PAPER No. 200.

THE ROADS TO KULU.

By J. Halcro Johnston.

Introduction.

Kulu proper consists of a number of comparatively wide valleys forming the head waters and source of the Beas. At the lowest point it is 3,300 feet above sea level and it is surrounded by high ranges rising in places to a height of over 21,000 feet. The Pir Panjal Range on the North separates it from the head waters of the Chenab or Lahul, the lowest point between Lahul and Kulu being the Rotang Pass 13,050 feet. To the East is the valley of the Spiti a tributary of the Sutlej approached by the Pin Parbati Pass 15,750 feet.

To the South lies outer Seraj also in the Sutlej valley reached by the Jalori Pass 10,286 feet high and to the West there is the State of Mandi. Lahul, Spiti and Outer Seraj all come under the Kulu Administration Sub-division.

The broad valley of the Beas degenerates into a narrow gorge shortly after the river enters Mandi territory. A motor road has now been made through this gorge but until a few years ago it was quite impassable and Kulu was very much cut off from the rest of India especially in the winter when the only access was through Mandi over the Dulchi Pass at a height of 6,700 feet.

The importance of Kulu lies principally in the wide differences between that country and the rest of the Punjab. In climate it is similar to Kashmir. Rainfall is about 40 inches a year; it is well distributed and is not so violent as it is in Kangra. The result of this is that Kulu is one of the few parts of the Himalayas where good fruit can be grown.

Trade is dependent upon, and is stimulated by differences such as those described and Kulu therefore is an important potential producing country and market. It is also a potential Hill Station for those who prefer a European climate. Kulu also derives importance as the terminus of one of the few trade routes between Chinese Turkestan and India. This route passes through Yarkand, Leh and Lahul. It suffers from the great handicap of having to cross four passes of over 16,000 feet which makes it difficult to compete with the easier routes through Gilgit and Kashmir which not only have fewer high passes to cross but are also shorter.

Communications.

The author has referred to the trade of Kulu as potential. At present there is very little, the country is mostly undeveloped and is hardly known as a hot weather station, the reason being that access is still very difficult. The nearest Railway Station is Jogindarnagar, 75 miles by road from Sultanpur. This road passes through Mandi and follows the Beas as far as Manali. It is a motor road but is unmetalled and in places as narrow as 8 feet. One-way traffic, working to time table, is therefore necessary.

This is the only motor road connecting Kulu with the outside world. There are however several mule roads some of which are important trade routes. The Kulu Lingti Road which carries the Yarkand trade passes over the Rotang Pass into Lahul. It then follows the Chandra and Bhaga rivers and crosses the Great Himalayan Range by the Baralacha Pass 16,000 feet high.

The Simla-Kulu road is a good mule road passing through Narkanda, Luri and Larji. It crosses by the Jalori Pass. This road is no-where less than 6 feet wide with a ruling gradient of 1 in 5 and has been passed once or twice by motors.

The Banjar-Rampur road crosses the same Range by the Basleo Pass 10,000 feet. This is an important trade route but the road is difficult for laden mules the gradients being in many places as steep as 1 in 3. Traffic to Rampur therefore prefers the longer route over the Jalori.

Before the construction of the motor road traffic with Mandi and Kangra followed one of two routes: Guma to Sultanpur over to Babu Pass or Drang to Bajaura over the Dulchi Pass.

These roads are still maintained as mule roads. The grades are however steep and they are not much used now.

History.

Kulu was in olden times ruled by Hindu Rajas, and it is doubtful whether in those days there were any roads worthy of the name. Tracks 2 or 3 feet wide just passable by ponies were no doubt made by begar labour along the principal trade routes. Timber was plentiful and most streams could be spanned by logs. There are at present many cantilever bridges of the Sangha type with spans up to 100 feet, but whether this type of bridge was used in the time of the Rajas or not, the author cannot say. The Beas was most probably crossed by means of rope jhoulas.

In 1839 the Sikhs took possession of Kulu and held it until 1846 when it was ceded to the British Government after the first Sikh War. Kulu became a sub-division under the control of an Assistant Commissioner and no doubt the roads to Simla and Kangra were improved but the District Gazetteer is silent on the subject. Major Banon has informed the writer that the first mule roads were made by a District Engineer called Theodore with begar labour. On one occasion a large number of Seraj men who had been making roads in Lahul, lost their lives in a snow storm on the Rotang Pass while returning home.

The road over the Babu Pass was constructed about 1866 and that over the Dulchi between 1881 and 1883.

About 1876 Mr. Duff Dunbar of Caithness who had spent many years in Kulu saw the necessity for a bridge across the Beas, south of Kulu and decided to build one at his own expense at Buntar. The work is said to have cost him Rs. 50.000, but for some reason was unable to finish it. The Duff Dunbar bridge appears to have been completed by Government in 1880 or later at a cost of at least Rs. 80,000. It was a very strong suspension bridge of 305 feet span. the eight cables being nine inches in circumference. These heavy cables and other materials had to be brought all the way from rail head at Rupar to Kulu. Prior to 1894 Public Works were in charge of the District Board but in that year a Provincial P. W. D. Sub-division was constituted and arrangements to improve communications were immediately made. The first Sub-Divisional Officer was Mr. W. H. Donald, the District Board Engineer, who held the office for about 20 years.

In 1891 there was an unmetalled cart road between Pathankot railway station and Palampur maintained by the P. W. D. but most of the bridges still remained to be built. The link between Palampur and the Mandi border was still a mule road under the District Board. The Raja of Mandi had been asked by Government to construct roads in his state. Rs. 75,000 had been spent in joining up Mandi with Bamla on the Hamirpur border and with Aiju on the border near Baijnath. These roads were designed to be suitable for cart traffic and the Raja asked Government to complete the links in British territory to allow of cart traffic between the Mandi border and rail head at Hoshiarpur or Phagwara and Pathankot. In 1899 the proposal to construct a cart road to Hoshiarpur *via* Una was dropped partly on account of the engineering difficulties and partly because it was not considered necessary to provide two cart roads between Mandi and the railway.

The Palampur-Baijnath cart road received administrative approval in 1893 and work was commenced in December 1898 at an estimated cost of Rs. 55,800, with a ruling grade of 1 in 20 and a width of 16 feet. It was completed in November, 1903 at a cost of Rs. 1,22,300 or about Rs. 9,800, a mile. (This did not include the cost of the Binwan and Awa Bridges). The excess was due principally to work on the Ghatt

Hill where grades up to 1 in 15 were adopted. In the meantime most of the biggest nullahs between Pathankot and Palampur had been bridged and in 1899 tongas were able to reach Palampur. The worst miles had also been metalled. The Raja of Mandi had improved his road between the boundary and Guma. Work in Kulu consisted mostly of bridge building. In 1894 there was a big flood in the Fugale which destroyed the bridge and several houses. A bridge over the Beas at Raison was destroyed the same year. In 1896-97 the Beas at Kulu was bridged. A Sangha bridge over the Saing at Largi was burnt down in 1896 and the present suspension bridge was built in 1897. Begar labour was stopped that year. The Simla road crossed the Beas at Dilasni by a Sangha bridge of 155 feet span built in 1893. This bridge was swept away by a flood on 5th August 1899 and replaced by the present bridge at Oot three miles down-stream, begun in 1897 and completed in 1900. This flood did a lot of damage, several persons and many animals lost their lives; the bridges over the Mohal and Rupru Nullahs were destroyed and the road on both sides of the Dulchi Pass was wrecked. There were heavy slips up the Rupru Nullah above Bajaura which by damming back the water probably accentuated the flood. The water rose 10 to 15 feet at Bajaura. As a result of this flood it was decided to build a new road on the left bank of the Rupru between Bajaura and the Dulchi, to rebuild the Beas bridge at a better site 3 miles down stream and connect Dilasni and Oot by a road on the right bank in Mandi State.

The old bridge over the Beas at Luri of the Sangha type built about 1888 was dismantled in 1900 and replaced by the present suspension bridge in 1901. The estimated cost was Rs. 9,160. At the same time a suspension bridge was built over the Sutlej at Rampur. This was paid for by the Bashahr State.

Work on the new road to the Dulchi Pass, a length of 9 miles, was started in January 1900 at an estimated cost of Rs. 13,700. The road was to be 10 feet wide with a ruling gradient of 1 in 10. The work proved more difficult than anticipated. Heavy slips occurred and it was not finished till the end of 1901, at a cost exceeding Rs. 3,2000 or Rs. 3,600 a mile. The road between Bajaura and Larji 5·7 miles in length was started in February 1900 at an estimated cost of Rs. 14,300. It was completed in 1901 at a cost of about Rs. 18,000 or Rs. 3,200 a mile. The minimum width was 5 feet. This estimate did not include the bridge over the Beas at Oot.

The Earthquake.

The great Kangra earthquake of 4th April 1905 did a lot of damage in Kulu and many lives were lost. The Duff Dunbar bridge was totally wrecked. This failure might have been avoided if the towers had been stronger. These were built of round boulders in lime concrete with a skin of masonry and it was found that the lime had not set. The Oot suspension bridge escaped undamaged. The earthquake

535

caused several heavy slips. One of these formed a dam across the Tirthan river on the road to Simla about 4 miles above Larji, and destroyed the 90-foot bridge there. The Luri and Larji bridges were slightly damaged. Otherwise, the bridges appear to have come through the earthquake with credit. No. 1 Company 1st Sappers and Miners was sent to Kulu to repair the damage. They built a temporary bridge across the Beas at Buntar of 326 feet span at a cost of Rs. 6,300 and another across the Tirthan at Daman of 147 feet span. The present Duff Dunbar bridge was built in 1911.

In 1912 the re-alignment of the road between the Sutlej at Baina and Jibi was sanctioned and work started. The estimated cost of the section Baina to Khanag was Rs. 39,400 for a length of 16½ miles and of the section over the Jalori Pass Rs. 61,700 for a length of 17 miles. The road was to be 8 feet wide with a ruling grade of 1 in 10. It was completed in 1915 but in many places grades of 1 in 5 were left and the road was 5 feet wide.

Larji-Mandi Road.

Proposals to convert the Dulchi-Pass road into a cart road had once or twice been made but had been dropped on account of the cost. In 1901 Mr. Wallis, the Superintending Engineer, strongly advocated a road through the Beas Gorge to be continued *via* Bamla and Una to Hoshiarpur. Prior to 1908 the Mandi State had constructed a road passable for animals for about 14 miles up the river from Mandi with a suspension bridge across the Beas about half way at Kokna. This left a gap of 8 miles which was quite impassable. In 1908 H. H. Sir Louis Dane, Governor of the Punjab, drew attention to Russian competition for the Central Asian Trade and wished to improve our communications with that country *via* Kulu. He recommended the construction of a road suitable for camels or carts with a minimum width of 10 feet between Kulu and Rupar. The alignment was to follow the Beas to Mandi and pass through Suket and Bilaspur crossing the Sutlej at Dehar. A Suspension bridge was built across the Sutlej and completed in 1911 and the road between Suket and Mandi required very little to make it passable for carts. The approximate cost of the work as estimated roughly in 1909 and 1910 was as follows :—

	Miles.	Rs.
Rupar to Nalagarh boundary ..	.. 8	26,700
In Nalagarh State ..	.. 28	100,300
In Bilaspur State	.. 23	131,100
In Suket State upto Mandi Town	.. 30	57,400
Mandi to Oot	.. 25	184,100
Total	.. 114	499,600

The distances are only approximate and the cost of a bridge over the Gambhar River in Bilaspur was not included. Mr. Gilbert's estimate of the cost of the Mandi to Oot section was Rs. 3,34,000. The portions of the road to be paid by the Provincial Government were the section between Rupar and Nalagarh boundary, the Gambhar Bridge and the upper section 10 miles long of the Mandi-Oot Road. The States were asked to construct the sections in their own States. The whole road was to have a minimum width of 10 feet and grades suitable for carts. The section Rupar to Nalagarh boundary was commenced in August 1910 and completed in September 1914 at a cost of Rs. 36, 300. The Nalagarh and Bilaspur Darbars expressed their sympathy with the project but were unable to undertake the work as their States were in debt. They asked for permission to charge tolls at the Dhar bridge but this would only be granted if they first constructed the approach roads. After a lot of correspondence on the question whether the work should be carried out by the Provincial Government or by the States themselves and after proposals for financing the States in the latter case had been discussed, it was finally decided that the project should be considered as a whole and carried out by the provincial P. W. D. Detailed estimates were being prepared when, owing to the war the proposal was dropped in 1915. Suket and Mandi States, left to themselves, have constructed a road between the Sutlej and Beas which is passable for motors though not up to specification.

Larji-Mandi Road First Section.

The Section between Mandi and Larji was reconnoitred by Mr. Donald in 1908 and he recommended that the right bank be followed all the way as it would give a shorter road and would save bridging. As the cliffs in the upper section were quite impassable an inspection path about 4 feet wide was commenced in 1909 along the proposed alignment and completed in 1912 at a cost of Rs. 13,700 The path was about 10 miles long. As a road of sorts already existed in the lower section from Khoti Nullah to Mandi it was decided to begin with the upper section—Oot to Khoti Nullah first and work on this was started in July 1912 at an estimated cost of Rs. 91,690. The length was approximately 9 miles. Both the Superintending Engineer and the Chief Engineer suggested that the difficult cliff salients should be tunnelled. This, however, was not done which is very unfortunate as it would have saved many bad bends, high walls and galleries (see photograph). A revised estimate of the cost of this section amounting to Rs. 1,78, 600 was sanctioned in December 1914 and the work was finished off in 1917 to a reduced specification suitable for mule transport at a cost of Rs. 184,000.

Larji-Mandi Road Second Section.

A more careful reconnaissance of the alignment for the second or lower section of the road made in 1913 showed that the left bank was



A BAD SALIENT ON THE LARGI-MANDI ROAD.

the easier. The cost of this section about 17 miles in length was estimated at Rs. 2,05,900 in 1914 or Rs. 9,000 a mile excluding 4 large bridges. In 1914 the Superintending Engineer recommended the present crossing at Pandoh so as to save two large bridges on the left bank above Pandoh.

In February 1915 a pathway 4 feet wide along 3 miles of the more difficult cliffs of the lower section of the road was sanctioned at a cost of Rs. 10,244 and work was completed in 1915 at a cost of about Rs. 15,600. This pathway was, however, found to be obliterated in 1917 when the survey was started and a new pathway 5 feet wide was sanctioned.

The project for the second or lower section had rather a checkered career. Between 1912 and 1919 no less than five attempts were made to estimate the cost. These estimates were made without any survey as the work was considered too urgent to allow of one. The 1st estimate made in 1912 gave the figure as Rs. 2,86,600. After this had been reduced twice and increased once Mr. K.G. Mitchell, Executive Engineer, saw the necessity for a survey which was sanctioned and in September 1918, he estimated the cost at Rs. 4,59,000. This estimate was sanctioned in October 1918 and work started in January, 1919. The estimate allowed for a minimum width of 10 feet ruling gradient of 1 in 20 and least radius of curvation of 60 feet. It included Rs. 1,03,000 for the two major bridges at Mandi and Pandoh and the balance, principally rock cutting, provided for 16½ miles of road at Rs 21,500 a mile.

A special Sub-division was formed with a Sub-Assistant Surgeon attached to deal with accidents and work was executed on petty contract. As local labour could not be had in sufficient numbers and was not used to heavy rock cutting special arrangements had to be made to import Pathans and Kashmiris. At the same time difficulty was found in financing the work and when the year's allotment came to an end the labour would return to their homes. This meant that every year the contractors were faced with heavy charges due to travelling costs and providing new shelters for the men to live in and were unable to work at the estimated rates. (The actual excess appears as an excess in quantity due to a strict control over the rates and an unsatisfactory system of measurement). A revised estimate was prepared in March 1920 and after several alterations was sanctioned in December, 1921 for Rs. 9,37,900. The author was sent to Mandi as Sub-divisional Officer at the end of 1921, where he remained for a year. One of his first duties was the construction of the Pandoh Suspension Bridge of 230 feet span. The towers of this bridge on the right bank were founded on rock while those on the left bank were on an abutment which had been designed of lime concrete with a facing of stone masonry. The lime used had no hydraulic properties and the rich mixture (1: 2 : 5)

prevented any air from penetrating the mass. Sample tests made during construction showed that the concrete was not setting and after 11 feet of the abutment had been built the Superintending Engineer ordered that Surkhi should be burnt and added to the lime. The remedy, however, came too late; the bottom 11 feet of the abutment soon showed signs of cracking and collapsed during a record flood on 12th August, 1922 just after the first cart had successfully completed the return journey over the 16½ miles of new road. The monsoon rainfall that year was very heavy and caused a flood in the Beas which is the record for at least 25 years to date. Parts of the upper section of the road where the river passes through a gorge were 5 feet deep in water and considerable damage was done by slips.

A second revised estimate for the lower section of the road to include the cost of rebuilding the Pandoh Bridge was sanctioned in December, 1922 for Rs. 11,03,000 the provision for the new bridge which was completed in 1923 being Rs. 1,30,000.

There was now a cart road for about 18 miles up the Beas from Mandi with a minimum width of 8 feet and many temporary wooden bridges but the Upper Section of the road was still only suitable for pack transport and by 1921 very little was left of the original road as the timber in the bridges and galleries had all decayed. In December, 1922, an estimate of Rs. 15,000 for rebuilding the bridges was sanctioned; in 1923 the rebuilding of the galleries and widening was started and in December, 1925, another Rs. 52,300 was sanctioned for the work.

Widening continued until the beginning of 1927 when motors were allowed to use the road as far as Oot Behali. The Larji-Mandi Road had taken about 15 years to build and had cost approximately Rs. 16,80,000 or Rs. 68,000 a mile.

Of this, the Mandi Darbar paid as contribution Rs. 50,000 between 1917 and 1919 and agreed to give the land under the road free of cost and maintain the roads over the Dulchi and Babu passes as before. They agreed to contribute Rs. 1,000 per annum towards the maintenance of the Larji-Mandi Road, while Government guaranteed the completion of a through cart road between Rupar and Kulu within a reasonable period. As this road has not yet been completed the Darbar has been exempted from the annual contribution of Rs. 1,000.

The completion of the work with the closing of the capital accounts left the Larji-Mandi Road still very narrow and with many temporary structures in the form of timber bridges. In the last 15 years these have gradually been replaced by steel girders or stone arches and the work of widening and improving curves has been going on every year. The first six furlongs of the road near Mandi were metalled and tarred in 1934.



A BAD SALIENT ON THE LARGI-MANDI ROAD.

Oot-Manali Section.

The extension of motor traffic up to Oot in 1927 called for an immediate improvement of the next section of the road to allow motors to reach Kulu. The money spent on the difficult section through the gorge could be justified only by opening up the valley itself in which the cost of road construction was very much less and consisted principally of that due to bridging.

The first estimate for a motor road in this section Oot to Kulu made in 1920, was Rs. 1,50,000 for a length of 18 miles. It provided for a land width of 50 feet with the cost of land at Rs. 750 per acre.

For three years this estimate underwent a series of revisions and was finally sanctioned in 1923 for Rs. 1,84,000. Funds, however, were not forthcoming and nothing was done until motors began to use the road in 1927 when it became necessary to strengthen the bridges. In October 1927 H. E. the Viceroy visited Kulu and the road was improved to allow his car to pass.

Since then the bridges have been made safe for light motor lorries but little else has been done to improve the alignment which follows the old mule road with many unnecessary curves. The present land width is only about 20 feet.

In 1929 a few tourists had begun to take their cars up to Manali in spite of notices prohibiting such traffic and the fruit growers asked for the improvement of this section also to allow fruit lorries to use it. All the bridges, however, were weak and there were some big nullahs to cross. In 1934 new steel bridges were erected across the Fojal and Sajain nullahs at a cost of Rs. 12,100 and Rs. 10,300 respectively. Since then the road has been open to lorry traffic but it is still very narrow and dangerous in wet weather.

The Road through Mandi State.

Probably no factor has hindered the development of communications with Kulu more than the fact that any practicable road must pass through Mandi State. The Darbar charge tolls on motors and passengers passing through the State and a customs duty on goods and they are often accused of making revenue out of the road and spending very little on it.

The 46 miles of the present motor road in State territory are very narrow, badly aligned and mostly unmetalled. The absence of culverts and side drains results in the washing away of the surface every time it rains. To widen, metal and tar the road and provide proper drainage would cost not less than Rs. 5 lacs for a 9-feet metalled width. The

removal of the tolls and customs would be equivalent to a capital payment of about the same amount. The improvement of the road and the removal of these charges would benefit both the inhabitants of Mandi and of Kulu and to a lesser extent of Lahul but it is very difficult to assess the share which should be charged to each. The population of Mandi is about three times that of Kulu proper but while every inhabitant of Kulu is to a certain extent dependent upon the road at least half of the population of Mandi are not. Also the improvement of the road by increasing motor transport would increase the revenues of the Provincial and Central Governments and of the Railways. This revenue is approximately one half anna per vehicle-ton-mile and an increase of 200,000 ton-miles per annum would be equivalent to approximately Rs. 6,000 per annum or if capitalized Rs. 1,00,000. Another point of importance is that Kulu would be likely to develop much more as the result of improved communications than Mandi, the fruit growing for instance. Taking all factors into consideration the author estimates very approximately the shares of the cost of improvements to the through road in Mandi territory due from British subjects and the Mandi Darbar respectively as 2/3 and 1/3. The author has assumed that tolls and customs duties are done away with. These considerations apply also to the proposed road between Rupar and Mandi.

Simla-Kulu Road.

In order to avoid the difficulties of a road through Indian States the Hon'ble Minister for Agriculture proposed the construction of a motor road between Simla and Kulu *via* the Jalori Pass and in 1935 about Rs. 15,000 were spent on improving this alignment to allow cars to pass. As a result of these improvements a few experimental trips were made but the road is still far from being passable for cars. The crossing of the Jalori Pass is a serious obstacle and in view of the much easier alignment through Suket and Bilaspur it is doubtful if the cost of converting the road over the Jalori into a motor road would be justified.

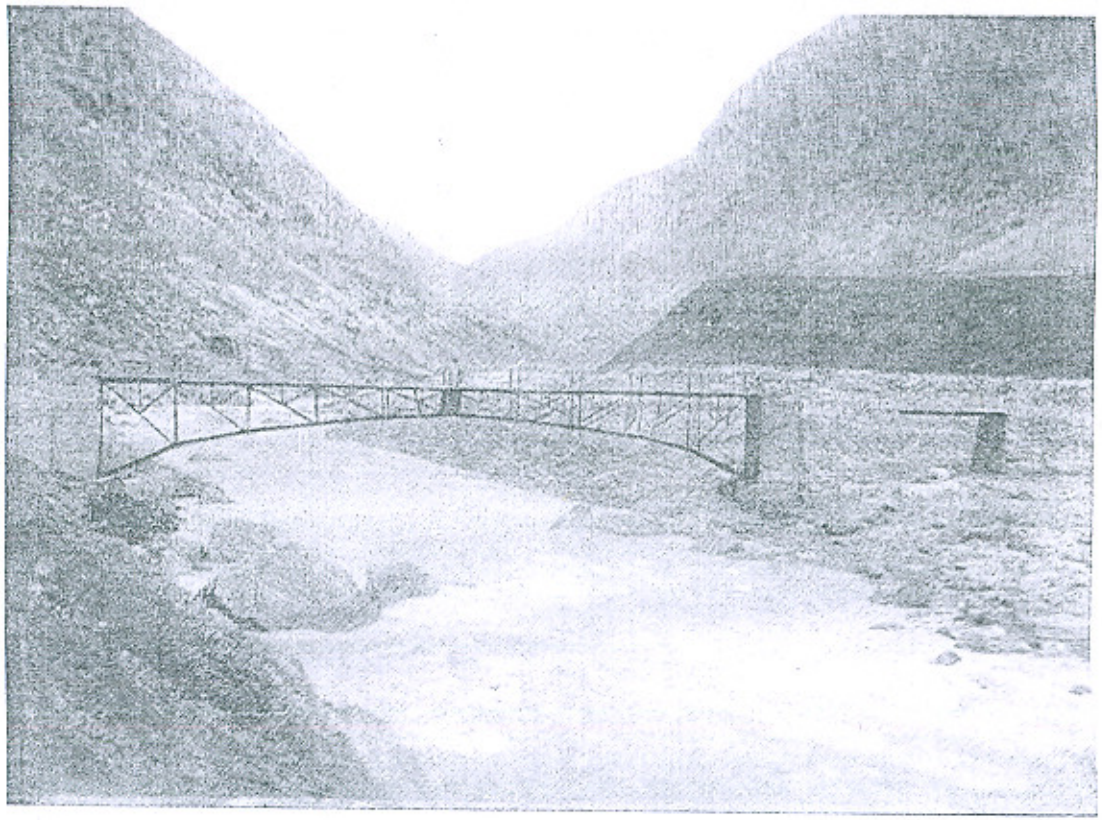
Bridges.

One of the heaviest items of cost both in construction and maintenance of roads in Kulu is that due to bridges and culverts and the subject deserves much fuller investigation. The large number of bridges replaced yearly or washed away shows that the average life of a bridge is very short. This is due principally to one of the following causes:—

(1) The short life of timber.

(2) Insufficient waterway.

(3) Poor masonry in abutments and piers or shallow foundations.



KOKSAR BRIDGE.

Particulars of 24 of the largest bridges in the Division are given in Appendix A. Some of the figures are approximate only, (for example, the slope of river bed). The catchment areas were measured from a ¼-inch map.

The life of a timber bridge varies usually from 10 to 15 years and it is, therefore, economical to use a masonry or steel structure even if the cost is about 2½ times more. Steel girders cost about Rs. 600 a ton in Kulu itself and this type of bridge actually costs little if any more than the timber bridge. If carefully designed, the weight of deck girders is given by the expression $0.002\ w l^2$ *tons* where ' l ' is the span in feet and ' *w* ' the useful load per foot run. In the case of a bridge 6 feet wide for mule traffic $w=0.4$ tons per foot. The total weight of steel in the Dhobi bridge is 16 tons and in the Beli Sajain 13½ tons. These bridges are 10 feet wide and are designed for a 4-ton axle load including impact or 112 lb. per square foot, equivalent distributed load. These bridges as well as those at Baina, Naggar and Koksar, were designed and built by Mr. Molony and show the advantages of steel construction.

Flood Waterway.

Probably, no factor effects the cost of bridges and culverts more than the correct waterway to provide for flood discharges. This figure can be correctly determined only from formulae which are based on actual records of floods in the locality and unfortunately such records have never been systematically kept in Kulu.

In the case of the Beas big floods occurred in 1894, 5th August 1899, 12th August 1922 and 1936.

The flood in 1922 which destroyed the Pandoh Bridge is said to have risen within 13 feet of road level of the Victoria Bridge at Mandi and a flood 30 years before, probably that of 1894, to have risen to within 8 feet of road level an increase of about 20 per cent.

In his paper on this subject published in the Mins. Proc. Inst. C. E. Vol. 217 Mr. Little shows the great advantage of expressing discharges in terms of the area of flood section and this can be done by combining Dickens formula for discharge with Mannings for velocities. This gives a formula which is approximately of the form :

$$A = \frac{CKM^{0.5}}{S^{0.3}}$$

where A= Area of flood section in square feet.

C= A factor depending upon locality, rainfall, etc.

M= Catchment area in square miles.

S= Slope of river bed at site.

K= A numerical factor depending upon the shape of cross section and given by the formula:

$$K^4 = \frac{P^2}{A}$$

where P= Wetted perimeter in feet.

The author has applied this formula to the Beas flood of 1922 with a 25 per cent. increase and finds that this gives the factor C as 20 square feet per mile where K=2·1. This gives the formula for the Beas as :—

$$A = \frac{20\,KM^{0.5}}{S^{0.3}}$$

The Chakki flood of 1896 gives C as 36 square feet per mile and K=4·3.

The author hopes later to determine the value of C for other conditions. The advantages of a discharge formula expressed in this form are that it eliminates the difficult factors velocity, co-efficient of roughness and hydraulic mean depth. It also shows that an error in the bed slope will not greatly affect the flood area especially in the hills where these slopes are steep.

The Pandoh Suspension Bridge, 288 feet between saddles, is stiffend with two wooden built-up beams 15 inches wide and 10 inches deep calculated, as explained in a previous paper, for a concentrated load of 2½ tons. Tests, however, indicate that the bridge can carry heavier loads than this the reason apparently being that if the stress in the timber exceeds the usual safe limit a larger and larger share of the load is transferred to the cables.

Costs—New Construction.

The costs per mile of several new roads have already been given. In most cases, however, it is quite impossible to tell what a road has cost because improvements are made yearly often out of the maintenance grant and the actual cost is, therefore, very much greater than that booked under capital.

The Larji-Mandi Road in 1927 had cost about Rs. 68,000 a mile excluding improvements charged to maintenance and since then a

considerable amount has been spent on further improvements. The high cost of this road was in the author's opinion due to three main causes :—

(1) No proper surveys.

(2) Under-estimating.

(3) No proper arrangements for financing the work.

The first and second of these are principally responsible for those following since the absence of accurate surveys made accurate estimating impossible and underestimating resulted in a breakdown of the financial arrangements. On the other hand it is equally true that had the question of financing the scheme received more forethought, more money would have been spent on surveys and on investigating the rates and the time it would take to complete. This question of time should be considered from an economic point of view for until a road is opened to traffic the money already spent lies idle. Had interest at 4 per cent. been charged in this case the actual cost of the work would have been about Rs. 22 lacs or Rs. 88,000 a mile.

The financial arrangements failed for not allowing the work to be carried out continuously and expeditiously. The engineer in charge had to arrange his programme often at great loss in order to utilize the funds available instead of the funds being arranged to allow for the greatest economy in construction. Had this been a railway or a canal, work would not have been started unless all arrangements for financing it had been made. For some reason a new road is not considered of the same importance but if losses of this kind are to be avoided in future the same methods must be applied.

Apart from the question of excessive costs the reader will probably ask whether the construction of the road was justified at all. The answer to this can be given without hesitation. The road is a financial success. The saving on the cost of carriage between Mandi and Larji gives a very good return on the capital spent and reduces the cost of transport throughout Kulu as well. Before the road was constructed the cost of carriage was about Rs. 2 per ton-mile of goods and 3 annas per passenger-mile; now it is $6\frac{1}{2}$ annas per ton-mile and one anna per passenger-mile. Interest charges on the capital expenditure work out at about 8 annas per ton-mile and 0·5 annas per passenger-mile and these figures get less every year as traffic increases. Considered as a business proposition it follows that the road could afford to pay a good dividend.

Costs of Maintenance.

The cost of maintenance of the roads in Kulu for the last 5 years are given in Appendix 'B' and the following table gives an approximate

analysis of the costs per mile for those years in the case of the Mandi Kulu Road, 43 miles long :—

TABLE I.—*Maintenance costs-Mandi-Kulu Road.*

Year.	1931—32	1932—33	1933—34	1934—35	1935—36
	Rs.	Rs.	Rs.	Rs.	Rs.
Establishment	140	128	138	140	140
Bridges and Culverts ..	82	106	44	25	100
Walls	59	47	60	50	50
Buildings, etc.	27	15	10	10	10
Metalling and tarring	...	..	..	25	70
Improvements, etc.	192	134	48	..	20
Total ..	500	430	300	250	390
Traffic tons per day	..	..	27	32	38
Cost in annas per ton-mile ..	..	..	0·49	0·34	0·45

These figures should be taken as approximate only as the figures of expenditure for any one road have to be collected from several different accounts and the classification is not always clear.

The author has also shown the cost per ton-mile on account of maintenance which is at present about 0·45 annas. This may be compared with 0·13 annas on the Kangra Valley Road which shows the saving resulting principally for metalling and tarring. In calculating these costs the weights taken are the full weights of loaded vehicles.

Costs of Carriage.

The cost of carriage on the Mandi road between Jogindarnagar railway station and Kulu is approximately 6 annas per ton-mile of goods carried due to the operation cost of running lorries of approximately 2·4 annas per ton-mile. By the cost per ton-mile is meant the cost per vehicle-mile divided by the total weight of the loaded vehicle. The cost of operation on this road may be compared with that under ideal conditions in the plains of approximately 1·1 annas per ton-mile.

The following analysis of these rates is based partly on figures kindly supplied by one of the lorry owners and partly on costs published in "The Statesman" by the General Secretary, Indian Roads and Transport Development Association Limited. The author would also refer the reader to 'Highway Economics' by S. JOHANNESSON, which gives similar figures for America.

TABLE II.—*Vehicle Operation Costs.*

		Plains.	Hills.
	Annual Costs.	Rs.	Rs.
1.	Taxes	200	250
2.	Depreciation due to time	700	700
3.	Insurance, Establishment, Interest, Rent, etc.	2,100	2,100
4.	Total Time costs	3,000	3,050
5.	Miles run per annum	30,000	22,000
6.	Load carried tons	1¼	1
7.	Total weights	2¾	2½
8.	Total ton-miles per year ..	82,000	55,000
9.	Speed, average—miles per hour ..	25	18
10.	Hours per year	1,200	1,200
11.	Time costs per hour, annas	40	41
	Costs per ton-mile in annas.		
12.	Time costs	0·59	0·89
13.	Petrol	0·27	0·93
14.	Oil and grease	0·04	0·09
15.	Tyres	0·10	0·18
16.	Repairs and spares	0·10	0·18
17.	Depreciation due to running	0·04	0·15
18.	Total cost per ton-mile	1·14	2·42
19.	Cost per vehicle-mile	3·14	6·08
20.	Cost per ton of goods	2·51	6·08

Note :— (8) = (5) × (7) ; (10) =(5)/(9) ; (11)=(4)/(10) (12)=(4)/(8); (19) =(18)×(7) ; (20)=(9)/(6).

Operation costs are affected principally by the following factors :—

(1) Road surface.

(2) Gradient.

(3) Curvature.

(4) Width of road.

(5) Cost of petrol, oil, etc.

These five factors do not act independently. The first four are principally responsible for the fifth; their effect is largely, by reducing speed and car-miles per annum, to increase the item due to 'Time costs.' But the speed limit at any point is generally determined by one factor only, surface, gradient, curvature or width in which case an improvement in the other three factors only will have little effect in reducing costs. For example, more advantage will be gained by reducing curvature on a level road then on a steep hill and a smooth road surface is of more importance in the plains than in the hills. Properly to determine their effect it is, therefore, necessary to consider a few different combinations of all four factors.

In this way the whole road can be classified under different types and the percentage length of road of each type can be measured.

If now the cost per ton-mile is known for each type of road the average cost for the whole road will be got by multiplying the cost under each type by the corresponding percentage length and summing for all types.

The author hoped to do this for the road between Jogindarnagar and Kulu and by comparing the result with the actual cost already given, namely, 2·4 annas per ton mile to check the calculated type rates. But unfortunately, he has not yet been able to collect statistics of the actual curvature and grades on the road. The author will, therefore, give only the rates as calculated for a few simple types of road. The calculations are based on 'Road Vehicle Performance' by R. W. Collins.

Surface.

Straight, wide, level, road with different *surfaces.*

The effect of road surface on operation costs is shown in the following table. Figures for load carried, speed and road resistance have be

assumed. Petrol costs have been assumed as proportional to total road resistance:

TABLE III.—*Operation costs due to Different Surfaces.*

	Surface.		
	A. Tarred	B. Hard clay	C. Very bad
Load carried tons	$1\frac{1}{4}$	1	$\frac{3}{4}$
Weight of lorry loaded tons ..	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$
Speed average miles per hour ..	25	20	10
Ton-miles per hour	69	50	23
Wind resistance lb. per ton ..	22	16	5
Road resistance lb. per ton ..	22	50	70
Total resistance T. lb. per ton ..	44	66	75
Costs per ton-mile in annas.			
Time costs at 40 annas/hour ..	0·58	0·80	1·74
Petrol and Oil $\frac{T}{75}$	0·59	0·88	1·00
Tyres, repairs, spares and depreciation.	0·24	0·32	0·50
Total ..	1·41	2·00	3·24

If now we assume that 75 per cent. of the total length of the road is of type B and 25 per cent. of type C we get for the whole road:

$$0{\cdot}75 \times 2{\cdot}00 = 1{\cdot}50$$
$$0{\cdot}25 \times 3{\cdot}24 = 0{\cdot}81$$
$$2{\cdot}31 \text{ annas ton-mile}$$

These are roughly the conditions of road surface on the Mandi Kulu Road and the average cost of 2·3 annas per ton-mile when compared with the actual cost of 2·4 shows that road surface alone will almost account for the increase in the operation costs on this road as compared with one in the plains. It is only with an improved surface that the other factors become of importance. The greatest loss is due to restrictions of speed and of useful load carried and all factors which are responsible for these restrictions should, therefore, be considered together.

Gradients.

Straight, wide, tarred road with different *gradients.*

The effect of gradients on operation costs is shown in Table IV:

TABLE IV.—*Operation costs due to different gradients.*

Gradient—G	Level 0%	Up +5%	Down —5%	Up +10%	Down —10%
Speed miles/hour ..	25	10	20	5	20
Load carried tons ..	1¼	1¼	1¼	1	1
Total load W tons ..	2¾	2¾	2¾	2½	2½
Ton-miles per hour ..	69	28	55	13	50
Wind resistance lb. per ton ..	22	5	16	1	16
Road resistance lb. per ton ..	22	22	22	22	22
Gradient resistance lb. per ton 2240 G. ..	0	112	—112	224	—224
Total resistance T lb. per ton ..	44	139	0	247	0
Costs per ton-mile in annas.					
Time costs at 40 annas per hour ..	0·58	1·43	0·73	3·07	0·80
Petrol and oil T/75 ..	0·59	1·84	..	3·30	..
Tyres, repairs, spares and depreciation ..	0·24	0·30	0·30	0·36	0·36
Total ..	1·41	3·57	1·03	6·73	1·16
Average for Up and Down ..	1·41	2·30		3·95	

Here also it will be noticed that the principal increase in cost is due to the reduction in speed. There are many steep gradients between Jogindarnagar and Mandi which cannot be eliminated and the Table shows that the increase in cost over this section is due to gradient just as much as to bad road surface. It also shows the economic disadvantage of a road over the Jalori Pass where there are about 20 miles with grades steeper than 10 per cent.

Curvature.

Wide, level, tarred road with different degrees of *curvature.*

The effect of different degrees of curvature on operating costs is shown in Table V. For want of reliable figures curve resistance has been assumed as 1/3 lb. per ton per degree which is approximately the figure for railways. The loaded weight of the lorry is taken as $2\frac{3}{4}$ tons.

TABLE V.—*Operation costs due to curvature.*

Degree of curvature per 100 feet.	5°	30°	50°	80°	120°
Average speed, miles per hour ..	25	18	13	7	3
Ton-miles per hour	69	50	36	19	8
Wind resistance lb. per ton ..	22	12	6	2	..
Road do do. ..	22	22	22	22	22
Curve do do. ..	2	10	17	27	40
Total Resistance T lb. per ton ..	46	44	45	51	62
Costs per ton-mile in annas.					
Time costs at 40 annas per hour ..	0·58	0·80	1·11	2.10	5·00
Petrol and oil T/75	0·61	0·59	0·60	0·68	0·83
Tyres, repairs, spares and depreciation	0·24	0·24	0·26	0·28	0·30
Total ..	1·43	1·63	1·97	3·06	6·13

This table shows clearly the loss resulting from sharp curvature and the comparative unimportance of curvature below 30° per 100 feet. The author regrets he has been unable to obtain statistics of the total curvature on the road but the following table shows the results for mile No. 5 beyond Mandi. It gives the percentage length of different degrees of curvature and the contribution of each of the operation cost per ton-mile over that particular mile. The total curvature in this mile is 1,220° (see diagram).

TABLE VI.—*Operation cost due to curvature in mile* 5.

Degree of curvature.	Percentage Length.	Rate.	Total cost.
		annas per	Ton-mile.
	Per cent.		
0—20 ..	55	1·4	0·77
20—40 ..	25	1·6	0·40
40—60 ..	12	2·0	0·24
60—80 ..	3	2·6	0·08
80—100 ..	2	3·6	0·07
100—120 ..	1	5·1	0·05
120—140 ..	2	7·4	0·15
		Total ..	1·76

Table V does not take into consideration either the losses due to accidents on sharp curves or the saving in length when they are removed. These, however, will lead to the same conclusion, namely, that sharp curvature is uneconomical and that it pays to remove it. One advantage of removing curvature is that the width of the road is increased without extra cost.

Many authorities including Wellington (Economic Theory of Railway Location) show that the removal of curvature is not always economical. But in that case they are generally referring to curvature

of less than 10° per 100 feet. On the Mandi-Kulu Road the case is quite different. Probably 50 per cent. of the whole length of road exceeds this limit.

Width.

The width of this road averages about 12 feet and in one or two places is only 8 feet. A large percentage of the traffic consists of pack animals, sheep and goats. The narrowness of the road results in loss of speed which is sufficient to account for most of the increase in operation costs. It would not, therefore, be economical to tar the road without at the same time widening it but as explained above this end can be attained by removing sharp curvature as this improvement always provides lots of wide passing places.

The Future.

When we consider schemes for improving communications to Kulu the first which in the Author's opinion deserves attention is one to open up a motor road to the South. The costs of operation on an alignment over the Jalori Pass and the small volume of traffic to be anticipated put that alignment out of court at once.

A tarred motor road between Nalagarh and Mandi would probably result in a traffic of 400 tons gross weight a day which is the present figure for the Kangra Valley road and it would give a saving in the cost of carriage of goods of about Re. 1 per ton-mile. If now we assume that 1 ton of goods is equivalent to 3 tons gross or vehicle weight and that this benefit is enjoyed by 100 tons a day the saving in operation costs or equivalent benefit will be Rs. 33 per mile daily or Rs. 12,000 per mile per year, a figure which would fully justify the construction of a good motor road.

Improvements to the present road would be of benefit rather by increasing the traffic than by reducing operation costs and this increase would not appear unless either the present road in charge of the Mandi State was improved or the new road to the South made. A good tarred road between the Plains and Kulu should increase the traffic on the Larji-Mandi Section to at least 300 tons a day and result in a saving in operation costs of about one anna per ton-mile on that section equivalent to a saving or benefit of Rs. 9·4 per mile per day or Rs. 3,400 per mile per year. This would justify an increase in maintenance charges of Rs. 800 per mile and the capital cost of the improvements. But as already explained it is first necessary to improve the existing road or make the new road between the Plains and Mandi town.

APPENDIX B.

COSTS OF MAINTENANCE ON DIFFERENT ROADS FOR FIVE YEARS.

Road	Mandi-Kulu.		Kulu-Rotang.		Rotang-Lingti.		Luri—Oot Banjar—Rampur.		Other Roads.	
Mileage.	43		40		90		85		53	
	Cost.	Per mile.	Cost.	Per mile.	Cost.	Per mile.	Cost.	Per mile.	Cost.	Per mile.
1931-32 ..	21,400	500	12,700	320	9,400	104	19,100	220	7,200	136
1932-33 ..	18,100	430	10,200	250	12,100	134	19,700	230	7,200	136
1933-34 ..	13,000	300	22,200	560	7,400	82	18,000	210	6,100	115
1934-35 ..	10,800	250	5,900	150	7,900	88	18,800	220	6,000	113
1935-36	16,600	390	8,200	210	6,200	69	23,400	270	6,000	113

APPENDIX A.

Bridges over 80 feet span.

	River.	Name of Bridge.	Type.	No. of spans.	Waterway feet.	Slope feet per mile.	Catchment square miles.	Flood area square feet.	Date of flood.	Loading (approx.)	Clear width of roadway feet.	Year when built.	Cost Rs.	Cost per foot Water way, Rs.
	Kangra Valley Cart Road													
8	Chakki ..	Lyall Viaduct ..	Brick arches ..	38	1515	28	250	12,000	August 1896	10-ton Road Roller.	16	1901	1,18,000	78
3	Grail ..	Grail ..	Concrete arches ..	6	144	50	30	..	..	do.	10	1902	..	..
9	Dehar ..	Dehri ..	Through girders ..	2	182	40	65	..	..	do.	12	1903	30,100	165
5	Buner ..	Buner ..	Deck girders ..	1	158	100	45	..	..	do.	12	1908	43,400	275
5	Neogal ..	Neogal ..	Brick arch ..	1	136	150	45	..	..	do.	12	1867	63,700	468
2	Luni ..	Binwan ..	Deck girders ..	1	124	100	70	1,400	..	do.	14	1928	1,54,500	1,250
	Larji-Mandi Road.													
1	Suket ..	Suketi ..	Stone arches ..	3	180	25	160	5,000	..	10-ton Roller.	11	1922	1,74,000	968
2	Beas ..	Pandoh ..	Suspension ..	3	312	40	2,140	6,500	12-8-22	2½ ton lorry.	10	1923	1,76,000	563
	Kulu-Manali Motor Road													
1	Phojal ..	Dhobi ..	Through girders ..	1	96	250	50	..	..	4-ton axle	10	1934	12,100	126
1	Sajain ..	Beli Sajain ..	do. ..	1	80	500	30	..	..	do.	10	1934	10,300	129
	Manali to Lingti Mule Road													
4	Beas	Manali ..	Wooden cantilever	1	90	140	138	..	..	60 lb./sq ft.	..	..	..	..
3	Chandra ..	Koksar ..	Steel arch ..	1	136	50	720	..	..	do.	6	1933	17,800	131
5	Bhaga ..	Thandi ..	Wooden cantilever	1	104	70	580	..	..	do.	6	..	..	..
3	Kado Tokoo ..	Darcha ..	do. ..	1	100	80	210	..	..	do.	6	1927	11,400	114
	Simla-Kulu Road.													
1	Tirthan ..	Khundan ..	Wooden cantilever	1	94	110	154	..	..	do.	8	1927	6,200	66
4	Tirthan ..	Phagu ..	Suspension ..	1	128	90	190	..	..	do.	6	1924	22,400	175
0	do. ..	Dhaman	Wooden cantilever	1	133	70	260	..	..	do.	6	1931	11,700	88
2	Sainj ..	Larji ..	Suspension ..	1	120	90	290	..	..	do.	6	1897	..	..
4	Beas ..	Oot ..	Suspension ..	1	210	30	1,340	..	..	do.	6	1900	16,000	76

Other Roads

DIAGRAM SHOWING CURVATURE IN MILE 5 MANDI KULU ROAD

PLATE I
(Paper 200)

TOTAL CURVATURE = 122°
AREA 1 sq·IN = 360°

SCALE { HORIZONTAL 1 INCH = 600 FEET
VERTICAL 1 " = 60° PER 100 FEET

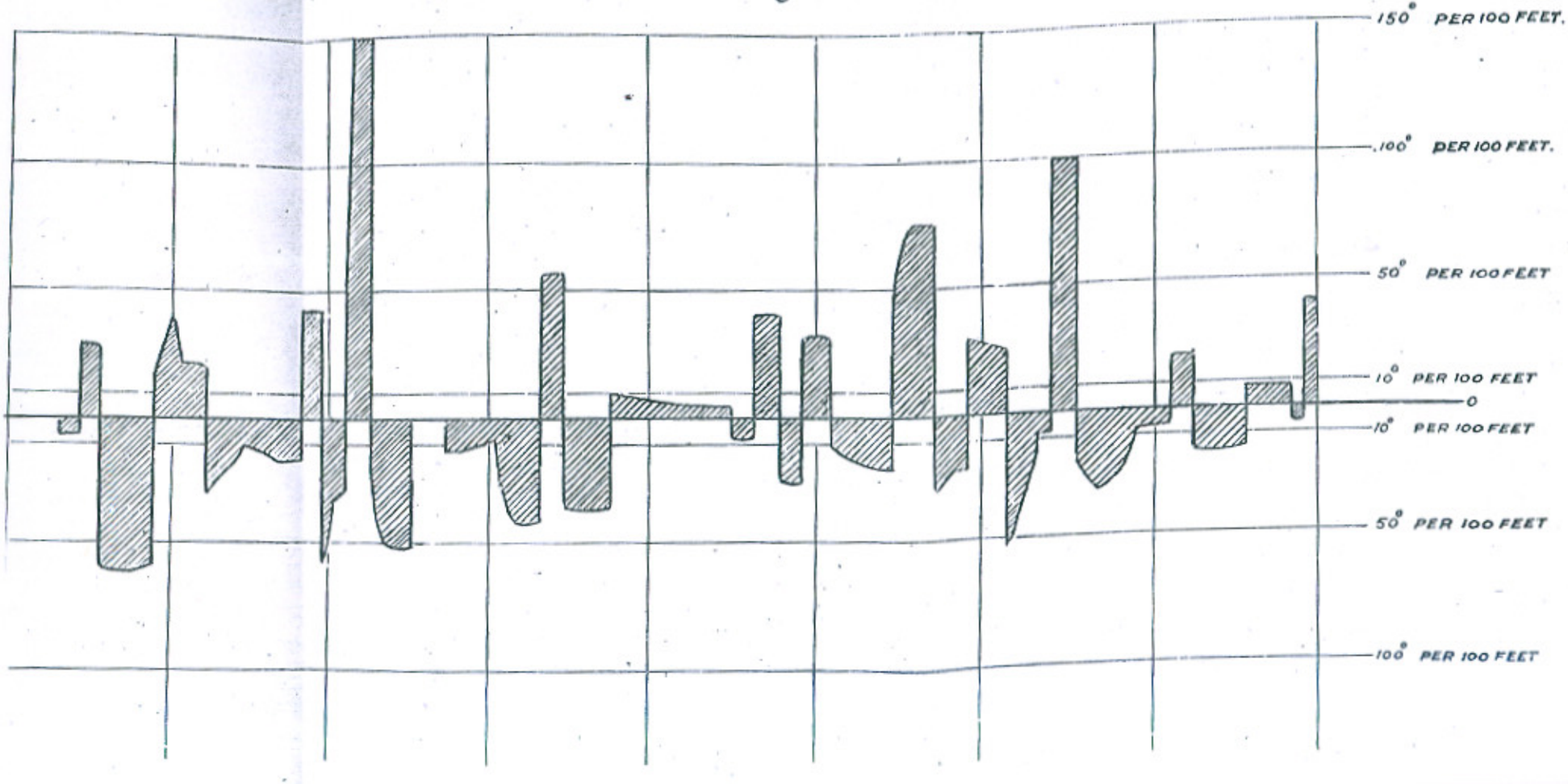
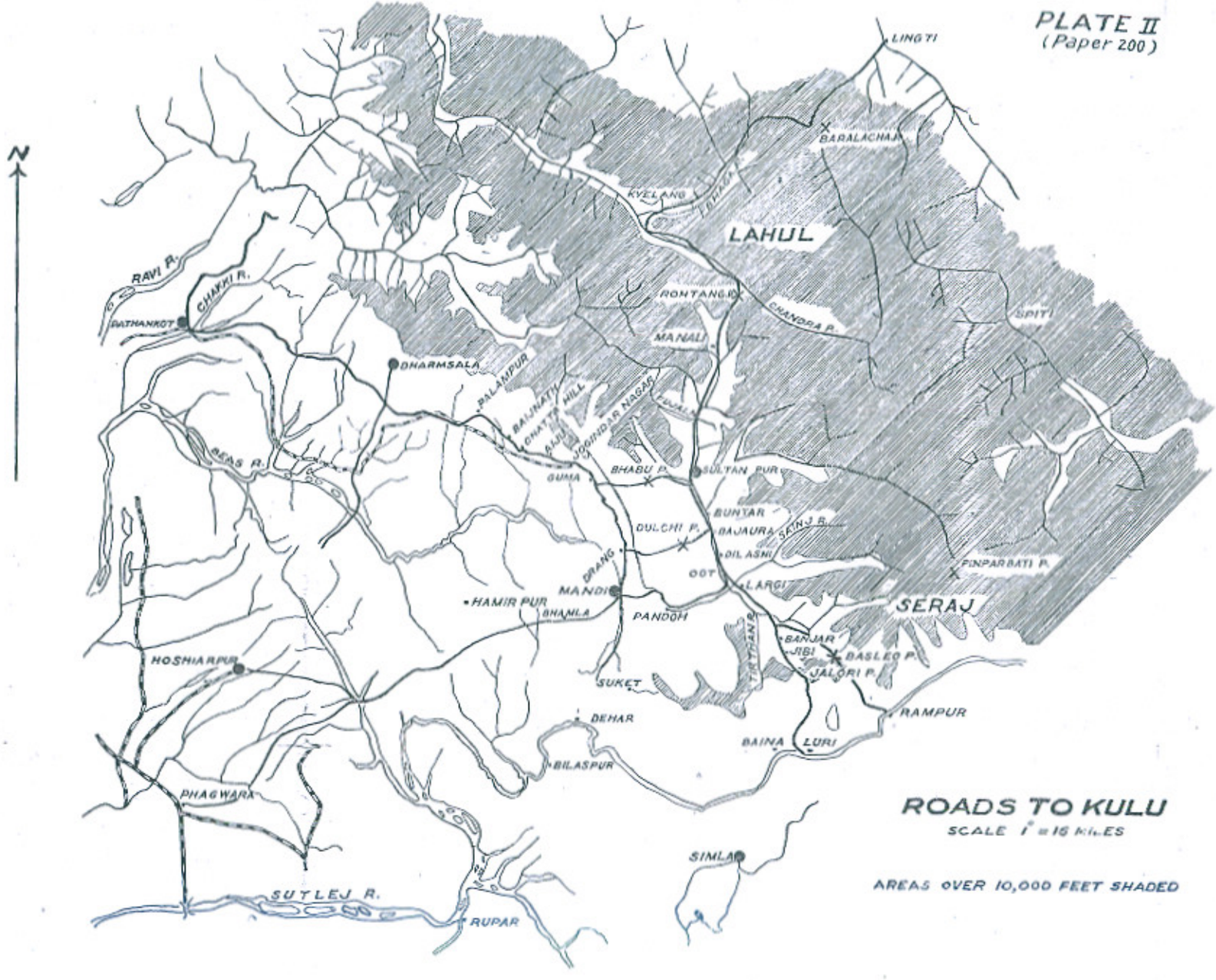


PLATE II
(Paper 200)



ROADS TO KULU

SCALE 1" = 16 MILES

AREAS OVER 10,000 FEET SHADED

DISCUSSION.

Mr. **J. Halcro Johnston** in introducing the Paper, said that he wished in the first place to correct a few mistakes which had come to light since the Paper was printed :—

Page 57. The Author of the Paper referred to in the last paragraph should read Mr. LILLIE instead of LITTIE.

Page 61. The last equation at the bottom of the page should read (19)/(9) not (9)/(6).

Page 67. Due to a mistake in the divisional traffic statistics the present traffic on the Kangra Valley road was shown as 400 tons gross per day (see paragraph 2 under *The Future.*) This should read 150 tons gross.

In the same paragraph the following corrections should be made for the same reason :—

for 100 tons *read* 75 tons.
,, Rs. 33 per mile *read* Rs. 25 per mile.
,, Rs. 12,000 per mile *read* Rs. 9,000 per mile.
and in the last para :
for 300 tons .... *read* 100 tons.
,, Rs. 9·4 per mile *read* Rs. 4·4 per mile.
,, Rs. 3,400 per mile *sead* Rs. 1,600 per mile.

Page 60. 2nd para. between Table I.
for 0·13 annas *read* 0·3 annas.
Appendix A, 1st Line. Lyall Viaduct.
For 38 spans *read* 37 spans.
,, year 1901 *read* 1891.
,, Rs. 1,18,000, *read* 2,00,000.
,, cost Rs. 78 per foot *read* Rs. 132 per foot.

The cost of the last bridge of the Appedix should read Rs. 34,100 not Rs. 100.

Mr. **W. H. Donald** at one time a member of this Congress had kindly sent the Author a note on the Roads to Kulu which he would like to read. Mr. Donald's long connection with the work had been

referred to in the Paper. He had had more experience of these roads than anyone else and his views were therefore of special interest.

Note by Mr. W. H. Donald.

"In 1858 some of the mutineers, who tried to escape, went through Lahoul and used the pathways over the Dulchi Pass, then known as the Rapru sheep track which still exists. It consisted of steps like that over the Rotang Pass.

Tea was planted by Sir John Lawrence in 1848 at Palampur and Chinamen came with the trade caravans from Central Asia through Lahoul and Kulu to Kangra and were employed in Kulu to plant the tea in Bajaura, Raison, Dobie, Katrain and Naggar. This was in 1864.

The road over the Bhabu Pass on both sides and the bungalows at Silbadwani and Karaon were made between 1866 and 1868 by Mr. Le Marchand. The Koksar bridge was built as a Sangha bridge by Mr. Elvis in 1869 when 80 men lost their lives on the Rotang Pass in a snow storm.

Mr. Theodare had charge of the roads and buildings in Lahoul up to 1885 and J. S. Mackay from 1886 to 1892.

From 1894 when Kulu was constituted a P. W. D. Sub-Division it was held by W. H. Donald, up to 1918. Since then there have been regular service charges.

On 24th May, 1894, there was a record hill slide combined with ice, mud, debris and large boulders. Blocks of ice from $5' \times 5' \times 5'$ to $20' \times 10' \times 8'$ came down with large boulders of the same dimensions and in some cases larger. This caused the destruction of all the cantilever bridges on the Fojal and on the Beas between Katrain and Bajaura.

In 1898 there was cloudburst between Bhuin and Larji which destroyed the road on the Mandi side, carried away the bridge at Bajaura and a land slide down the Dilasui Nullah destroyed the Dilasui cantilever bridge of 155 feet span. This necessitated the construction of the Bajaura Nullah Pass Road in British territory and the Dilasui Larji Road with the Suspension Bridge at Oot, and improvements of the road between Larji and Luri over the Jalori Pass.

In the Kangra Earthquake of 1905 the Duff Dunbar suspension bridge was destroyed and was restored as a mule track.

The Larji-Mandi bridle road or test path was begun in 1909 and was completed as a motor road in 1927. The first motor was brought to Kulu on 7th February, 1927.

The rest of the Kulu Roads from Oot to Manali became automatically motor roads and cars and lorries plied regularly.

A motor went twice over the road from Oot to Simla *via* Larji and the Jalori Pass so there is nothing against motors running regularly."

Mr. **M. F. Thomson** remarked that he was particularly interested in this Paper as he lived in the neighbourhood, but there were one or two points which did not seem to be included in the Paper. No mention

was made of the road from Mandi to Hoshiarpur *via* Bhambly. While he knew that this road was not aligned for motor traffic, he understood that the surface was not too bad and he thought that it would not be very difficult to re-align it. In addition, the cost might not be so excessive, as the road already existed. He agreed that it did not pass through a populous part of the country and had this disadvantage. The other road, which did not appear to have been mentioned was the road from Hoshiarpur to Kangra. He would like to know if there was any particular reason why the Author had omitted this in his Paper, as this road was suitable in alignment for motor traffic although he understood that the surface suffered during the monsoon.

One other point was that no mention was made of the road which had been mooted from time to time that connected Baijnath with Kulu *via* Swarkothi. The speaker quite agreed with the author that these hill roads were not satisfactory for several reasons.

With regard to the road from Rupar to Mandi he would like to know how soon this road could be made suitable for motor traffic, provided Government was willing to expend a reasonable sum of money.

Mr. **W. C. Chopra** remarked that he had had the good fortune of having travelled by all the alternative routes to Kulu from Baijnath, namely, by the Bhabu-pass route through Jatingri and Silbadhwan the Dulchi-pass route through Bajaura, and the Mandi route through Pandoh and Oot. He would like, as a traveller, that Dulchi-pass route between Bajaura and Drang be converted into a good motor road. The author said on page 51, that proposals for this were given up on the score of cost. It was not clear why cost should be particularly heavy when no great heights were to be negotiated, the pass being only at 6,700 feet. If this road was built it would be open all the year round, and the real bad portion left would be that between Ghatta and Drang. The Bhabu-pass road could not really be shorter and certainly would be more costly on account of the pass being at about 9500 feet, and the road snow-bound during winter. The "Mandi proper" length would then be used for local traffic or by such people as wanted to have a sojourn at the beauty spot of Pandoh, where the suspension bridge built by the author under very strenuous circumstances lent charm to the glorious scenery around.

It would be interesting to know whether the record flood was that of August 1922 or the one in June 1894. In the latter year it was certainly the highest on the Grand Trunk Road, and since the rainfall at Dharamsala was also the highest on record that year, it was likely that up in the hills, also, the record must have been held in 1894. However, the author was correct in saying that the 1922 flood was the highest for a quarter of a century, as 1894 was beyond that limit.

Mr. **H. W. Thick** remarked that he would like to be allowed to supplement Mr. Thomson's remarks. The Electricity branch was now considering the construction of a 132 KV. Trunk Transmission line from Jogindranagar to Delhi. A good road on the line Mandi Baned-Bilaspur-Nalagarh-Rupar would be very useful for the construction and maintenance of such a transmission line ; but it would be even better if such a road were extended right down to Ambala. He would like to explain that the maps showed a metalled road as existing from Rupar, by Karar to a point near Chandigarh on the Ambala-Kalka Road. Rupar-Karar-Chandigarh-Ambala was about 12 miles longer than the line Rupar-Karar-Ambala and it would save a large sum of money and considerable distance if the above transmission line could follow the more direct alignment.

Mr. **Trevor Jones** made remarks to emphasize the importance of properly constituted surveys as a preliminary to road construction projects, especially hill roads. The preparation of surveys was not quite so easy in the B. & R. Branch as it was in the Irrigation as under paragraph 2·39 of the P. W. D. Code, survey staff could only be entertained to be charged thereafter to the estimate to be prepared. Some such facility should be extended to the B. & R. Branch as it was impossible for the existing staff to undertake survey work of any magnitude in addition to their own duties. He thought, however, Mr. Johnston was unduly optimistic if he ever hoped that a road project could materialize as a comprehensive and complete scheme in one operation as in the case of Irrigation and Railway works. As far as roads were concerned it was a question of doing work piecemeal and as available funds permitted. The Nalagarh-Mandi Road mentioned by Mr. Johnston was on the list for improvement in so far as the Punjab connection was concerned and no doubt in the near future it would be possible to motor throughout; but a tarred and properly aligned road could not be expected just yet.

Mr. **Brij Mohan Lal** said that as he had spent quite a few years in Kangra District prior to 1930 in charge of roads to Kulu, he had read this Paper with keen interest. The author had given a very lucid description of the roads in Kulu and those leading to it, but the map attached to the Paper as Plate II was not sufficiently informative for a stranger. A copy of relevant portion from the map of the Punjab attached to the latest Administration Report of the Punjab P. W. D., Buildings and Road Branch, would have shown all the roads and places more distinctly.

It was very interesting to read in the first few pages of the Paper how the original estimate for construction of each new road proved abnormally low during the execution of the work, and how each road was completed at a much higher cost even after sacrificing the originally intended specifications for gradients, curves and road widths. In this connection he would like to bring to notice that even the main Kangra

Valley Cart Road from Chakki to Palampur was started with an original estimate for Rupees three lacs in 1865 but up to 1875, 8 lacs had been spent and the work was still incomplete. Uncompleted portions were then taken piece by piece in accordance with the funds available and the work dragged on to 1900, when the total cost incurred till that year was above fifteen lacs. All these instances clearly showed the necessity of careful surveys and estimates before any work on hill roads was taken in hand.

The main work in maintenance of roads in Kulu consisted in renewing old bridges. Most of the old bridges of large spans in Kulu were of the cantilever type locally known as "Sangha." Incidentally he would mention that a photograph of one of these bridges in the Paper would have been much appreciated. In the old days, good mature deodar trees were available in the forests, and bridges made from them had lasted more than thirty years. But recently, owing to the heavy exploitation of Kulu forests, mature trees were not available, and therefore the life of the wooden bridges constructed after 1920 had been only 10 to 15 years as stated by the author on page 56. The old wooden bridges were now being replaced by steel girders. He would enquire from the author whether he had considered the alternative of constructing Cement Concrete bridges. With reduction of carriage costs to $6\frac{1}{2}$ annas per ton-mile, cement and steel for reinforcement should not cost a great deal, and with stone aggregate and sand being locally and cheaply available in the nullahs themselves, reinforced cement concrete should not cost any more than in the plains. Concrete bridges should not therefore cost much more than steel girders at Rs. 600 a ton. Moreover, the concrete bridges would not require any maintenance while steel bridges required frequent painting which, if neglected, might shorten the life of the steel bridges considerably. Concrete had another advantage over steel from an aesthetic point of view. In the surroundings of Kulu hills, concrete bridges would look much better. Building of concrete bridges was not a new idea for Kangra, as a number of unreinforced lime-concrete arches were built on the Kangra Valley Road and Chakki-Dalhousie Road in the early eighties of the last century and were standing perfectly well without costing a pie for maintenance. The construction of concrete bridges would no doubt require more skill and supervision, but there were now so many firms specializing in concrete work, that the construction of these would not be a difficult matter at all. It was therefore suggested that the author might try a concrete arch for his next bridge in Kulu. He also mentioned that any future bridge on the Mandi Kulu Road should be designed for a ten-ton steam Road Roller instead of for 4-ton Axle loads, as the road would have to be metalled sooner or later.

In Appendix A the Author had shown the waterway of bridges in running feet and not in square feet. Had he shown this in square feet, it would have been possible to compare it with the flood area.

The speaker also inquired what type of masonry has been used in the abutment of the various steel girder bridges. For wooden cantilever bridges they were usually built in dry stone masonry reinforced with timber framing.

The most interesting portion of this Paper, said the speaker, was the calculation of vehicle operation costs from which the Author had tried to justify the heavy expenditure on these roads. He pointed out item 13 in Table II, page 61, which showed petrol costs for plain sas "0·27 annas per ton mile." This gave the cost of petrol for running a car, assuming it to be 2 ton gross weight only half an anna, that unfortunately the actual was more than one anna per mile. The figure of 93 under column " Hills ", however, appeared correct.

On the last page the Author had visualized the future and suggested a scheme to open up a motor road to the South *i.e.*, to Rupar *via* Bilaspur. From page 51 it would be seen that the estimated cost of this road from Rupar to Mandi was three lacs in 1910. Judging from previous experience, this would not cost less than thirty lacs, a huge sum which he doubted if the Punjab Government would ever be able to finance. Moreover this would pass through four states *viz.*, Mandi, Suket, Bilaspur and Nalagarh. We had sufficient trouble from the Baijnath-Mandi Road which passed through only one State. With four States to deal with, the difficulties could easily be imagined. In the speaker's opinion, all energies for the present should be concentrated on the following works in Kulu given below in this order of urgency :—

1. Widening and improving the road between Oot and Kulu.
2. Improving curves of Mandi-Oot Section.
3. Arriving at some reasonable agreement with the Mandi State for improvement of Ghatta-Mandi Road an removal of tolls.
4. Strengthening of bridges on Mandi-Kulu Road to take 10-ton rollers.
5. Metalling and tarring the road from Mandi to Kulu.

All the above might easily cost about 10 lacs. The above improvements would make Kulu a very popular hill resort, and increase the traffic sufficiently to justify the expenditure.

Mr. **R. R. Handa** asked the author why steel girder-bridges were used in preference to R. C. Bridges. The carriage of big and heavy girders over the hilly roads would be much more costly than the carriage of a few iron bars.

A country like Kulu was eminently suitable to the use of reinforced concrete bridges, as good bajri and sand were available in the bed of the nallah at almost no cost. Timber for shuttering was also available in the nearby forests at very cheap rates. Carpenter labour was also cheap.

Reinforced concrete arches to span across openings as wide as 200 feet had been used with success.

He brought this type of construction to the notice of the B. & R. Branch of the P. W. D. for serious consideration.

Mr. **L. A. Freak** congratulated the author on his interesting account of the history of the development of roads to Kulu and the engineering difficulties experienced. However, in his opinion, the justification for a second road to Kulu was doubtful. There were only 200 acres of fruit gardens and practically no land available for further extension. For 200 acres of orchards there was no need for two roads. The main produce in Kulu was rice, wheat, barley, maize and some sugar at the south end of the valley but these crops were not exported either to the plains or to Simla. If Government had funds to spend on road development then, per rupee available, more people and more produce could be benefited by new roads inthe plains than by a second road to Kulu. In addition, the development of a second route would cause a loss to the Kangra Valley Railway from Pathankot to Jogindra-nagar. However, if a second road to Kulu should be decided on the speaker suggested that the claims of the Mandi-Una-Hoshiarpur route should be considered against the author's suggested Mandi-Rupar route. The former was motorable a few years back though gradients and corners were bad and needed considerable improvement; in Kangra District a regular bus service was running on this route. On the Mandi Rupar route the portion from Mandi to Dehar was motorable but also needed considerable improvement especially to the gradients. Dehar Bridge over the Sutlej would need widening and so far as the speaker was aware no road existed beyond the bridge.

He was obliged to the author for the appendix giving cost of bridges from which it could be seen that in recent years steel bridges were cheaper than wood and that steel girder bridges and steel arch bridges were cheaper than suspension bridges. He would particularly mention the steel arch design used at Naggar and Koksar as this design was very economical and easy to construct by cantilevering out from either side and so made erection simple over rivers in which centerings or supports could not be placed. The parts for such steel arch bridges were not heavy and so could be readily carried in mountainous country as was done in the case of Koksar Bridge where the parts had to be carried over the Rotang Pass and yet the cost of the bridge was reasonable.

Finally, he would suggest that spelling be standardized, in particular he would mention the river Phojal which had been spelt as "Fugale" on page 50, "Fojal" on page 55 and "Phojal" in Appendix A.

The **Author** in replying to the discussion said that several speakers had criticized the proposed road between Rupar and Mandi. Motors had already been over most of this road except for eight miles just south of the Behar Bridge. It would not therefore take long to make it passable for motors throughout. Mr. Thomson had asked how long it would take to convert it into a motor road; this was largely a question of money and the standard aimed at. He agreed with Mr. Freak that there were more urgent calls for roads in the Plains but new roads should be made in the Hills also, if the cost was economically justified. He believed that Kulu would develop very much more than Mr. Freak anticipated.

The road to Rupar should have priority over that to Hoshiarpur for several reasons. It passed through richer and more highly populated country and the cost of construction per mile would be less if all rivers were to be bridged. The Hoshiarpur-Mandi road passed through very difficult country and bridging would be a serious problem. Mr. Thick had given another reason for making a road *via* Rupar. Mr. Brij Mohan Lal had referred to trouble with Native States. He did not see why he should anticipate any difficulty. The trouble which he referred to on the Baijnath-Mandi road was presumanly a bad surface. This could be remedied if Kulu were to contribute a little more to the cost of improving the road.

A Dulchi pass motor road proposed by Mr. Chopra could not be justified financially when there was already a motor road on a much better alignment along the Beas. Mr. Thomson had referred to a road between Baijnath and Kulu. If he would study a map of the country he would see that this was out of the question as there were high mountains in between. Two speakers had asked why Reinforced Concrete had not been used instead of steel for bridges.

Mr. Freak had already explained some of the advantages of steel. Many of the bridges were of very light construction built for pack transport where the spans were great and the cost of erection heavy. In the case of smaller bridges these were often of a temporay nature and it was more economical to use steel beams which could be used over again when the bridge was reconstructed. Supervision in out of the way localities was another great difficulty.

If the bridges were designed for heavier loads as suggested by Mr. Brij Mohan Lal reinforced concrete would no doubt have advantages over steel.

The abutments of the latest bridges were being built with cement mortar.

Mr. Brij Mohan Lal considered that the cost of petrol per ton-mile in the Plains was too low. He was probably correct but it had to be remembered that the rate represented a lower limit for the ideal conditions of a straight, wide, smooth, level road with no traffic and the economical type of engine that would be used in a goods lorry. Under such ideal conditions petrol also would be cheaper and so the cost of carriage would be less.

The same speaker had suggested improvements in the map. More information could have been shown if it were possible to use larger sizes.