roads. The total return from all these sources will amount to Rs.454 lakhs per year. After deducting the maintenance costs which will amount to approximately 1·6 crores per year and the loan charges at 3 per cent and 6 per cent for perpetuity and redeemable loans, the investment will yield $2\frac{1}{2}$ per cent to 3 per cent on capital of Rs.45 crores invested with the very modest assumptions made above.

The above analysis of the financial aspect of the roads deals with the question from a very wide angle without any limitations of central or provincial revenues. But if roads have to be considered as a national necessity for defence as well as economic development they have to be looked upon from that angle and the future road policy with regard to their administration and finance must rise above such parochial considerations.

APPENDIX 2.

(*i*) Specifications for premixed Tar Carpet.

(1) $1\frac{1}{2}$ in. gauge stone metal with 5 per cent free supply of screenings should be collected equivalent to $3\frac{3}{16}$" unconsolidated thickness and coarse *bajri* 3/8" to 3/4" gauge shall be collected at the rate of 3 cft. per hundred square feet.

(2) The stone metal shall be premixed with No. 2 tar at the rate of $2\frac{1}{4}$ lbs per cft. and the coarse *bajri* at the rate of 4 lbs per cubic foot.

(3) Due to sandy soil and the prevalence of blowing sand every care shall be taken to prevent the premix from becoming sanded or dirty. The premixing shall be done on the brick soling surface and kept covered with gunny bags.

(4) After premixing the materials shall be left to mature for a period varying from 4 to 5 days according to the temperature—longer period being allowed in cold weather.

(5) The premixed stone shall be laid to template and lightly rolled. The premixed stone and the whole thoroughly consolidated. Seal coat shall then be applied before traffic be allowed over the work. The quantity shall be 14 lbs tar and 2 cft. fine *bajri* 1/8" to 3/8" gauge per hundred square feet.

(*ii*) Specification for " Semi Grout " with 4 inch Metalling.

(1) A 3/4 in. to 1 in. cushion of good clay shall be spread uniformly on the consolidated soling coat and thoroughly saturated and lightly raked.

(2) 2 in. thick stone metal of $1\frac{1}{2}$ in. gauge shall be closely and uniformly spread and hand packed to proper camber over the earth cushion.

(3) 5 to 8 per cent quarry screenings shall then be uniformly spread over the surface and washed down into the interstices with water.

(4) The remaining 2 in. thick of clean dry metal $1\frac{1}{2}$ in. to 2 in. gauge shall then be uniformly spread and particular care taken to closely hand pack it, so that the carpet is quite even and dressed to correct camber.

(5) The surface shall then be first rolled dry starting from the sides towards the centre and then consolidated with water as for ordinary " water bound macadam. " The rolling shall be stopped when it is found that the surface is sufficiently consolidated, that roller wheels leave little impression on it and that the binding materials have worked up to about 1/2" to 3/4" of the surface. Any depression that may appear shall be made up with the metal, a 5 per cent reserve of which shall be kept for the purpose from operations 2 and 4 above.

(6) The surface shall then be allowed to dry out for a day or so and traffic kept off.

(7) Road Tar shall then be uniformly sprayed by means of a sprayer over the dry surface at the rate of 25 lbs per 100 sq. ft. (for 6 tons per mile 10 ft. wide).

(8) Coarse grit 3/4 in. gauge (1/4 in. to 3/4 in. grade consisting of 70 per cent 3/8 in. and 30 per cent 1/4 in. to 3/8 in.) shall then be spread uniformly spinning baskets at the rate of $3\frac{1}{4}$ cu. ft. per 100 sq. ft. (or 1725 cu. ft. per mile 10 ft. wide).

(9) The surface shall then be rolled dry and the consolidation continued and completed till the *bajri* is firmly wedged in position and there is no movement of the surface under the roller.

(10) Next day the surface shall be lightly rolled and any unevenness that may appear shall be removed with premixed grit.

(11) When the surface has dried out, it shall be dusted and cleaned, tar sprayed at the rate of 18 lbs per 100 sq. ft. ($4\frac{1}{2}$ tons per mile 10 ft. wide) and medium gauge (1/4 in. to 3/8 in.) grit uniformly spread at $2\frac{1}{4}$ cu. ft. per 100 sq. ft. (1200 cu. ft. per mile 10 ft. wide) and rolled in.

(12) The surface shall then be sealed with the road Tar or Bitumen at 14 lbs per 100 sq. ft. ($3\frac{1}{4}$ tons per mile 10 ft. wide) and fine grit (1/8 in. to 1/4 in. gauge spread at $1\frac{1}{2}$ cu. ft. per 100 sq. ft. (800 cu. ft. per mile 10 ft. wide) and whole surface rolled and finished.

(13) The road shall be kept closed to traffic for about 2 to 3 days at least.

NOTE.—In operation 9, sprinkling of a little water over the surface after having lightly rolled in the *bajri* will be found beneficial.

(*iii*) **Built up Spray Grout (Dry) Specification with 4 in. Metalling.**

(1) A 3/4 in. to 1 in. cushion of good clay earth shall be spread uniformly on the consolidated soling coat.

(2) 2 in. thick stone metal of $1\frac{1}{2}$ in. to 2 in. gauge shall be closely and uniformly spread and hand packed to proper camber over the earth cushion. (This metal shall be from under the stacks, the top cleaner metal being kept for spreading on top).

(3) 5 to 8 per cent free quarry screenings shall then be uniformly spread over the surface.

(4) The remaining 2 in. thickness of clean dry metal $1\frac{1}{2}$ in. to 2 in. gauge shall then be uniformly spread and particular care shall be taken to hand pack it so that the carpet is quite even and dressed to correct camber.

(5) The surface shall then be rolled dry starting from the sides towards the centre. Any depression that may appear shall be made up with the metal, a small (2 to 3 per cent) reserve of which shall be

kept for the purpose from operations 2 and 4 above. The dry rolling shall be continued till the metal gets fairly interlocked without crushing the metal.

(6) Road Tar No. 2 shall then be uniformly sprayed by means of a sprayer over the dry surface at the rate of 36 lbs per 100 sq. ft. (or 8·5 tons per mile 10 ft. wide).

(7) Coarse grit 3/4 in. gauge 1/4 in. to 3/4 in. consisting of 70 per cent 3/8 in. shall then be spread uniformly by spinning baskets at the rate of 4½ cu. ft. per 100 sq. ft. (or 2400 cu. ft. per mile 10 ft. wide).

(8) The surface shall then be rolled lightly with the S. R. Roller. Being fresh it will resume and form ridges under the roller wheels and therefore only a few turns shall be given just to lightly wedge in the grit and surface left to season.

(9) Next day in summer and (after 5 or 6 hours in winter) the surface shall be thoroughly rolled till all the 1st Coat grit is fairly wedged in position and there is no movement of the surface under the roller. Any unevenness that may appear in the final surface shall be removed with premixed grit.

(10) When the surface has dried out, it shall be dusted and cleaned, tar sprayed at the rate of 18 lbs per 100 sq. ft. (4¼ tons per mile 10 ft. wide) and medium gauge (1/4 in. to 3/8 in.) grit uniformly spread at 2½ cu. ft. per 100 sq. ft. (1200 cu. ft. per mile 10 ft. wide) and rolled in.

(11) The surface shall then be sealed with tar or bitumen at 14 lbs per 100 sq. ft. (3½ tons per mile 10 ft. wide) and fine grit (1/8 in. to 1/4 in. gauge) spread at 1½ cu. ft. per 100 sq. ft. (800 cu. ft. per mile 10 ft. wide) and whole surface rolled and finished.

(12) The road shall be kept closed to traffic for 4 to 5 days at least.

APPENDIX I.

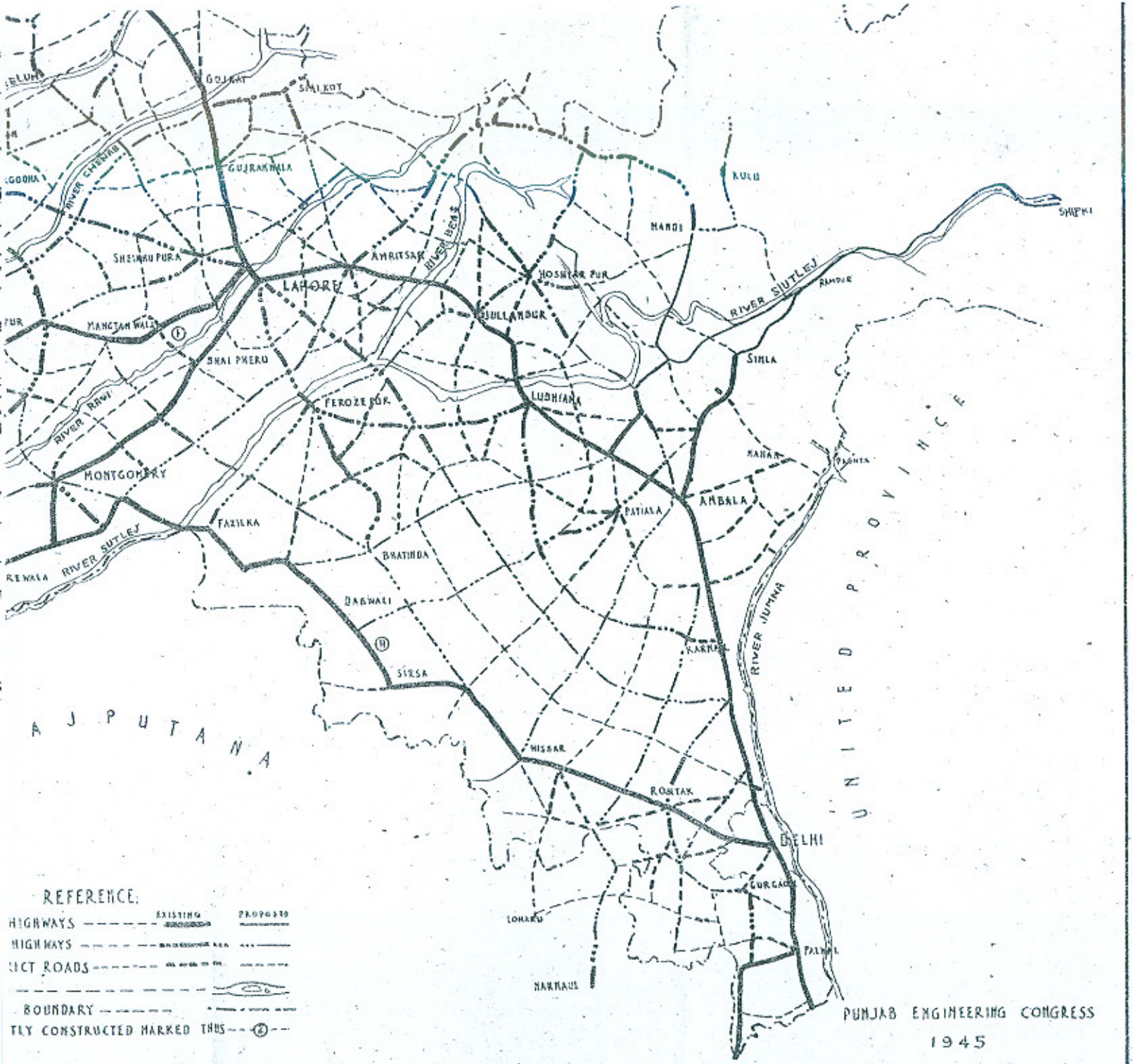
Statement of Waterways of Main Nullahs on Musakkel-Tallagang Road, Arterial Road No. 10.

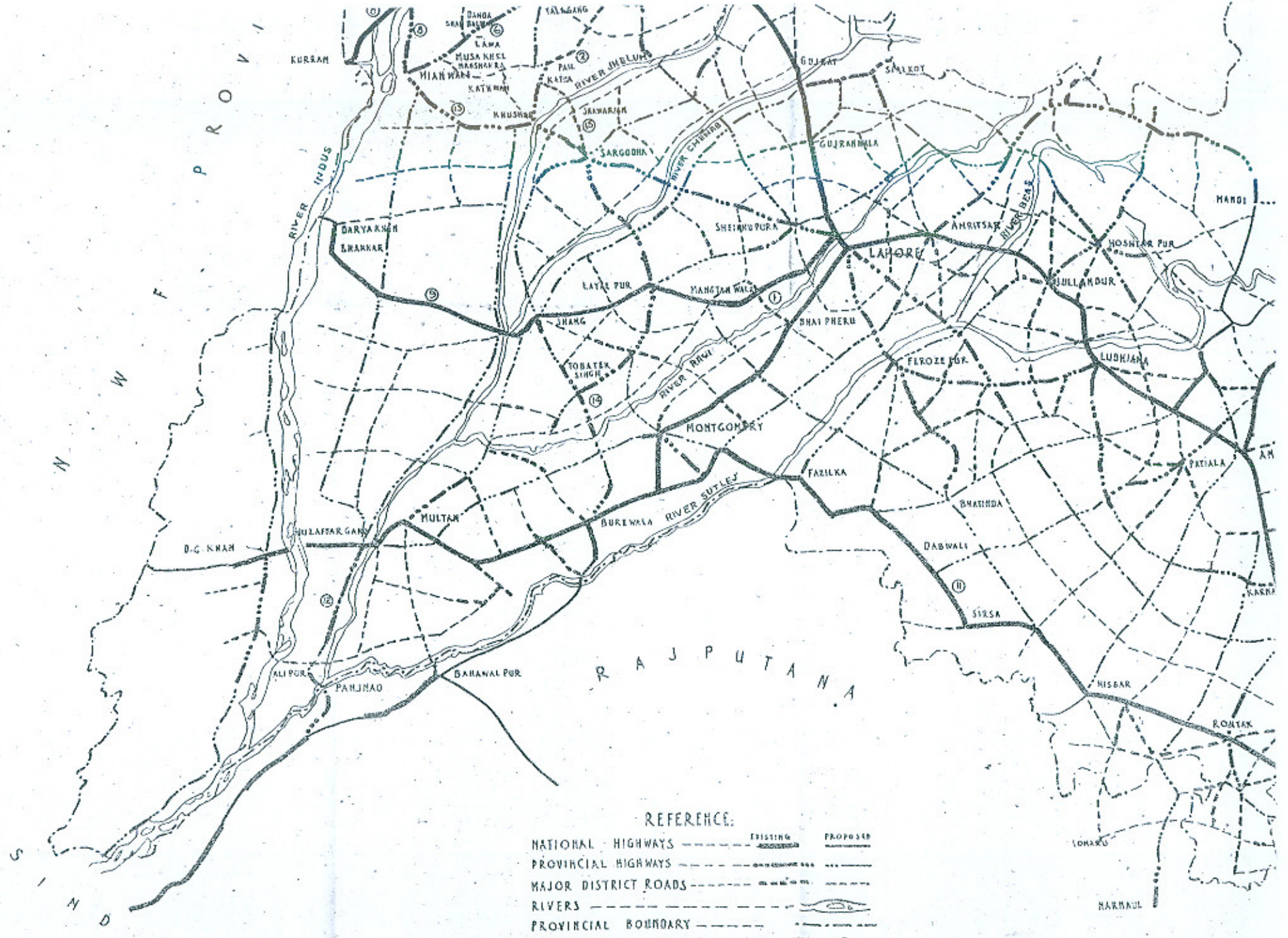
Serial No.	Name of Nullah.	Catchment area in Sq. Miles	Maximum discharge anticipated—D	Maximum flood discharge as actually worked out from Hydraulic Data.	Waterway required in S. Ft.		Natural bed width of channel in defined section.	Waterway proposed.	Maximum discharge possible with floods up to bottom of girders and no scour.	Maximum capacity of bridge to Maximum flood.		Remarks and other local information about the channel at the proposed crossing.
					As per Drainage Table.	As per Talbot formula.				To as worked out in Column "4"	To as worked out in Column "5".	
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Ghambir River ... (West)	166·0	16,900	21,610	1,359	1,979	122'	155' span	72,700	4·3	3·4	River in well-defined sand stone banks. Bed of sand and shingle.
2.	Nikki Nullah ...	26·34	4,700	4,875	554	493	57'	One 30' and One 15' span	9,340	2·0	1·9	Channel a ravine in sand stone. A fall on the bridge site. Hence velocity in ravine high. From section it is clear that a 30' span will take ordinary floods and to meet an exceptional floods a 15' span may be added.
3.	Lati Nullah ...	28·79	5,260	2,700	578	528	42'	54' span	7,257	1·4	2·7	Well defined in sand stone banks.
4.	Sirri Nullah ...	17·72	3,800	4,000	456	370	19' to 80'	54' span	13,900	3·7	3·5	Channel regular, one side sand stone, other on sand and shingle. Foundations to be taken below spring level. Wells would be required.
5.	Ankar Nullah ...	90·5	11,370	12,000	1,011	1,240	40' to 63'	54' span	17,040	1·6	1·4	Section defined and regular sides; sand stone; bed sand and shingle. One span 54' will do.

APPENDIX III.

Statement showing cost of New Roads by Sub-Heads.

Work.	Length in miles.	Date of commencement.	Date of completion.	Formation.	Cost per mile.	Soling coat.	Cost per mile.	Wearing coat.	Cost per mile.	Surfacing.	Cost per mile.	Road structures other than major Bridges.	Cost per mile.	Major Bridges.	Cost per mile.	Land Acquisition.	Cost per mile.	Miscellaneous.	Cost per mile.	Total cost.	Total cost per mile.	Remarks.
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CLASS.																						
o-Jhang-dhian Arterial	10·1		16-6-41	31-3-43	66,927	676	1,38,551	5,500	3,12,500	3,094	3,31,275	3,248	16,500	162	...	...	10,534	103	79,006	775	9,97,015	9,775	Premium 8 per cent. over schedule rates.
ian-Dhak-Ferry-Road Art.	32·23		25-11-40	31-3-44	43,543	1,349	96,586	2,976	83,104	2,580	75,311	2,333	50,761	1,572	...	...	5,533	181	27857	862	3,33,793	11,026	Premium 18 per cent.
o-Mianwali ahpur District	32·32		1-11-10	31-3-42	28,165	855	1,56,451	4,753	80,013	2,451	80,129	2,307	41,215	1,253	...	...	25,703	781	6,629	201	4,27,317	12,380	Abatement 2 per cent.
o-Mianwali nwali District	21·73		1-11-40	31-3-42	26,101	1,201	1,07,958	4,966	61,475	2,829	61,425	2,826	45,859	2,111	...	...	17,359	800	17,354	798	3,43,231	15,793	Abatement 2 per cent.
ugh-Kurram in Mianwali o. 2.	63·23		19-7-41	24-3-43	1,26,550	2,000	252,404	4,320	2,00,340	3,169	2,20,520	4,146	2,20,526	3,383	...	...	1,67,966	2,650	88,284	1,396	13,87,559	21,272	Premium 14 per cent.
dipur- ...	18·33		9-9-40	31-1-42	24,931	1,360	81,276	4,434	65,526	3,567	1,03,133	5,626	9,609	529	..	...	5,690	309	22,555	1,231	3,12,650	17,054	
No. 24	12 Trackway				14,936		45,500	5,658					6,568				3703		14,772		83,064	6,925	
i-Chitta-Art. No. 23.	18		12-1-41	31-1-43	17,166	972	51,585	2,866	64,331	3,668	41,217	2,290	11,391	644	...	...	...	...	6,589	362	1,95,355	10,742	
section of Delhi-Arterial No.	35·20	..	...	16,038	456	1,07,529	3,055	2,79,578	7,934	35,743	334	13,775	391	...	...	...	...	16,415	466	4,58,870	13,039	
ngtwala ...	13·37	..	...	67,825	5,073	49,181	3,678	82,212	6,149	44,536	3,331	26,217	1,961	12,553	939	23,031	1,726	9,481	710	3,15,039	23,567	No premium.
Total ...	351·05	...	...	4,42,099	1,259	11,54,813	3,849	12,30,121	3,504	10,17,224	2,901	4,42,687	1,261	12,583	...	2,00,466	599	2,89,625	826	49,00,530	13,959	
HEAVY.																						
ngang Road in Mianwali Dis-ict.	46·14		27-7-41	28-3-43	6,34,017	13,741	1,93,695	4,197	1,69,030	3,663	1,84,191	3,992	1,70,993	3705	1,92,605	4,169	93,778	2,032	57,100	1,237	16,94,727	36,730	Premium 9 per cent.
Khushab to Sahiwal in Jhelum Districts	65·85		22-6-41	24-4-43	5,02,046	7,611	2,02,134	3,146	1,52,170	2,366	2,16,502	4,502	1,79,182	2,721	...	...	1,15,196	1,749	43,206	657	15,29,556	23,221	Premium 9 per cent.
Gungle-Bpur-ang Road Art. Tahgang to	16·0		17-6-41	25-7-42	19,711	1,213	39,647	2,715	44,655	2,791	32,141	4,509	35,547	1,597	...	...	40,240	2,515	20,193	1,262	2,82,954	17,622	Premium 15 per cent.
ang Road Art.	27·17		15-6-41	18-6-43	1,63,634	6,023	1,41,033	5,219	1,83,751	5,863	58,582	1,972	85,356	3,141	4,15,741	15,301	12,126	446	77,951	2,869	11,60,900	40,816	Premium 16 per cent.
Gungle-Bpur-ang Art.	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
ti Section	7·38		1-6-41	12-9-42	11,365	1,540	88,810	5,359	31,858	4,317	29,887	4,050	49,257	6,674	...	...	71,250	9,652	2,444	332	2,37,671	32,213	Premium 10 per cent.
Bpur-Road ...	27		16-8-41	31-1-45	1,31,715	4,880	77,410	2,867	67,506	2,501	76,525	2,834	1,01,015	3,741	...	...	34,146	1,265	21,158	784	5,12,475	18,980	Premium 9 per cent.
ch-Dhallian ...	6·71		9-7-41	1-4-42	3,639	1,141	20,187	3,009	28,433	4,237	23,308	3,384	12,943	1,930	...	...	5,177	771	3,713	554	1,00,228	15,026	Premium 13 per cent.
otal ...	196·26	..	...	11,81,987	7,551	7,33,529	3,763	2,82,426	3,477	7,35,536	3,748	6,21,809	3,178	6,08,141	...	3,69,838	1,886	2,25,845	1,151	56,65,361	27,848	
tal ...	547·32	..	...	15,24,086	3,515	18,91,422	3,825	15,12,547	3,495	17,52,760	3,257	10,66,491	1,949	6,20,691	...	6,50,293	1,188	5,15,670	942	1,05,65,889	18,940	


GUJRAT
SIALKOT
GUJRANWALA
RIVER CHENAB
SHEIKHUPURA
LAHORE
AMRITSAR
RIVER BEAS
HOSHIAR PUR
KULU
MANDI
SUTLEJ
RIVER SUTLEJ
JULLANDUR
SIMLA
MANGTAN WALA
SHAI PHERU
RIVER RAVI
FEROZEPUR
LUDHIANA
KARNAL
AMBALA
PATIALA
MONTGOMERY
FAZILKA
BHATINDA
DABWALI
SIRSA
HISSAR
ROHTAK
DELHI
GURGAON
PALWAL
NARNAUL
RIVER JUMNA
UNITED PROVINCE
RAJPUTANA
REFERENCE:
HIGHWAYS
EXISTING
PROPOSED
DISTRICT ROADS
BOUNDARY
PUNJAB ENGINEERING CONGRESS
1945


N W F P R O V I
KURRAM
DANDA SHAH BILAWAL
LAMA
MUSA KHEL
MARSHAKRS
MIANWALI
KATHMIN
PAIL
KATHA
RIVER JHELUM
GUJRAT
SIALKOT
KHUSHAB
JHAWARIAN
SARGODHA
RIVER CHENAB
GUJRANWALA
RIVER INDUS
DARYA KHAN
BHAKKAR
SHEIKHUPURA
AMRITSAR
RIVER BEAS
HOSHIAR PUR
LAHORE
JULLANDUR
LAYAL PUR
MANGTAN WALA
JHANG
BHAI PHERU
TOBA TEK SINGH
FEROZE PUR
LUDKIANA
RIVER RAVI
MONTGOMERY
FAZILKA
PATIALA
MULTAN
BUREWALA
RIVER SUTLEY
BHATINDA
MUZAFFAR GARH
D.G. KHAN
DABWALI
SIRSA
ALI PUR
PAHJNAD
BAHAWAL PUR
R A J P U T A N A
HISSAR
ROHTAK
S I N D
REFERENCE:
NATIONAL HIGHWAYS
EXISTING
PROPOSED
PROVINCIAL HIGHWAYS
MAJOR DISTRICT ROADS
RIVERS
PROVINCIAL BOUNDARY
ROADS RECENTLY CONSTRUCTED MARKED THUS

MAP SHOWING
POST-WAR ROAD DEVELOPMENT SCHEME
FOR THE PUNJAB

SCALE : 32 MILES TO AN INCH

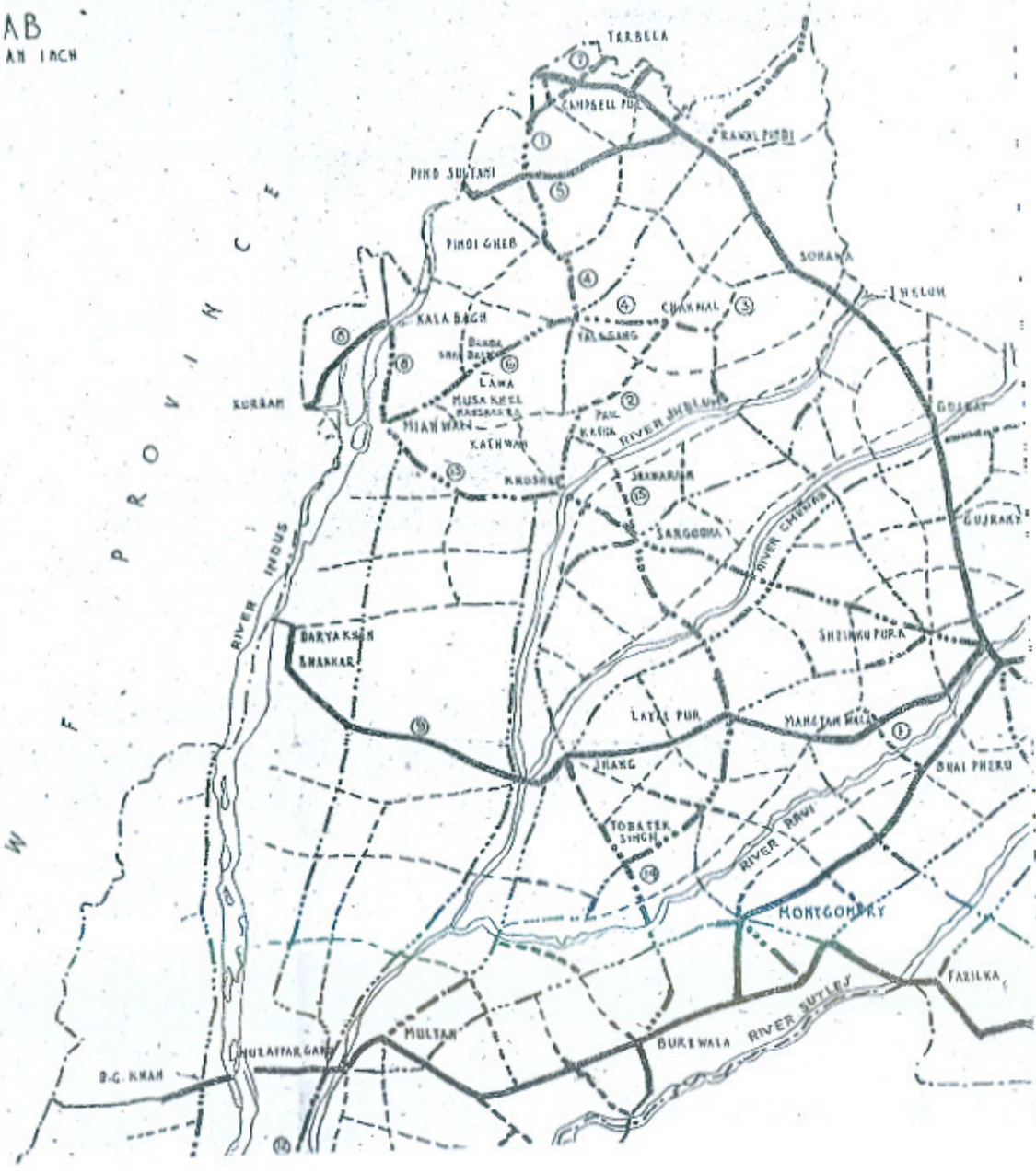


PLATE 1
PAPER 274

DPMENT SCHEME

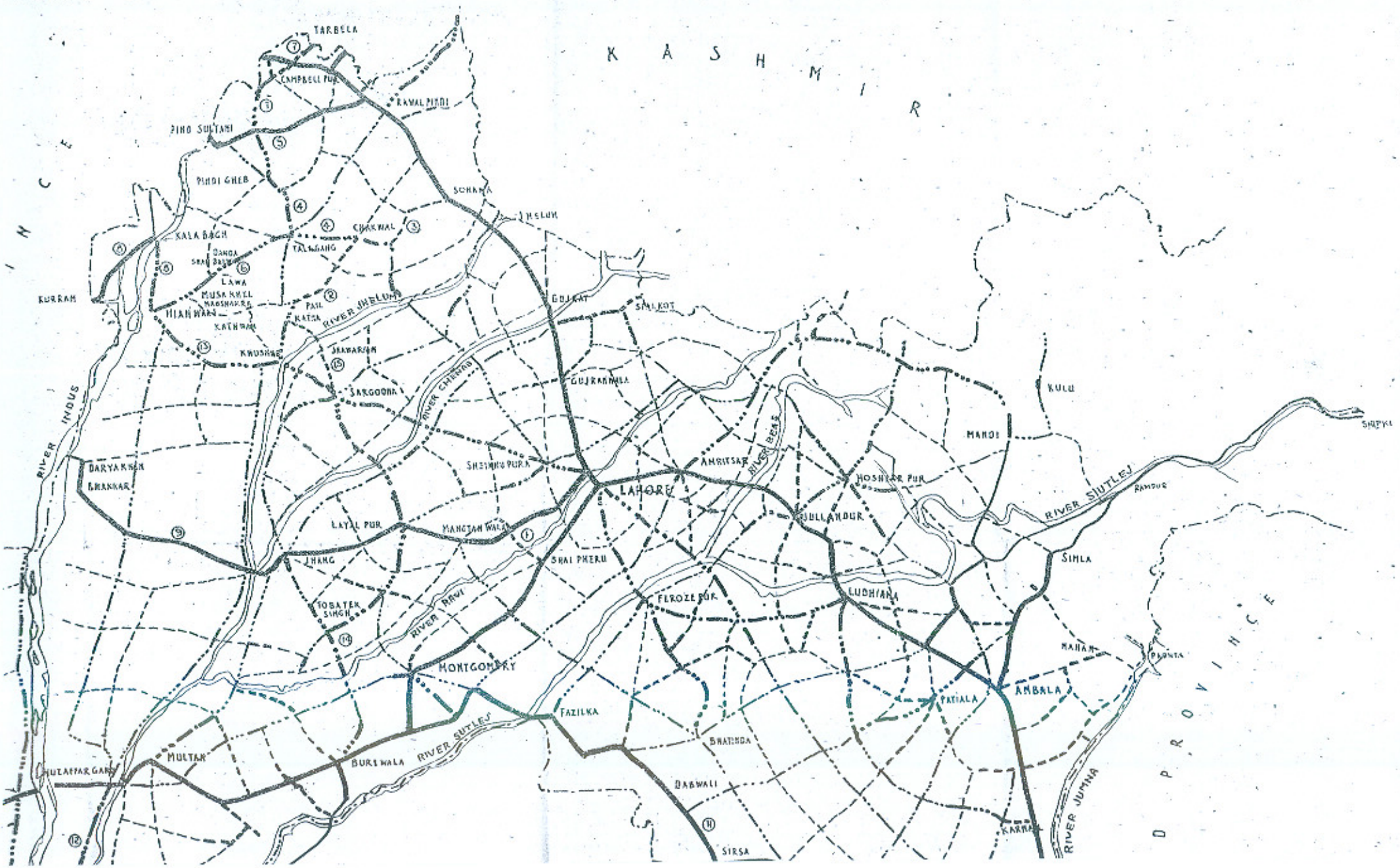


PLATE 2
PAPER 274

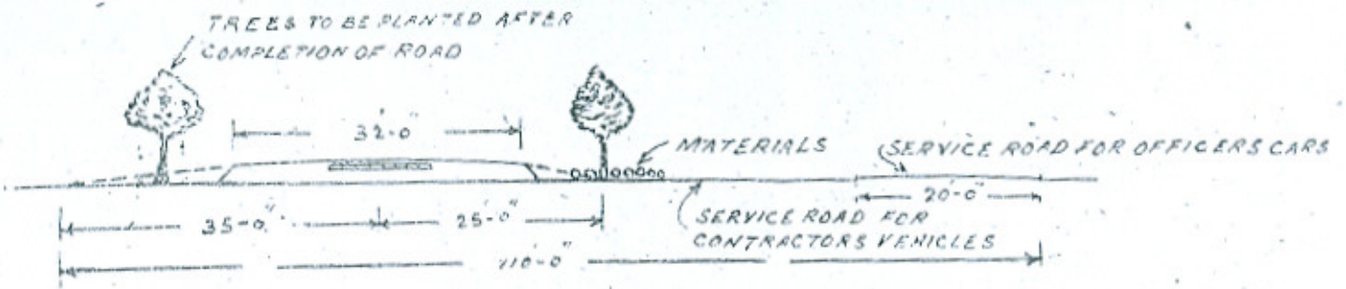
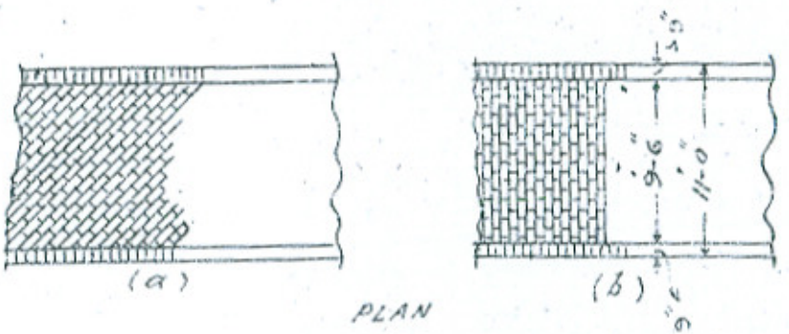


FIG 1



PLAN
FIG 2

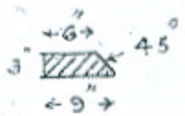


FIG 3

PUNJAB ENGINEERING CONGRESS
1945

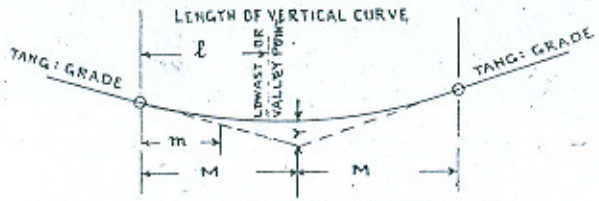
TABLES FOR VERTICAL CURVES

PLATE 3
PAPER 274

TABLE A

DISTANCE IN FEET FROM ℄ TANGENT POINT OF VERTICAL CURVE	LENGTH OF VERTICAL CURVE 200 FT.					
	LEVEL GRADE MEETS A RISING OR FALLING GRADE OF :—					
	PLAIN				HILLY	
	1:100	1:50	1:40	1:30 MAX:	1:20 RULING	1:15 MAX: IN 300
	ORDINATES MEASURED VERTICALLY FROM TANGENT GRADES (IN FEET)					
1	2	3	4	5	6	7
0	0	0	0	0	0	0
25	0.02	0.03	0.04	0.05	0.08	0.10
50	0.06	0.13	0.16	0.21	0.31	0.42
75	0.14	0.28	0.35	0.47	0.70	0.94
100	0.25	0.50	0.63	0.83	1.25	1.67
125	0.39	0.78	0.98	1.30	1.95	2.61
150	0.56	1.13	1.41	1.88	2.81	3.75
175	0.77	1.53	1.92	2.55	3.83	5.10
200	1.00	2.00	2.50	3.33	5.00	6.67

LENGTH OF CURVE	ON BRIDGE APPROACHES PUT LENGTH OF CURVE SHOWN IN FIRST COL: IF HEIGHTS EXCEED.					
200	2	4	5	7	10	14
100	1	2	2½	3½	5	7
50	½	1	1¼	1¾	2½	3½



ORDINATE AT MIDDLE OF VERTICAL CURVE

$Y = \frac{L}{800}$ (ALGEBRAIC DIFFERENCE OF TANGENT GRADES EXPRESSED AS FEET RISE OR FALL IN 100)

INTERMEDIATE ORDINATES AT DISTANCE "m" FROM THE NEAREST TANGENT POINT OF VERTICAL CURVE

$y = Y \times \frac{m^2}{M^2}$ (ALL IN FEET)

LOWEST OR VALLEY POINT

$\ell = L \times \frac{\text{TANGENT GRADE AT BEGINING OF CURVE}}{\text{ALGEBRAIC DIFF: OF TANGENT GRADE.}}$

FOR 100 LONG CURVES, REDUCE ALL DISTANCES AND HEIGHTS IN TABLE BY ½, FOR 50 CURVES TO ¼. USE AS LARGE CURVE AS FEASIBLE.

AT BRIDGE TOPS KEEP 100 LEVEL AS SKETCHED BELOW



LAYING OUT OF CURVE FOR CASE IN TABLE "A"

TO LAY OUT CURVE IN PRACTICE SET UP LEVEL PORTION FIX O AT ½ LENGTH OF CURVE FROM INTERSECTION AND LAYOUT ORDINATES AT DISTANCES AS PER TABLE.

TABLE B

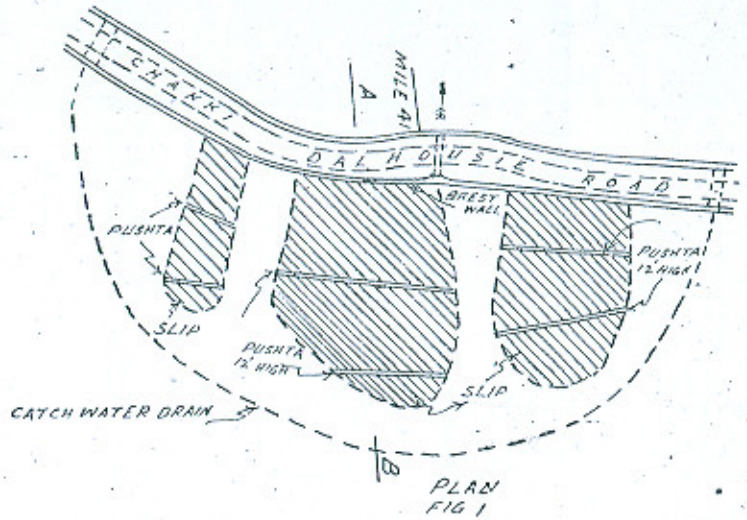
DISTANCE IN FEET FROM TANGENT POINTS OF VERTICAL CURVE.	LENGTH OF VERTICAL CURVE 200 FT.					
	1:m RISING MEETS 1:n RISING					
	ORDINATES MEASURED VERTICALLY FROM TANGENT GRADES (IN FEET)					
	1:30 R & 1:20 R	1:20 R & 1:15 R	1:50 R & 1:30 R	1:50 R & 1:20 R	1:50 R & 1:15 R	
0	0	0	0	0	0	
25	0.03	0.03	0.02	0.05	0.07	
50	0.11	0.11	0.08	0.19	0.29	
75	0.24	0.24	0.19	0.42	0.66	
100 MID POINT	0.42	0.42	0.33	0.75	0.17	

LAYING OUT OF CURVE FOR CASE IN TABLE "B"

SET UP LEVEL AT BEGINNING OF CURVE, END OF CURVE AND LAY OUT ORDINATES FROM BOTH SIDES AT DISTANCE AS PER TABLE.

PUNJAB ENGINEERING CONGRESS
1945

PLATE A
PAPER 274



PLAN
FIG 1

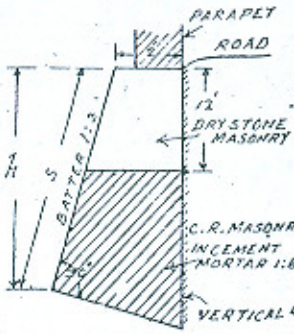


FIG 2

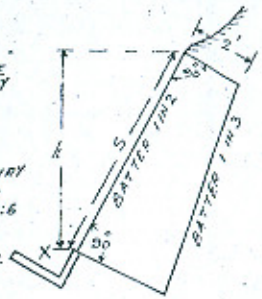
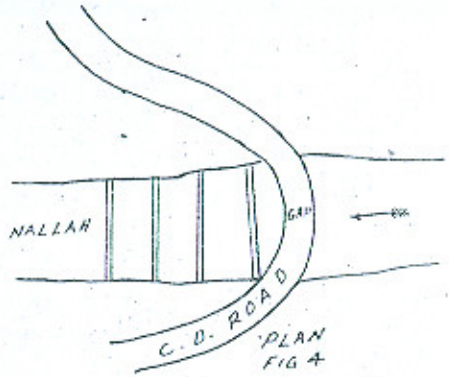
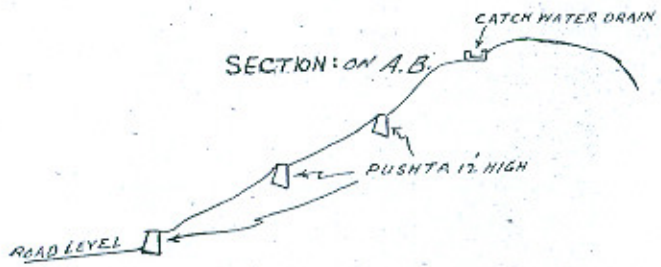
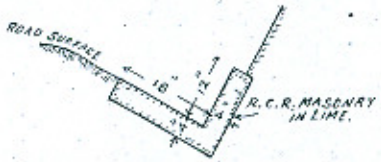


FIG 3

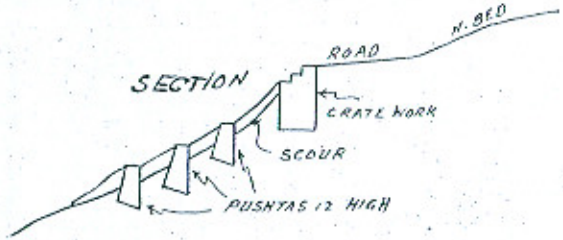


PLAN
FIG 4





DETAIL AT X

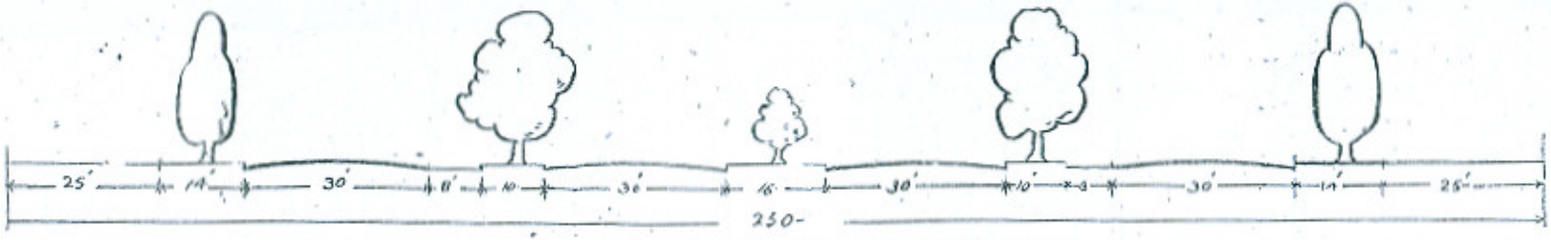


PUNJAB ENGINEERING CONGRESS
1945

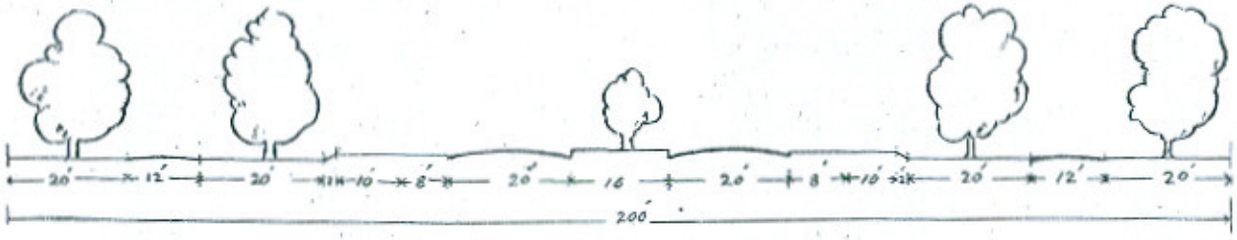
PLATE 5
PAPER 274

CROSS SECTION OF PROPOSED ARTERIAL ROADS IN THE POST WAR ROAD DEVELOPMENT SCHEME FOR THE PUNJAB

scale 1" = 20'



NATIONAL HIGH WAY INSIDE THE TOWN.



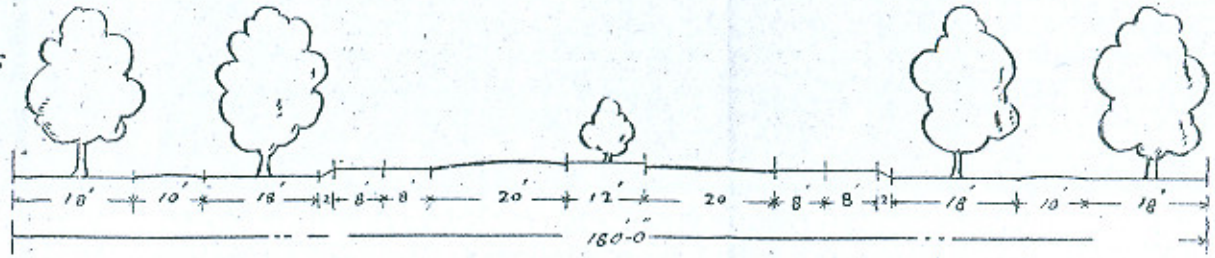
NATIONAL HIGHWAY

PUNJAB ENGINEERING CONGRESS
1945

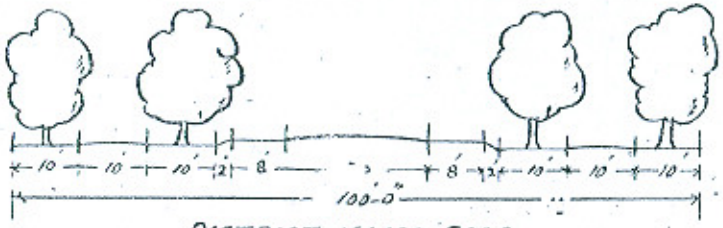
PLATE 6
PAPER 274

CROSS SECTION
OF PROPOSED ARTERIAL & RURAL ROADS IN THE POST WAR ROAD DEVELOPMENT SCHEME FOR THE PUNJAB

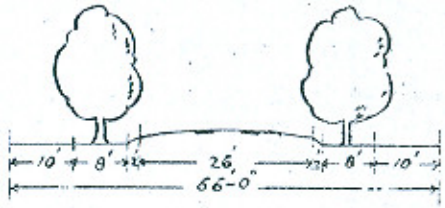
Scale 1"=20'



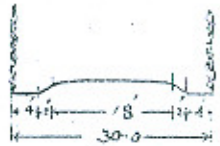
PROVINCIAL HIGHWAY



DISTRICT MAJOR ROAD



DISTRICT MINOR ROAD



VILLAGE ROAD

PUNJAB ENGINEERING CONGRESS
1945