PAPER No. 246

SOME MODERN BITUMINOUS RESURFACING METHODS AND THEIR FAILURE UNDER PRESENT-DAY HEAVY TRAFFIC CONDITIONS

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Introduction

It is truly said that our failures are only stepping-stones to success. This is as well demonstrated in the art of road construction as in any other growing industry because the science of road construction is still in its infancy.

It is with this end in view that the author has endeavoured to collect a few examples of resurfacing methods which, in his opinion, have proved a failure and a study of which may indirectly prove of benefit to those who may be embarking on similar construction under similar conditions of traffic.

Need for Experiment

Owing to the growing increase in motor traffic, the art of road construction has undergone a revolution. The old, waterbound road is no longer suitable for the requirements of present-day traffic, nor is it an economic proposition in the long run. Its place has now been taken by bituminous or concrete pavements whose details of construction vary greatly according to the needs of traffic. Each pavement is designed to suit a particular need and it is in these details that the necessity for making experiments is keenly felt.

Position of the Punjab as regards its Roads

Although our Province easily leads other provinces in respect of its tar-surfaced roads, it cannot be said that it has achieved all-round success in the field of road construction ; for there are other Provinces which lead the Punjab in the matter of roads made with cement concrete which is admittedly a superior kind of road crust. For example, the United Provinces possesses the largest mileage of cement concrete roads in India.

Though we can justly be proud of possessing the largest tarred mileage in India, yet this tarred surface is, at best, the old waterbound macadam, surfaced with a bituminous material. Surely this cannot claim to suit all kinds of traffic, and it is here that we have to look for more scientific methods of construction involving greater expenditure.

The notion has gained ground in the mind of the general public and particularly of those who have a say in the control of our finances that, with the adoption of tar for road painting, the road expenditure in the Province should be steadily decreasing,but this notion is wrong, for, although the average cost of maintenance per mile has decreased by about 50 per cent. during the last decade, the total expenditure cannot bear the same proportion due to the ever increasing tarred mileage which is added on to the mileage of the Province from year to year, and the use of better specifications for road crust to stand up to the very heavy traffic in and around big cities where not only a better specification of road surfacing has been necessary but the width of metalling has had to be increased from two to threefold. All this adds to the cost of maintenance, and the notion that road expenditure should go on decreasing with the adoption of tar is erroneous.

Heavy Traffic at Lahore

The traffic on the roads leading into Lahore is specially heavy, amounting to more than 5,000 tons or more than 2,000 vehicles per day of 24 hours. As quite a large proportion of this consists of heavily-laden lorries and bullock-carts the annually painted road surfaces rapidly deteriorate and become uneven and as heavy patching has to be done to keep them passable, their maintenance becomes costly. In order to evolve a more durable type of road crust, a number of experiments have, therefore, been made in the last few years at Lahore.

Lahore—Multan Road near Chauburji

The Lahore—Multan road carries heavy bullock-cart traffic in the first seven or eight miles from Lahore due to the existence of brick-kilns in Mile 7, and the surface of the road on the incoming side to Lahore undergoes a heavy strain. This portion of the road used to get very wavy and bumpy, making motoring very uncomfortable. As the ordinary tar coat over the water-bound surface was not able to stand the traffic, a cement concrete track seven feet wide was added to the existing metalled width on the incoming side to Lahore in Miles 2 and 3 of the Lahore—Multan—Quetta Road in 1934. This track has stood the heavy bullock-cart traffic very well without any repairs worth the name having been necessitated so far, except for filling of joints. However, the portion of the road in front of the Chauburji Quarters was not so treated as the width of the road there was already 30 feet as against 16 feet in the remaining miles.

It was felt that the traffic, when distributed over a wider area, will not break the surface or produce corrugations but it did not turn out to be so and the whole 30-foot width got full of ups and downs transversely as well as longitudinally. As ordinary surface painting did not stand up to the traffic, a better specification of road surfacing seemed necessary and it was decided to lay a one-inch tar carpet in this length which has been described in this paper as Experiment "A."

Grand Trunk Road between Lahore and Ravi

Similarly, the part of the Grand Trunk Road forming a portion of the Circular Road round Lahore between Bhati Gate and the Willingdon Hospital carries very heavy traffic of the order of 7,000 tons per day on a 30-foot width and the surface-painted waterbound macadam was not able to stand it with the result that the surface remained always bumpy and uncomfortable for driving. The portion of the road beyond the Willingdon Hospital after the Chhota Ravi Bridge is not so heavily strained up to the foot of the southern approach to the Ravi Bridge because of the existence of a cart-road alongside the main road to which the bulk of cart traffic is diverted, relieving the main road of an appreciable amount of traffic. The effect of this diversion is very wholesome and the main road which is only surface-painted keeps perfectly all right under motor traffic.

Then again, as we go up the approach to the main Ravi Bridge, the traffic gets concentrated and the surface is damaged as far as its junction with the Lahore—Sheikhupura Road where traffic bifurcates.

So it was very necessary that in these reaches of the road, where traffic is concentrated due to the congestion of combined motor and bullock-cart traffic, some sort of stronger construction of road pavement be provided. Hence a one-inch bitumuls carpet (described as Experiment "C" in the paper) was provided for the portion of the road between Bhati Gate and the Willingdon Hospital and a one-inch tar carpet (described as Experiment "B") for both the approaches to the main Ravi Bridge.

All these experiments were duly carried out in strict accordance with the required specifications but, as the following pages will show, the one-inch bitumuls carpet as well as the one-inch tar carpet failed and a still stronger construction seemed necessary. A proposal was, therefore, sent up to provide a cement concrete road to bear all sorts of traffic (this was to be 40 feet wide up to the Willingdon Hospital to provide four traffic lanes).

However, as the cement concrete road was expensive and it would have taken some time to get it sanctioned, something had to be done in the meantime.

So, as an experiment, "built-up grout" specification (described as Experiment "D" in this paper) was used in a small length of one furlong over a 10-foot width in the lower part of the southern approach to the Main Ravi Bridge on the incoming side to Lahore.

This experiment stood up for some time but got wavy again in the hot weather.

A two-inch thick bitumuls carpet was also proposed and laid in a small length as a further experimental measure in front of the Willingdon Hospital and over the Chhota Ravi Bridge (described as Experiment "E" in this paper). This is standing all right so far and promises to behave better than its sister experiments, the main reason being the immunity of this road from bullock-cart traffic.

This then provides no solution to the vexed problem of mixed traffic. Indeed it requires no mean ingenuity on the part of an engineer to design a road crust which should meet the requirements of two extreme types of traffic—one of the phenomenal bullock-cart with its slow pounding motion and the other of the fast omnibus with its terrific dust-laden travel.

The best crust known so far for such mixed type of traffic is, no doubt, the cement concrete road which it will be the aim of this paper to stress.

Experiments Described

Details of Experiment "A"

Brief Specifications

Materials required per hundred s.ft. :

		Aggregate	*Binder*
1.	Tack coat ..	.. ..	Tar No. 2, 8 lbs.
2.	Base coat of coarse premix	6 c.ft.—$\frac{3}{8}$" to $\frac{1}{4}$" Pathankote broken stone chips rolled in 1.5 c.ft. of sand after premixing with tar No. 2 at 4 lbs. per cubic foot ..	Do. 24 lbs.
3.	Top coat of fine premix ..	1.5 c.ft. $\frac{1}{4}$" to $\frac{3}{8}$" Pathankote *bajree*. .75 c.ft. $\frac{1}{8}$" to 3/16" Pathankote *bajree* rolled in .5 c.ft. of Pathankote sand premixed at 5 lbs. per c.ft. ..	Do. 11 lbs.
4.	Seal coat ..	1.25 c.ft. of $\frac{1}{8}$" to $\frac{3}{8}$" Pathankote *bajree* ..	Socony Asphalt 11.25 lbs. and 0.75 lb. Socosol

Methods of Mixing and Laying

Mixing was done in rotary mixing drums in 2-c.ft. batches. Sand was added dry to the premix while still in drum and the whole was rotated till the sand was also coated with tar and had stuck to the stone aggregate. Care was taken to see that sand did not form into lumps. Coarse aggregate for the base metal was made up of the graded Pathankote broken stone chips $\frac{3}{8}$" to $\frac{5}{8}$" and for the fine top

course two grades of Pathankote bajri were mixed in the following ratio :

$\frac{1}{4}''$ — $\frac{1}{8}''$ = 2

$\frac{1}{8}''$ — $\frac{3}{16}''$ = 1

The surface of the road was brought to camber by means of cutting down humps and filling up low places, leaving minor irregularities below one-quarter inch to be evened up in actual laying of carpet. A month was allowed to elapse between the patch-work and the actual laying of premix so that patchwork had sufficient time to set up under traffic.

Work of premixing the Pathankote chips and bajri was started on 16th October, 1937 and the actual laying of premix on 28th October, 1937 after the premix had been allowed to weather from 10 to 12 days. Before putting the premix a tack coat of road tar No. 2 at 8 lbs. per hundred square feet was applied with a sprayer. The premix, *i.e.*, coarse aggregate 6 c.ft. of Pathankote stone chips was spread into sections of 100 s.ft. (so as to ensure uniform thickness of carpet) by means of wooden screeds of one inch by one inch section and about 7 feet long laid on the road longitudinally two feet apart. As half the width of road, *i.e.*, 15 feet, was tackled at a time, so the 7-foot long screed just gave the limit for 100 s.ft. section. These strips were moved forward as the work of spreading the premix progressed. Spreading of premix was done by means of toothless wooden rakes so as not to segregate the fines from the coarse metal. Over the coarse premix was laid the fine premix $2\frac{1}{4}$ cubic feet per hundred square feet. This gave a one-inch thick unconsolidated carpet which, when rolled under a steam road roller of 10 tons, was compacted to $\frac{3}{4}$ inch. Rolling was continued till every place had been gone over at least six times and till the movement of the carpet stopped.

The rim of the roller was kept wet by means of wet gunnybags to prevent premix being picked up by the wheels.

The portion thus treated was closed to traffic for the night and a seal coat of Socony Asphalt Grade No. 105 heated to 350° C at 11.25 lbs. per 100 square feet flushed with .75 lb. of Socosol was applied the next morning and covered over with 1/16″ to 3/16″ grit at $1\frac{1}{4}$ c.ft. per hundred square feet and then rolled. The surface was then opened to traffic.

Cost per 100 square feet worked out to Rs. 8-9-0. Work was finished on 12th November, 1937. The carpet presented a very even appearance when the work was finished and behaved quite well during the winter months. However, with the coming of the hot weather, some movement of the premix was noticed and, gradually by March, 1940, the surface got wavy again though not to the previous extent.

As soon as the work in front of Chauburji Quarters was finished, the same gangs which had by this time been trained in this particular work were taken to the Ravi Bridge and work on both the approaches towards Gujranwala and Lahore was carried out to the same specification with the difference that on the Lahore side approach of the Ravi Bridge Wah stone metal and grit were used instead of Pathankote chips and grit. Details of this experiment are given in item I(*a*) and (*b*) of Appendix A.

The work appeared to be all right when finished and compared very favourably with that done in front of Chauburji Quarters but in the ensuing hot weather, movement of the carpet occurred to an appreciable extent on the incoming side of approach to Lahore, although in a few places movement was noticed on the Gujranwala approach too. The Lahore side got very uneven and bumpy probably due to the downward gradient of the road and also due to the weaker quality of Wah stone chips as compared with Pathankote chips used on the Gujranwala side approach where the carpet behaved much better for some times though by the end of March, 1940, the incoming side of both the approaches got furrowed to such an extent that provision had to be made in the annual repair estimate of the road for 1940-41 to reconstruct them.

These experiments, therefore, at their best turned out to be a failure.

Experiment "B"—One-inch thick Bitumuls Carpet

It was decided to lay a bitumuls carpet on the portion of road between Bhati Gate and Willingdon Hospital which carried as heavy a traffic as the approaches to Ravi so that a fair comparison could be made with tar carpets as described in Experiment "A" and done about the same time.

Brief Specifications

Materials required per hundred square feet.

Items	*Aggregate*	*Binder*
Tack coat	.. ....	.. W. R. M. Bitumuls mixed with equal quantity of water—5 lbs.
Base coat	.. 6.4 c.ft. $\frac{3}{4}$″—1″ Wah stone chips 1.6 c.ft. $\frac{1}{8}$″—$\frac{1}{2}$″ Wah stone chips	
Coarse aggregate	.. 8 c.ft. premixed W. R. M. Bitumuls at 4.5 lbs. per c.ft. =	36 lbs.
Top coat fine aggregate	.. 2 c.ft. of $\frac{1}{8}$″—$\frac{3}{8}$″ Wah stone chips $\frac{1}{2}$ c.ft. of $\frac{1}{8}$″—1/16″ Wah stone chips 1$\frac{1}{2}$ c.ft. of Pathankote sand	
	4 c.ft. premixed at 7 lbs. per c.ft. =	28 lbs.
		69 lbs.

Mixing was done as before in the case of tar premix in 2 c.ft. batches in revolving drums in the proportion mentioned above. Work of premixing Wah stone chips with W. R. M. Bitumuls was started on 15th November, 1937. Actual laying of carpet was started on 19th November, 1937, so that the premix had four days to weather out.

The surface was first indented with pick axes with holes about an inch deep and a foot apart all over. All loose scales from the surface were removed and surface below the scales was also roughened so as to provide a bond for the premix. After thoroughly cleaning surface with brushes a tack coat at 5 lbs. W. R. M. bitumuls per 100 square feet mixed with 5 lbs. of water was applied by means of a spray pump.

After bitumuls had broken up on exposure to sun, *i.e.*, when the colour of emulsion changed from grey to black, a layer of coarse premix (base coat) $\frac{3}{4}''$ thick was laid at 8 c.ft. per 100 square feet. The surface had been divided up into sections of 100 square feet by means of wooden screeds which helped to maintain uniform thickness of carpet.

After laying the base coat about 250 feet length and 15 feet wide for the day's work of roller, it was lightly rolled with a 10-ton roller in the afternoon after the premix had been exposed for two or three hours. Then the fine stuff (top coat) at the rate of 4 cubic feet per 100 square feet was laid over it and before closing the day's work in the evening the surface was again lightly rolled.

The road was kept closed to all traffic for five to six days and opened only after it had thoroughly set. During the setting period it was discovered that portions of road which were under shade of trees did not set hard and remained loose and had to be patched up with extra emulsion mixed with the fines. Unfortunately, the weather was not quite bright during this operation and actually cloudy and chilly weather prevailed which deleteriously affected the carpet, for no sooner the rain fell than the carpet began to come off in loose sheets showing thereby that the carpet had not stuck to the old surface nor had even set up. The whole carpet had to be removed afterwards and thus the experiment was wholly a failure.

The probable reasons for its failure appear to be:

(1) A slow-setting Bitumuls W. R. M. having been used as a tack coat instead of a quick-setting emulsion like H. X.

(2) Bad weather.

(3) No seal coat had been given, with the result that the rain that attended the laying of the carpet percolated into and disintegrated the premix.

Fortunately, only a small length of the carpet was laid as, on account of the All-India Exhibition in December, the work had to be stopped and it was not resumed as the carpet had broken up.

Experiment "C"—Two-inch thick Bitumuls Carpets

As one-inch bitumuls carpet described in Experiment "B" had failed, Mr. Kerr of Bitumuls Emulsion offered a better specification involving the use of a grade of Bitumuls which was adopted as a further experimental measure with certain slight modification in order to utilize the materials salvaged from Experiment "B" already referred to.

Specifications are set forth in Appendices "B" and "C." The cost per 100 square feet works out to Rs. 15.

The work was commenced and finished during the month of August, 1938, and has so far stood well as already referred to in paragraph 3 of this paper. Unfortunately, however, this portion of the road does not carry bullock cart traffic, hence this experiment, too, does not provide any solution for the mixed type of traffic.

Experiment "D"

Built-up Spray Grout Consolidation

It was mentioned in Experiment "A" that one-inch tar premix had failed and the surface over the Ravi Bridge approaches got wavy again. So, as an experiment, a strip of road, 10 feet wide and one furlong in length, on the extreme incoming side to Lahore at the end of the eastern approach, was scarified down to the soling coat. The scarified metal was found to be too full of tar and bitumen and the excess of binder might have been the reason for the movement of surface.

The old metal was now broken up and screened through screens of different gauges to get graded metal for being reused.

The old metal from $\frac{3}{4}''$ to $1\frac{1}{2}''$ gauge was used with fresh metal of the same gauge to form a total thickness of $4\frac{1}{2}''$ loose metal. This was consolidated to "spray grout specification," *vide* Appendix "D."

In the remaining length of the same approach only fresh metal $1\frac{1}{2}''$ thick was consolidated on top of the old surface after bringing the same to proper camber and uniform grade, to the same specification.

But none of these experiments have been able to arrest the wave formation.

Thick Premix Carpets Described

The experiments described in the foregoing pages were those made by the writer himself and did not include thick premix carpets worth the name. Under this head some experiments made by other engineers in heavily trafficked areas outside the Province will be mentioned to make the paper more useful and illustrative.

In Delhi, similar problems have arisen on the roads leading to railway goods shed where heavily laden iron-tyred bullock carts commonly called "*thelas*" ply for hire.

In 1931 the Municipality laid $2\frac{1}{2}$" Shell Crete to the specification of Burmah Shell Company (see Appendix E), on the Hamilton Road leading to the railway goods shed. This is in fair condition. Two-and-a-half-inch asphalt concrete was laid on the road from Ajmeri Gate over the bridge to Pehar Gunj Police Station. This road is subject to heavy *thela* traffic. It has become uneven. In 1936, Lal Kuan Road was similarly treated. It has become so rough that $1\frac{1}{2}$" coat is being given over it this year.

So the experiment of $2\frac{1}{2}$" asphalt concrete, too, has not proved a success.

Briefly the specifications of this concrete are as follows:

Materials required per 100 square feet:

Aggregate		*Binder*	
Stone 1" to $\frac{3}{4}$"	20 c.ft.	Shelmac B. S. at 3 lbs. per c.ft. of stone	= 60 lbs.
Badarpur sand	10 c.ft.	at 9 lbs. per c.ft. of sand	= 90 lbs.
			150 lbs.

Shelmac B. S. is heated to 275° F.

Stone grit is first put in the mixer and stirred over with a few turns of the machine before Shelmac B. S. is poured over it. Then Badarpur sand and binder at the rate of 9 lbs. per c.ft. of sand is added and turned over.

Mixture 3" to $3\frac{1}{2}$" loose is laid on the road and consolidated to give $2\frac{1}{2}$" carpet.

Conclusion

For detailed specification, see appendix "E."

From the foregoing experiments it will be inferred that none of these bituminous carpets have been able to provide a satisfactory permanent smooth surface for the very heavy mixed type of traffic, *i.e.*, iron-tyred bullock carts and motor buses.

As against this, cement concrete tracks made about this time and even as long ago as the year 1926 are standing quite well, for example the seven-foot concrete track made in mile 2 of the Lahore—Multan—Quetta Road in 1934, and the 10-foot concrete track in Mile 306, Grand Trunk Road, made in 1937, both of which carry heavy bullock-cart traffic. Outside this Province, concrete pavements have met with still greater success. In Benares the first length of concrete road was laid in 1926 and is still keeping in excellent condition.

During 1927—30 concrete pavements were laid in a portion of the road between Benares and Moghalserai and Unao to Cawnpore and, in the opinion of the Superintending Engineer, 1st Circle, P.W.D., United Provinces, these lengths do not show any signs of breaking up except a few temperature cracks here and there. Quite adjoining to our Province, in Delhi, concrete roads were made in Chandni Chowk and portion of Queen's Road running parallel to the railway goods shed. Both of these carry very heavy traffic, especially the latter, and are standing up quite well since 1934 without any maintenance.

One is, therefore, driven to the irresistible conclusion that cement concrete is the only suitable material for producing a road surface which will stand up to any kind of heavy traffic and will not suffer deterioration for a long time. The Superintending Engineer, 1st Circle, United Provinces, opines that the life of the concrete pavement can be safely taken as more than 20 years.

The reason for this seems to be obvious. Owing to the extreme heat of the Indian plains, the bituminous carpet gets plastic and movement of the aggregate takes place under the traffic producing corrugations and ruts.

The tendency in the past in this Province has been to use more and more of tar and bitumen for its roads due to its cheap initial cost and this is why the Punjab leads other Provinces in respect of its tar surfaced roads but to say that the Punjab has the best roads in India and that it has reached the zenith of road condition and facilities is to deceive oneself for the Punjab road is, as already referred to in introductory paragraphs, only an improved type of the old orthodox waterbound macadam which cannot be expected to be permanent and stand up to the heavy traffic and must, where traffic conditions demand, be replaced by more durable and scientific methods of road construction. There is no doubt that cement concrete is the finest medium known for such demands but it is not suggested that concrete is required universally throughout the Province but in localities where traffic has grown or is likely to grow out of all proportion, to the existing road capacity, concrete roads should be provided as early as possible.

The only obstacle in making a cement road is its heavy initial cost but it should be borne in mind that a concrete road in the long run is more economical than any thick bituminous carpet or almost equal in cost to a waterbound macadam road where newly constructed (*vide* Appendix " F "). Even if there be a slight difference of Rs. 150 per annum (as actually worked out in the table in Appendix " F ") it will be more than offset by comfort and pleasure in driving and the absence of obstructions in traffic involved in the frequent subsequent resurfacings.

Having thus seen the desirability of possessing concrete roads in the Punjab, it is suggested that this construction should be used wherever any entirely new road is to be built or widening of the existing road is to be done as it has been shown (in the Appendix "F") that concrete road 6″—4″—6″ almost cost the same as 3″ waterbound macadam over 4½″ brick soling with two coats of tar taken over a period of 20 years. The widening, of course, will have to be done on one side of the road only, preferably on the incoming side to towns, for it will be this side that will carry the heaviest traffic. Thus the widening will provide a concrete track by itself alongside the existing road. This track may appear to be assymetric with respect to the centre line of the metalled road but it will be only a temporary phase in the programme of road development, for a time is soon approaching when at least the main arteries will have to be 30 feet wide and then another concrete track may be added on the other side. But the point about symmetry is not so important.

The only question that remains to be solved is: How is this heavy initial cost of concrete road to be met? The solution lies in borrowing the money for which a loan is to be floated by the Government. As capital is idle these days, it will be found that the loan will be readily subscribed to at a cheap rate of interest.

As regards payment of capital, it will be seen (from the table in Appendix "F") that, with the yearly maintenance together with the amount of interest and payment of capital in equal instalments, is about the same in all cases except the last type of resurfacing in Column 6 which is, of course, recommended where traffic is light.

Annual liability thus being almost the same in the case of concrete road and bituminous pavements, the advantage of possessing the concrete road is obvious.

Cement, which is the principal item in cement concrete roads, is cheaply available these days and so is the capital required for initial outlay; there is, therefore, every reason why cement concrete roads should be provided wherever conditions of traffic so demand and for new construction and widening of roads.

Statement showing pa

1	2	3	4	5	6	7	8	9		10	
							Temperature	Rainfall			
Name of Division	Name of Road	Mileage precise limits, experiment length treated	Length, breadth and area of experiment and height of embankment	Date of commencement and completion	Nature of materials and condition of old road treated including subgrade soling and how treated	Specifications or specifications with particulars of the areas to which they apply	(*a*) During construction, (*b*) Range during a year	(*a*) During construction	(*b*) Yearly average	(*a*) Quantities and kind of aggregate used with rates and cost stating whether it was graded or not	If graded percentage of different sizes used
1. 1st Lahore Provincial Division A (*a*)	G. T. Road	Mile 3 (F$\frac{3}{3}$ to 2/7) Mile 4 (3/1 to 3/3)	(1) Gujranwala side approach of Ravi Bridge— Length done = 1640′ Breadth = 24′ Area = 39,360 s.ft. (2) Lahore side approach— L=(2112′+475′)=2587′ Breadth=27.2′ (average) Area= 70,536 s.ft. (*a*) Height of embankment above G. L. for Lahore side approach = 9′ Height of embankment above G. L. for Gujranwala side approach = 13$\frac{1}{2}$′. (*b*) Height of embankment above H. F. L. for Lahore side approach= 5$\frac{1}{2}$′ (Av.) Height of embankment above H. F. L. for Gujranwala side approach of Ravi Bridge= 10$\frac{1}{2}$′ (average.)	Date of commencement = 19thNovember 1937 Date of completion = 23rd December, 1937	(*a*) Gujranwala side approach—brick-on-edge soling 4$\frac{1}{2}$″ thick metal consolidated and then tarred. (*b*) Lahore side approach— Flat brick soling 3″ thick and 6″ stone metal consolidated and then tarred.	1″ Tar Premix briefly described in the body of the paper.	(*a*) Not known (*b*) 55°.	Slight rainfall during construction	17·9″	(1) Pathankote chips $\frac{3}{8}$″ to $\frac{1}{8}$″ = 2,425 c.ft. @ 28/-% c.ft. = 679. Pathankote chips $\frac{1}{4}$″ to $\frac{3}{8}$″ grit = 700 c.ft. @ 28/-% c.ft. = 196 Pathankote chips $\frac{1}{4}$″ to 3/16″ grit. 1,025 c.ft. @ 30/-% c.ft. = 307 (2) Wah chips $\frac{1}{2}$″ to $\frac{3}{4}$″ = 3,162 c.ft. @ 30/-% c.ft. = 949 Wah chips $\frac{1}{8}$″ to $\frac{1}{2}$″ = 1,246 c.ft. @ 30/-% c.ft. = 374 Wah chips $\frac{1}{8}$″ to $\frac{3}{8}$″ = 1,500 c.ft. @ 28/-% c.ft. = 420 Wah chips $\frac{1}{8}$″ to 1/16″ = 125 c.ft. @ 28/-% c.ft. = 35 Total cost =3,050 The aggregate was graded.	..
2. A (*b*) First Lahore Provincial Sub-Division	G. T. Road	Mile 1 (0/3 +400) to 0/6)	Length = 985′ Breadth = 30′ Area = 29,550 s.ft. Length = 1175′ Breadth = 15′ Area = 17,625 s.ft. Total area= 47,175 s.ft. (*a*) Height of embankment above G. L.=1$\frac{3}{4}$′ (Av.) (*b*) Does not arise.	(B) BITUMULS CARPET 1″ THICK Date of commencement = 19th November 1937 Date of completion = 30th November, 1937	Flat brick soling 3″ thick and 4$\frac{1}{2}$″ stone metal consolidated and then tarred	1″ Bitumal Carpet as described in the Paper.	(*a*) Not known. (*b*) 55°.	Rainfall during construction.	17·9	Wah Chips $\frac{3}{4}$″—1″=3,647 c.ft. @ 30/-%c.ft.=1,094 Wah Chips $\frac{1}{2}$″—$\frac{3}{4}$″=650 c.ft. @ 30/-% c.ft.= 195 Wah Chips $\frac{1}{4}$″—$\frac{3}{8}$″=1,050 c.ft. @ 28/-% c.ft.=294 Wah Cbips $\frac{1}{8}$″—$\frac{1}{4}$″= 350 c.ft. @ 28/-% c.ft. = 98 Pathankot Sand = 650 c.ft. @ 26/-% c.ft.= 169 Total = 1,850 The aggregate was graded.	..

APPENDIX "A"

particulars of premix carpet on roads in Lahore

(A) 1" Tar Premix

		11				12	13	14					15	16	17
	Thickness of metal laid for surfacing and consolidation	Quantities and precise description of binder used with rates and cost				Labour cost with analysis of number of different classes of labour, men, days and daily wages of each class	Description of plant used	Total cost for jobs and cost per hundred s.ft. for:					Camber given to finished surface	Mean yearly traffic per 24 hours, motor vehicles and bullock carts separately	Nature and condition of roadside avenues. To what extent the work shaded from sun, protected from weather generally, or subject to drop from the trees
		Coaltar	Socony	Socosoil	Total			(a) Aggregate	(b) Binder	(c) Labour including fuel and sundries	(d) Operation of plant	(e) Total			
	1" thick unconsolidated.	89 drums @ 4·5 cwt. =20 ton @ 133/- per ton=2,660	35 drums @ 3.5 cwt. = 6 ton @ 155/- per ton=930	3 drums @ 4·5 cwt = 67 ton. @ 155/- per ton = 104	3,694	Mates 11 @ -/14/- =9/10/- Coolies 332 @ -/8/- = 166 Women coolies 11@ -/10/ = 6/14/- Women coolies 99@ -/7/- = 43/5/- Women Coolies 10 @ -/5/- = 3/2/- Boys 23 @ -/5/- = 7/3/- Drivers 21@ -/10/-=13-/2/- Spraymen 8 @ -/14/-=7/-/- Bhishties 12 @-/10/-=7/8/- Chowkidars 39 @ -/8/- = 19/8/- Cartmen 10 @ 2/8/-=25/-/- Blacksmith 1 @ 1/-=1-/-/ Total = 309/4/-	1. Drag Broom. 2. Chapties. 3. S. R. R. 4. Tar Boiler.	12 c.ft. @ 28/- per 100 c.ft. = 3/6/-	43 lbs. @ 133/- per ton = 2/6/- 12 lbs. Socony @155/- per ton =-/13/- Total = 3/3/-	-/14/9 per 100 s.ft.	-/-/3	7/8/-	(1 : 72)	Motor Vehicles Number | Weight 1,374 | Tons 4,293 Bullock-carts Number | Weight 615 | 923 tons	Trees at irregular intervals. Road remained under shade for quite a long time during the days and drippings from trees occur on to the road surface during rain.
	1" thick unconsolidated.	W. R. M. Bitumuls used =15.4 tons @ 155/- per ton = 2,387				14 mates @ -/12/- per day = 10/8/- 532½ coolies @ -/8/- per day = 266/4/- Total = 276/12/-	1. Drag broom. 2. Chapties. 3. S. R. R. 4. Straight-edge and templates.	12 c.ft. @ 28/-% c.ft. 3/6/-	69 lbs. Bitumuls @ 155/- per ton = 4/12/-	1-3-8	-/1/-	9/6/8	(1 : 72)	Motor Vehicles Number | Weight 1,450 | 4,350 tons Bullock-carts Number | Weight 790 | 1,185 tons	Thick avenues of tall trees. Road protected from sun and weather. Dripping from trees also occurs.

APPENDIX "B"

BITUMULS 2" COLD PREMIX SPECIFICATION AS PROPOSED BY MR. KERR OF THE BITUMULS EMULSIONS LIMITED

Materials per 100 sq. ft.

Base Course—

6 c.ft. $1\frac{1}{2}$" stone metal premixed with 2.50 lbs. W.R.M. per c.ft.
6 c.ft. 1"-$\frac{3}{4}$" stone metal premixed with 3.00 lbs. W.R.M. per c.ft.

Top Course—

4 c.ft. $\frac{3}{8}$"-$\frac{1}{8}$" stone metal premixed with 7.00 lbs. W.R.M. per c.ft.
2 c.ft. below $\frac{1}{8}$" stone grit premixed with 8.00 lbs. W.R.M. per c.ft.
2 c.ft. sand premixed with 9.00 lbs. W.R.M. per c.ft.
95 lbs. W.R.M.
25 lbs. H.X.

Method of Mixing and Laying

Mixing to be done in rotary mixing drums, as follows :

BASE METAL $1\frac{1}{2}$"—$\frac{3}{4}$"

2 c.ft. batches will be premixed with 5.5 lbs. W.R.M. (50% $1\frac{1}{2}$" 50% $\frac{3}{4}$")

TOP COURSE $\frac{3}{8}$"-SAND

2 c.ft. batches graded as follows :
1 c.ft. $\frac{3}{8}$"—$\frac{1}{8}$"
$\frac{1}{2}$ c.ft. below $\frac{1}{8}$"
$\frac{1}{2}$ c.ft. sand
will be premixed with 15.5 lbs. W.R.M.

The roadway shall be roughened by pickaxes to form a keying surface.

A tack coat of one gallon per 100 s.ft. shall be brushed on to the roughened surface after cleaning.

12 c.ft. of Base Course shall be spread per 100 s.ft. and laid to proper camber.

When the 12 c.ft. of Base Course is evenly distributed, 2 c.ft. of the fine mix for the top course will be cast over it, per 100 s.ft. and then rolled lightly to set into position.

After three to four hours the top course fine mix will be spread at the rate of 6 c.ft. per 100 s.ft. and will be rolled after three hours, or just before closing down the day's work.

Seal coat will be sprayed at the rate of 15 lbs. per 100 s.ft. after 48 hours and will be blinded with 2 c.ft. grit per 100 s.ft.

APPENDIX C

SPECIFICATIONS OF BITUMULS CARPET 2″ THICK LAID IN MILES 1 AND 2 OF GRAND TRUNK ROAD (AS ACTUALLY DONE)

1. Roughen the road surface with pickaxes, making holes about 1″ to 1½″ deep 1′ apart.

2. Clean the road surface thoroughly with brushes taking care that all loose scales of old tar are removed.

3. Spray on tack coat at the rate of one gallon per hundred s.ft. of H. X. Bitumuls after dampening the surface slightly with water.

4. Premix in rotary tar drums 2 c.ft. of 1″ to ¾″ Wah stone metal with 6 lbs. of W.R.M. Bitumuls at 3 lbs. per c.ft. for bottom course. The grading of each 2 c.ft. batches.

1″ to ¾″ gauge old metal (salvaged from the old Bitumuls) 1 c.ft.
1″ to ¾″ gauge new metal .. .. .. 1 c.ft.

5. Spread bottom course of premixed stone metal 1″ to ¾″ at the rate of 12 c.ft. per 100 s.ft. Level off with straight edges to template.

6. Premix fine material in rotary drums in batches of 2 c.ft. graded as below :

⅛″ to ⅜″ with grit new	..	1 c.ft.
⅛″ to ⅜″ (salvaged)	..	½ c.ft.
Pathankot sand	..	½ c.ft.
		2 c.ft.

with Bitumuls at the rate of 15.5 lbs. and dampen lightly if necessary.

7. Spread 2 c.ft. of the fine material premixed per 100 s.ft. to fill in partly the voids of the base course.

When firm to the foot roll over about twice to set in position early next morning when the temperature is low.

8. Lay the top course of fine material premixed as described above in Item 6 at the rate of 6 c.ft. per 100 s.ft.

9. Dragbroom this course to level up and roll very early when the surface is cool, early next morning.

10. Two days after when the carpet is firmly set up spray on seal coat at the rate of 1½ gallon of H. X. Bitumuls per 100 s.ft. and blind this with Wah fine grit ⅛″ to 1/16″ at the rate of 1½ c.ft. per 100 s.ft.

11. Roll over the following morning early once only and open to the motor traffic after 3 or 4 days.

12. Open to all traffic after the motor traffic has been over it for at least two weeks.

APPENDIX "D"

SPECIFICATIONS FOR BUILT-UP GROUT CONSOLIDATION

1. Scarify old road surface with pickaxes or a scarifier to a depth of 2 inches or more as found necessary.

2. Bring the subgrade to proper camber of 1 to 72.

3. Screen the scarified metal into screens of different gauges to obtain metal of $1\frac{1}{2}''$—$\frac{3}{4}''$, $\frac{3}{4}$—$\frac{1}{4}''$ and $\frac{1}{4}''$—$\frac{1}{8}''$ gauge.

4. Spread one-inch fresh earth over the prepared subgrade and over that spread the old scarified metal $1\frac{1}{2}''$—$\frac{3}{4}''$ gauge.

5. Lightly roll the metal with sprinkling of water to set the rounded pieces of stone metal firmly in the bed of earth previously laid.

6. Now spread about $1\frac{1}{2}''$ of fresh stone metal over the old metal, putting all screenings of the new metal on top. Dress to template and consolidate thoroughly both layers of metal with copious supply of water so that earth from below rises to the top, but the surface should not be too compact and should present an open texture.

7. Spread the remaining $1\frac{1}{2}''$ fresh stone metal on top of the consolidated metal and lightly consolidate dry without any addition of water.

8. Spray first coat of tar at 18 lbs. per 100 s.ft. and spread over it scarified metal $\frac{3}{4}''$—$\frac{1}{4}''$ gauge at 3 c.ft. per 100 s.ft. and consolidate well with water till there is no sign of movement in the metalling.

9. Let the surface dry up for the night in hot weather and 24 hours in winter in order that it may receive the second coat of tar on the dried skin of stone metal. No traffic should be allowed to come on the new work.

10. Spray 2nd coat of tar at 18 lbs. per s.ft. and spread Bajri $\frac{3}{8}''$—$\frac{1}{4}''$ at 2 c.ft. per 100 s.ft. and roll dry. No water should be added now.

11. A 3rd coat of tar should be applied at 14 lbs. per 100 s.ft. Spread Bajri $\frac{1}{4}''$—$\frac{1}{8}''$ at $1\frac{1}{2}$ c.ft. per 100 s.ft. Roll dry to a fine finish.

12. Keep off the traffic from the new work for four days, in summer and one week in winter.

APPENDIX "E"

SPECIFICATION FOR 2 AND 2½" "SHELCRETE"

Cleaning

Before laying Shelcrete the existing road surface shall be thoroughly swept of all loose earth, dust, caked mud, etc., with wire and bristle brushes and pointed hammers, if necessary. The brushing shall be continued till all the stone heads in the existing surface are exposed and all loose dirt removed from their interstices.

Patching

The entire surface shall then be checked for levels and pot holes and depressions, if any, in the existing road shall be cut square to a depth of two inches and, after removing all loose metal, dust, etc., from them, shall be primed with Shell Primer No. 2 heated to about 250° F. and applied at the rate of 10 to 15 lbs. per 100 square feet. They shall then be made good with pre-coated metal of suitable gauge to correct levels and shall be thoroughly hand-rammed. The material required for this work shall be extra to that in the main work.

Shelcrete

The "Shelcrete" shall consist of stone, sand and a Bitumen binder mixed in a paddle mixer laid in one layer and consolidated with a power roller of 10 to 12 tons in weight.

Stone

The stone shall be trap or other hard stone from an approved source of supply and shall be free from faults, dust, earth and other impurities and shall, as far as possible, be without a skin. It may be either crushed or hand-broken ranging from ¼" to 1¼" for 2" "Shelcrete" and ¾" to 1½" gauge for 2½" Shelcrete and of reasonably uniform quality throughout. The size shall be as nearly cubical as possible without many flakes and suitable screens shall be provided to screen it of flakes, grit, dust and other impurities. It must be absolutely clean and dry when used in the mix. Nine c.ft. of stone shall be provided per 100 sq. ft. of the road surface, per inch consolidated thickness of "Shelcrete."

Sand

The sand shall be clean, tough, of medium grading and preferably angular in grains. It shall be absolutely dry and free from dust, earth, vegetation, shale, loam, *kankar* nodules and other impurities.

Before use it shall be screened through a $\frac{1}{4}$"-sieve to remove oversized grains and shall be dried either by spreading in the sun or warming in pans to remove its moisture. If the work is carried out in winter the sand shall be warmed as a rule to a temperature of 212° F. or as near to it as possible. Where a suitable grading cannot be had from one sand, two sands from approved sources shall be used in suitable proportions. The quantity of sand shall be from 40% to 50% of the stone as directed by the Engineer.

Proportioning the Aggregate

The aggregate shall be proportioned by volume, using either wooden c.ft. boxes or a suitable hopper fixed to the mixer. The latter alternative is preferable. In either case arrangements must be made to remove all dust and impurities from the aggregate before it is put into the mixing box. Where c.ft. boxes are used they may be emptied in baskets or *ghamellas* for carrying the aggregate to the mixer but such procedure shall apply to the stone only and not to the sand which must be carried in boxes. Where a hopper is used it shall have a partition showing the correct volumes of stone and sand used in the mix.

Bitumen Binder

The binder shall be Shelmac B. S. and its quantity required in the mix shall be from 3 to $3\frac{1}{3}$ lbs. per c.ft. of stone and 7 to 9 lbs. per c.ft. of sand according to its grading.

Heating the Bitumen Binder

The binder shall be heated in a standard bitumen boiler to a temperature from 300 to 310° F. The contents of the boiler shall be stirred off and on during the day and maintained at the above temperature throughout. In no circumstances shall the temperature be raised beyond 320° F. At the end of each day the surplus contents of the boiler shall be emptied and stored in empty drums. The boiler shall then be loaded with fresh drums and heated as above for the next day's work. As the level of binder in the boiler falls in the course of the day, the stored drums shall be added one by one to the boiler and its temperature adjusted. The boiler must be fitted with a suitable thermometer and must have a capacity for at least eight hours' run on the mixer or about six drums of Bitumen at a time.

Fire shall always be lit after the boiler is loaded and *in no case shall an empty boiler be fired.*

Proportioning the Bitumen Binder

The binder shall be proportioned by weight and a suitable weighing scale shall be provided for the purpose. The scale shall have a circular dial showing wide divisions which can be clearly seen at a glance. The dial shall at all times be kept clean to facilitate checking.

Separate buckets shall be provided for the binder required by each aggregate and these shall be marked so as to prevent confusion. Each bucket of the binder shall be weighed every time it is used and all the buckets used on the work shall at all times be kept on a small fire to keep them warm throughout the day. At the end of the day all buckets must be cleaned.

Mixing

The mixing of the aggregate and binder shall be carried out in a twin shaft paddle mixer of 5 to 7 c.ft. capacity fitted with an engine of not less than 10 H.P. in suitable batches of $4\frac{1}{2}$ to 6 c.ft. each.

The stone shall be put into the mixer first and mixed with about $\frac{2}{3}$rd the quantity of binder required per batch. When the stone is thoroughly coated sand shall be added followed by the remaining $\frac{1}{3}$rd binder and the mixing continued till the aggregate is thoroughly mixed. The mixing box must be fitted with cross bars spaced about 4″ apart to prevent a bucket or a basket from falling into it.

Carrying the Mix

The mixed aggregate shall be carried to the road in suitable wheel barrows of not less than 5 c.ft. capacity and spread thereon with pickaxes and forks and levelled with rakes to correct levels. Rakes shall be so used that the mix is spread uniformly without segregation. The wheel barrows, picks, forks and rakes shall be kept reasonably clean throughout the process of the work by wiping them off and on with cotton waste properly soaked in furnace oil and at no time shall an excess of oil be allowed. Alternatively, they should be warmed and cleaned with a rag.

Spreading and Rolling

When a sufficient area of the "Shelcrete" is spread and levelled as above it shall be rolled with a ten-ton power roller.

The rolling shall start at the edges and finish at the crown in successive laps of 6″ to 9″. To prevent the mix from sticking to roller wheels, they shall either be kept moist continuously with gunnies soaked in water or be lightly smeared with a small quantity of furnace oil. After rolling for a time the surface shall be checked for levels and faults, if any, shall be corrected with additional material. For this purpose the depressions shall first be marked neatly and its sides grooved about $\frac{3}{8}$″ or so. The patches shall be lightly scarified with a rake and then additional mix spread thereon uniformly after first painting the grooves lightly with hot binder. The patches shall be hand-rammed first and then rolled with a power roller. The rolling shall be continued till the surface interstices in the carpet are uniformly filled in by the coated sand in the mix working to the surface. This is accelerated if the sand used is previously warmed. With cold

sand it takes longer to obtain this finish and if the rolling is persisted in the stones might be crushed. In such a case the entire surface shall be flushed with a fresh mix of sand coated with about 5 to 6 lbs. of binder per c.ft. and spread at the rate of about 2 c.ft. per 100 s.ft. The sand shall be spread uniformly and the roller passed over it till the surface presents a close appearance. *This sand shall be extra to the aggregate used in the mix.*

Jointing

Before laying a new day's mix to joint in, the previous day's work shall be cut vertical to the full thickness of the carpet and the vertical face shall be painted with hot binder and fresh mix shall then be placed against it to a uniform thickness so as to give a uniform level throughout the entire length of the work after consolidation. The material cut from the joint can be used after breaking it into small pieces and mixing them in a mixer with fresh batches in small quantities at a time.

Barriers, etc.

Suitable barriers, arrangements for traffic control and night watchmen shall be provided during the progress of work. After consolidation the road can be opened to traffic immediately provided the kerbs are first put in position.

APPENDIX "F"

Comparative Statement of Cost of various Road Pavements in the Vicinity of Lahore

	6"—4"—6" cement concrete road 1 : 2 : 4 @ 35% s.ft.	2½" "Shelcrete" over 3" new stone metal laid over existing *kankar* surface @25% s.ft.	2½" "Shellcret" over existing surface @ 20% s.ft.	3" waterbound macadam over 4½" brick soling with 2 coats of tar @ 17% s.ft.	Reconditioning existing surface with 2¼" stone metal and with 2 coats of tar @ 9-8-0% s.ft.
	1	2	3	4	5
Cost per mile of 12' width ..	22,400	16,000	13,000	11,000	6,000
Repayment of capital cost with interest @ 3% per annum in equated payments distributed over a period of 20 years ..	1,507	1,077	875	741	384
Maintenance charges per annum ..	50	550	550	600	600
Establishment charges @ 14% ..	7	77	77	84	84
Total annual liability ..	1,564	1,704	1,502	1,425	1,068
Liability in 20 years ..	31,280	34,080	30,040	28,500	21,360

NOTE.—For analysis of rates see Appendix "G."

APPENDIX "G"

ANALYSIS OF 6″—4″—6″ CEMENT CONCRETE ROAD PER 100 S.FT.

1½″ stone metal 22.75 c.ft. @ 20% c.ft.	= 4·55
¾″ to ¼″ metal 15.00 c.ft. @ 28% c.ft.	= 4·20
Cement bags 7.59 bags @ 2/- bag	= 15·18
Labour for laying slab, etc., including making camber and curing, etc.	= 5·00
Pathankote sand 19 c.ft. @ 26%	= 4·96
Soda silicate treatment	= 1·00
Total ..	34·89

Rs. 35% c.ft.

Analysis of 2½″ "Shelcrete" over 3″ new Stone Metal laid *over existing Kankar on surface* %s.ft.

1″ stone metal 20 c.ft. @ 22% c.ft.	= 4·4
Pathankote sand 10 c.ft. @ 26% c.ft.	= 2·6
Shelmac B. S. 150 lbs. @ 185/- per ton	= 12·0
1½″ stone metal including consolidation 25 c.ft. @ 20% c.ft.	= 5·0
Labour for mixing laying, etc., @ 1.25 "Shelcrete" ..	= 1·25
Total ..	25·25

Say Rs. 25% s.ft.

Analysis of rate for 2½″ "Shelcrete" over *existing stone* surface % s.ft.

1″ stone metal 20 c.ft. @ 22% c.ft.	= 4·4
Pathankote sand 10 c.ft. @ 26% c.ft.	= 2·6
Shelmac B. S. 150 lbs. @ 185 per ton	= 12·0
Labour for laying Shelcrete	= 1·25
Total ..	20·25

Say Rs. 20% c.ft.

Analysis of rate for 3″ Waterbound Macadam over 4½″ *Brick Soling with 2 Coats of Tar Paint* % *s.ft.*

Brick soling including consolidation 37.5 c.ft. @ 16% c.ft.	= 6·00
1½″ stone metal including consolidation 25 c.ft. @ 23% c.ft.	= 5·75
Tarring 2 coats with 15 tons of tar per a mile 12′ wide (@5%)	= 5·0
Total ..	16·75

Say Rs. 17

Analysis of Rate for Reconditioning existing *kankar surface with 2¼″ stone metal including 2 coats of tar.*

1½″ stone metal including consolidation 19 c.ft. @ 23% c.ft.	= 4·37
Tarring 2 coats with 15 tons tar for a road 12′ wide ..	= 5·00
Total ..	9·37

Say Rs. 9/8% s.ft.

DISCUSSION

The AUTHOR, before introducing his Paper, brought to notice a few mistakes that had appeared in the print, *viz.*, the words, "For detailed specifications" in Appendix "B" on page 183, should appear before the heading "Conclusion." In paragraph 4 on page 185 the word "with" before the words "yearly" maintenance was redundant. Also on pages 177 and 178 experiments named "C," "B" and "E" should be changed into "B," "D" and "C" respectively. Introducing the Paper, the Author stated that it was seldom that one felt inclined to expose one's shortcomings, but it did one good to have a little introspection at times and take stock of what sins of commission and omission one had committed.

He thought that the Punjab road construction had reached such a stage when this introspection was needed. Though this province could this day boast of its huge tar-surfaced mileage as compared with other provinces, yet after all this achievement consisted of only an improved type of old waterbound macadam and could not have any pretensions to scientific methods of construction. If this speed of conversion of the provincial mileage into tar-surfaced mileage went on unchecked and whole constructive energy directed towards this process, he was afraid the province would soon find itself lagging behind other provinces in possessing the really modern roads. The United Provinces had already stolen a march over our province in that the U. P. possessed over 200 miles of concrete road while we could count our concrete mileage on fingers—a state of affairs of which we could hardly be proud.

2. It had been made abundantly clear in the Paper that under the heavy combined bullock-cart and motor traffic the bituminous roads could not keep their profile and soon developed waves and corrugations, making riding uncomfortable while cement concrete roads, once properly made, did not alter their shape nor need any maintenance worth the name.

The only objection to making concrete roads was their high initial cost but a way had been suggested in the Paper, which could easily tide over the difficulty without increasing the provincial annual bill of road expenditure.

By looking at Appendix "F" it would be noticed that annual liability in possessing and maintaining a 6″—4″—6″ cement concrete road was practically the same as in having and maintaining an old type waterbound tar-surfaced road over a period of 20 years which had been considered as the minimum life of a concrete road. After that period the maintenance charges in the case of a concrete road were almost negligible which is an obvious advantage over the tarred surface.

The only exception made was in the case of reconditioning an existing *kankar* road with $2\frac{1}{4}$-inch thick stone metal with two coats of tar dressing.

This specification had mostly been used in the Punjab and was the cheapest construction for moderately light traffic. But since the Author wrote this Paper, he had been in correspondence with the officers of the United Provinces P. W. D. and had been informed that they were reconditioning their existing *kankar* roads with three-inch thick concrete slabs on the old surface. This slab would easily compete with our cheapest specification for the cost per mile of 12-feet width using three-inch slab is Rs. 15,000. If this amount was to be paid back in 20 years at 3 per cent. interest the annual equated instalment would come to Rs. 1,009. Adding to this yearly maintenance and supervision charges of Rs. 57, total annual liability became Rs. 1,066 which was the same as in the case of our cheapest specification.

So from whatever point the problem was looked at, whether it was in the domain of converting existing *kankar* roads with $2\frac{1}{4}$-inch stone metal or making new roads or widening existing roads, cement concrete would be an obvious and a happier choice.

Only if the higher authorities controlling our finance took courage in both their hands and decided to raise a loan for making our future roads in concrete, it would be possible to change entirely methods of road construction for the better. Money was easily available in these days and could be had for the mere asking provided interest was promised.

The Author hoped that we would then soon get rid of the monotonous, dull-looking and frail tar-surfaced roads, and, in their place would possess attractive, neat-looking and robust concrete roads.

MR. SUJAN SINGH said that the cost of tar and asphalt specifications mentioned in the Paper varied from Rs. 9-8-0 to Rs. 20 per 100 square feet as against Rs. 35 per 100 square feet for 6″—4″—6″ cement concrete. Therefore, the comparison drawn by the Author was not altogether a fair one. The life of a road naturally depended on the type of specification used, and the amount of money spent. There were still heavier specifications involving tar and asphalt which the Author did not appear to have seen, which gave much longer life with a very low maintenance. In Europe there were asphalt roads as old as 20 to 25 years. It might be said that climatic and traffic conditions in Europe were different. In this country also there were many examples of asphalt and tar roads lasting for over 15 years. From his own knowledge he could cite a few of the many instances of asphalt roads lasting four to 13 years.

When the Speaker was with the Karachi Corporation in the year 1927 a portion of Bunder Road from Densohall to Mereweather Clock Tower was treated with three-inch thick asphalt sheet. This section, after 13 years, was still in good condition. The traffic on this road was very heavy and there had been very little maintenance.

Anderson Road at Quetta was treated with $2\frac{1}{2}$-inch asphaltic concrete in the year 1932 and is still in good condition. After the earthquake of 1935 this road was subjected to very heavy traffic of

tractors and other vehicles employed for salvage work and in spite of this strain no repairs were found necessary.

One mile of the G. T. Road outside Peshawar was constructed with asphalt in May, 1937. Almost exactly after three years a thin seal coat was given. The traffic census on this road for the year 1940 was 531 tons per foot width.

In these three instances the cost of the asphalt specification was between Rs. 20 to Rs. 30 per 100 square feet as against the cost of Rs. 35 per 100 square feet for the cement concrete specification mentioned by the Author.

Mr. Basant Singh said that the Author of this Paper had brought out certain failures in the use of the black material as a road binder. It would not be out of place if he mentioned certain experiments done sometime in 1935 and which were considered quite a success.

One-inch consolidated "Shel-Sheet" with proper brick edging to save it from spreading out was laid in miles 305/4 to mile 305/6, G. T. Road, *vide* attached specifications and observations. The observations showed that the one-inch "Shel-Sheet" was able to stand for a considerable time. In miles 306 to 306/4 one-inch tar sheet was also tried. The difference between the tar and the asphaltic sheet noticed was that the "Shel-Sheet" started to break in the ensuing winter, whereas the tar sheet showed no signs of breaking under the action of the cold weather. Slight corrugations, however, did appear. It would be interesting to note that the corrugations did also appear in the train rails and are even regular but of much shorter pitch. The Municipal Tramway Association in England framed a committee in 1933 to investigate this problem.

In mile 310, G. T. Road, opposite Naulakha Talkies, an experiment in Bitumuls carpet (explained and attached separately under "Bitumuls Carpet in Mile 310, G. T. Road") was carried out. Present observations on that experiment showed that it was a success till now.

Specifications of Built-up-Spray-Grout work started by Mr. Harris in the Lahore Municipality are attached. It would be seen that a five-coat work done on the Circular Road in September, 1939, has on it a traffic intensity of about 9,000 tons per day and is behaving extremely well. Similarly on other roads, a few of which have been mentioned in the statements attached, have been treated with four-coat work. There have been roads of minor importance where three-coat work had been tried. Up till now all the roads so treated were behaving fairly well.

In addition, it was worth mentioning that two-inch "Shelcrete," done in 1933 on a portion of Fane Road, received no seal coat up till 1939, and the actual maintenance cost of the two-inch Shell macadam on Shalamar Road done in the year 1935 has been nominal. Since then it would only now receive a thin surface dressing coat this year.

The Speaker believed that the tar macadam which increased by leaps and bounds in England from 30 per cent. in 1922 to 54 per cent. in 1931 (statement attached) is also a very fair substitute for conditions in this province.

He certainly believed that cement concrete is one of the very good materials for road construction and that there could be still better specifications like wood blocks on thick cement concrete base, or even steel setts as in the Mersey Tunnel in Liverpool, but the whole problem which road engineers in general and engineers in the local self-government departments in particular had to face was the question of cost. Usually the money available as compared with the total area of roads to be dealt with was a nominal figure and so what was actually needed is a committee of experts to deal with the standardisation of different specifications for different traffic conditions. An illustrative example of this proposal would probably be as under:

Specification to be employed.	Traffic Tonnage per day.	Expected life of the specification
Earth road	100	1
Gravel waterbound and stabilized earth ..	250	1
Limestone Waterbound	500	1
Granite or Quartzite Waterbound ..	1,000	1
Granite or Quartzite surface-dressed ..	2,000	3
Tar macadam or three coats Built-up Spray Grout or penetration macadam.	3,000	5
Asphalt macadam or	5,000	10
"Shelcrete" two inches or four and five coats Built-up Spray Grout or "Shelcrete" or Cement Grouted three inches.	10,000	
Mastic Asphalt two inches or thin cement under five inches thick.	20,000	
Two-coat asphalt four inches ..	40,000	10—15
Compressed rock asphalt or cement concrete above six inches	50,000	15—20

Changes in Surfacing Materials in England.

CENSUS POINTS FROM 1922 TO 1931

	1922	1925	1928	1931	
(1) Waterbound macadam ..	1508=43%	755	327	239	=5%
(2) Surface dressed macadam ..	732=21%	1496	1165	1014	=21%
(3) Tar macadam ..	1057=30%	1687	2567	2686	=54%
(4) Bitumuls and asphaltic surfaces ..	56=1.6%	274	420	782	=15%
(5) Wood blocks ..	8	34	46	45	=1%
(6) Granite setts ..	101=3%	133	138	124	=2½%
(7) Concrete ..	1	13	23	65	=1½%

The use of tar macadam increased by leaps and bounds.

Life under a daily tonnage of 3,000—5,000 may be safely expected to be five years. This, of course, mainly depends on :

1. The foundation and subsoil.
2. The quality of work.
3. The traffic—its amount and nature.
4. The care used in maintenance and cleansing.

SKID

The skidding tests carried out in 1933 by the Ministry of Transport gave the best results on a tar-macadam road dressed with half-inch granite chips built three years before the test was actually carried out.

Experiments on G. T. Road 1935-36. Miles 306, 307 and 308.

305—305/4—*Incoming half width* .. 1″ Shelmac Premix.

I. (1) Primer on tack coat .. 10 lb. tar.

(2) (*a*) Beas coat "Premix" $6\frac{1}{3}$ c.ft. Pathankot chips.
$1\frac{2}{3}$ c.ft. Ravi sand.
$25\frac{1}{3}$ lbs. Shelmac.

(*b*) Topping coat "Premix" 4 c.ft. bajri.
1 c.ft. Ravi sand.
16 lb. Shelmac.

(3) Had to be sealed with Pathankot *bajri*. 15 lb. "Shelmac" and 2 c.ft.

Outcoming half width .. 1″ Tar Premix.

II. (1) Primer or tack coat .. 10 lb. tar.
(2) Base coat "Premix" .. 6 c.ft. Pathankot chips.
$1\frac{1}{2}$ c.ft. Ravi sand.
24 lb. tar.
(*b*) Topping coat "Premix" $2\frac{3}{4}$ c.ft. Pathankot *bajri*.
$\frac{3}{4}$ c.ft. Ravi sand.
11 lb. tar.
(3) Seal Coat .. 15 lb. "Shelmac" and 2 c.ft. *bajri*.

Both the base and the topping were consolidated together in both the above specifications I and II.

305/4 to 306—

III. 1" "Shel-Sheet" laid by the All-India Road Construction Company.
$3\frac{1}{4}$ c.ft. Pathankot chips.
$3\frac{1}{4}$ c.ft. Pathankot *bajri*.
3 c.ft. Pathankot sand.
$1\frac{1}{2}$ c.ft. of Ravi sand.

With a bitumen content ("Mexphalt" 2: "Shelmac" 1) of $51\frac{3}{4}$ lbs.

OBSERVATIONS:

This work was started on 20th July, 1925, and immediately after it was completed it had to undergo a severe winter weather. The incoming side started to show signs of breaking up in portions. These were repaired and as soon as the hot weather started the repaired portions and the original sheeting fused into each other and became one mass again. After one hot weather had passed no more trouble was noticed. A concrete track for the loaded carts, laid some time after, has added greatly to its life.

306—306/2—

Specification as for 305—305/4 outgoing half width, *i.e.*, Specification II above.

306/2—307/3—

IV. 1. Peeling the existing tarred surface and patching.
2. First coat tar No. 2 .. 28 lb.
Pathankot *bajri* .. 3 c.ft.
3. Second coat "Shelmac" 15 lb.
Pathankot *bajri* .. 2 c.ft.

307/3—307/4—

V. 1. Peeling the existing tarred surface and patching.
2. First coat Bitumuls W
X @ .. $27\frac{1}{2}$ lb.
Coarse grit .. 3.3 c.ft.
3. Second coat Bitumuls W
X @ .. $27\frac{1}{2}$ lb.
Fine grit .. 2.2 c.ft.

307/4—307/5—

VI. The same as Specification V above except that Bitumuls H X was used in place of Bitumuls W X.

307/5—307/6—

VII. 1. Peeling the existing surface (tarred) and patching.
2. First coat of tar No. 2.. 28 lb.
Pathankot *bajri* .. 3 c.ft.
3. Second coat of Bitumuls
W X .. 25 lb.
Fine grit .. 2.2 c.ft.

307/6—307/7—

VIII. As per Specification IV above except that tar No. 2 was used at 30 lb. instead of 28 lb.

307/7—308—

IX. 1. Peeling and patching.
2. First coat tar No. 2 .. 35 lbs.
Pathankot grit .. 3 c.ft.
3. Second coat tar No. 2 14 lbs.
Pathankot grit .. 2 c.ft.

Bitumuls Carpet in mile 310, G. T. Road.

1. *Preparation of the base.*—The existing uneven armour coat, which had failed, was peeled off and the waterbound surface underneath was thoroughly patched with Bitumuls W. R. M. premixed metal and chips. The quantities used were as under :

Pathankot metal $1\frac{1}{2}''$ gauge-Bitumuls X. R. M. @ 2 lb. per c.ft.
Pathankot Chippings $\frac{3}{4}''$ gauge Bitumuls Z. R. M. @ $2\frac{1}{2}$ lb. per c.ft.

The patches were left to traffic for about a week. Half widths were tackled at a time.

2. *Carpet.*—The carpet consisted of the following quantities :

(*a*) Pathankot metal $1\frac{1}{2}''$ gauge premixed with Bitumuls X. R. M. 6 c.ft. per % s.ft. .. = @ 2 lb. per c.ft.
(*b*) Pathankot chippings $\frac{3}{4}''$ size 6 c.ft. per % s.ft. .. = @ $2\frac{1}{2}$ lb. per c.ft.
(*c*) Wah chips with limestone dust per 100 s.ft. .. = 6 lb. per c.ft.

(2 lb. water was added to moisten the aggregate before bitumuls was added.)

The premixed aggregates were allowed to air for about two hours before they were put on the road.

(*a*) was spread on the road first, followed by (*b*) ; and (*c*) was added on the top. All was raked level and rolled by a steam road-

roller. Pneumatic-tyre traffic was let on it after four or five days and the cart traffic allowed after another six days.

OBSERVATIONS :

As soon as the pneumatic-tyre traffic was let on, its ironing effect was noticed. The traffic was controlled by empty tar barrels so that before the cart traffic was allowed on it, the whole of the road had been traversed by the pneumatic-tyre traffic. If this had not been done and loaded carts had been let on, the carpet would have again moved as was noticed on another small portion treated in the same way.

This portion of the road has behaved extremely well and even up till now, *i.e.*, after a lapse of six years, the portion is giving no trouble.

Some Modern Bituminous Resurfacing Methods and their Failures

MR. G. C. KHANNA said that the aim of the Author in writing this Paper was to advocate the use of cement concrete as pavement over all the roads in the Punjab, irrespective of the nature and intensity of traffic that they carried. This was a very bold generalisation on a controversial subject, and it was therefore difficult to agree to what he stated in his Paper. It is no doubt true that concrete roads are extremely durable and permanent, and have a smooth, even surface which does not get any corrugations or distortions throughout their life and that their maintenance charges are practically nil.

Another advantage of a concrete pavement is that once it has been laid with proper care and supervision, the departmental officers can completely forget its upkeep and devote their energies in prosecution of other projects. The worry and time spent on annual maintenance of roads, a considerable item in each division, can be saved, and thus the efficiency of the department can be considerably increased.

Having said all this in their favour, he said that concrete roads for all kinds of traffic intensities are a luxury which our province could ill afford. If traffic is heavy, concrete roads are ideal ; for light traffic they are uneconomical.

He continued that in the Appendix " F " the Author had worked out the comparison of costs of roads surface which appeared faulty. In case of concrete roads, the cost of subgrade over which the concrete is to be laid had been omitted. The cost of making subgrade by laying brick-soling coat would raise the initial cost by Rs. 3,800 and ultimate cost by Rs. 5,300, making the cost of road after 20 years as Rs. 36,600—the most expensive of all types. Even the most ardent admirers of concrete roads do not recommend the laying of cement concrete directly over earth. Experiments have been made here and there, but it is too early to generalise.

Details are given of experiments which failed under heavy traffic. In his opinion failure was due to faulty specifications in each case. In order to compete against each other, various firms gave specifications which are too poor for character and volume of traffic that the road carries. He requested more experienced engineers to give their opinion on these experiments. His own opinion was as below :

Experiment A.—Three-quarter-inch thick tar carpet is suitable for the same intensity of traffic, which surface-dressed roads can carry. It should on no account be used for heavier traffic. The advantage of using this carpet is that slight unevenness and ruts in the road surface are set right at economical cost. It cannot carry heavier traffic as size of stone used is too small. As soon as tar gets plastic, the small-sized stone chips, which have a small modulus, get displaced by fast-moving traffic and the surface gets distorted. Better results could be obtained if a thicker carpet with $1\frac{1}{2}''$ stone metal as coarse aggregate had been used. What is the use of sand in a tar carpet ? It absorbs a large quantity of tar, without doing any good to the carpet. Stone-chips or *bajri* hardly need any cushioning, especially when they are premixed with tar. Do we use any sand in case of surface dressing ?

Experiment B.—The cause of failure seems to be the breaking up of emulsion before its use.

Spray Grout.—I do not think that this specification is any better than surface dressing. In a recent publication by the Road Tar Association of England, the use of water immediately before or after tar has been sprayed is strictly prohibited. In this specification water is used in a large quantity. The opinion of engineers who have used this specification with success is invited.

Shell Crete.—The asphaltic concretes were a copy of cement concrete mixtures in which cement was replaced by asphalt. The result was a voidless mass of carpet which was compact like cement concrete but non-rigid and plastic, especially in summer.

The traffic set in a creep in the carpet which the carpet could not resist on account of its plastic nature. This creep caused corrugations and distortions which resulted in disintegration of the carpet.

The carpet, however, cracked in big pieces ; the individual stones did not get loose from the body of the carpet.

Asphaltic carpet without sand has been a success at several places because in this case carpet had some voids.

Mr. Brij Mohan Lal said that the Author had done well in bringing before the Congress the problem of modern road surfaces economically suitable for heavy traffic conditions. While the ordinary-surfaced waterbound macadam stands up all right to the medium intensity of traffic—say about 1,500 tons on a 12-foot width—it is unable to bear heavier traffic than this. The Author had dealt in his Paper with the Grand Trunk Road to the west of Lahore on the Gujranwala side.

The Grand Trunk Road to the east of Lahore towards Amritsar carried even heavier traffic due to the existence of too many brick kilns beyond Shalamar and heavy goods and passenger traffic between Amritsar and Lahore. During the last 10 years various improved surfaces had been tried in the length of seven miles beyond Lahore but none had proved so successful as the cement concrete track 10 feet wide laid for about a mile beyond Shalamar Gardens and for about two miles beyond the Lahore Railway Station in 1938. In 1934-35 one-inch tar or bitumen carpets were laid beyond Shalamar for a mile and cement-bound macadam surfaced with tar constructed beyond the railway under-bridge for more than a mile, but due to a heavy traffic of more than 5,000 tons, they soon became rough in about a year. A cement concrete track of 6″—4″—8″ section was then laid in 1938 on the left side of the above lengths to carry the heavy incoming traffic. Since then, the surface in the remaining width of the road also remained in a better condition. The length between the Shalamar Gardens and the junction with the road to Civil Lines, Lahore, *via* railway over-bridge was not treated as above considering that the metalled width here was 30 feet, but it always remained in a very rough condition in spite of heavy surfacings and patchwork at a heavy cost every year. A one-inch tar carpet was also tried near Baghbanpura, but that too had proved of no avail. The Speaker, therefore, agreed with the Author that the only economically suitable surface for heavy traffic was cement concrete.

In Appendix " F," the Author had tried to compare the ultimate cost of various road pavements over a period of 20 years. In his analysis of cost, he had assumed the average cost of stone, sand and cement rather on the lower side. In Column 4 of the Table he had considered a pavement of three-inch waterbound macadam over brick-on-edge, but a 4½-inch thick waterbound macadam was generally laid; three-inch thickness was too little. Assuming the cost of materials a little higher, the Speaker worked out the cost of a cement concrete pavement as Rs. 25,000 and that of a 4½″ waterbound macadam surfaced with tar as Rs. 13,000 per mile of 12-foot width. Total annual liabilities on this worked out to Rs. 1,660 for cement concrete and Rs. 1,500 for a waterbound macadam, giving a difference of about Rs. 150 per year. As in the case of very heavy traffic beyond 2,000 tons, the cost of maintenance of a surfaced pavement would be more than Rs. 600; this difference would disappear and would probably make the surfaced waterbound more expensive. It was, therefore, clear that a cement concrete pavement was cheaper than any other in the long run for heavy traffic. But in case of light traffic, the Speaker did not agree with the Author that widening of existing roads or construction of new roads should be done in cement concrete.

In case of heavy traffic, however, the Punjab would have to find the money sooner or later for constructing cement roads either from loans or other means to keep heavy trafficked roads in a good condition.

In replying to Mr. Sujan Singh, the Author said that it was an admitted fact that cement concrete road is any time superior to the heaviest specification of a road crust involving use of asphalt and tar; hence Mr. Sujan Singh's comment was out of place. He had referred to three-inch thick asphalt sheet laid on a portion of Bunder Road in Karachi. The Author was very much doubtful if this portion carried any iron-tyred traffic which is the most destructive type of traffic ordinarily met with on the highways in Northern India for which the only suitable kind of road crust is the cement-concrete slab. Other instances quoted by him were not of much use for comparison as they were not over 10 years old while the cost per 100 s.ft. mentioned was almost the same as that of a concrete road.

Replying to Mr. Basant Singh the Author said that experiments done in 1935 as corrugations had appeared on the tarred surface in the experiments carried out in 1935 and shell-sheet began to break in the ensuing winter, it could not be called a successful experiment.

The built-up-spray-grout work done on Circular Road in September, 1939, has had but too little a life to form a basis for comparison with a cement concrete road. This specification actually failed on the Ravi approach referred to by the Author in the Paper.

The Shellcrete laid on Fane Road does not appear to take much iron-tyred traffic, hence it is no wonder that the road was in good condition.

The climatic condition and the nature of traffic in England are far from being a substitute for conditions obtaining in India for, whereas the climate in England is cold, the climate in India has extremes of heat and cold while as regards traffic there could hardly be any bullock-cart in England with iron tyres.

Mr. Basant Singh stated that tar macadam had increased by leaps und bounds in England but he did not appear to be aware of the fact that the mileages of concrete roads in British Isles had risen from 182 in 1926 to about 3,200 in 1937 as given on page 15 of Punjab P. W. D. Paper No. 85 and that in the Continent of Europe and United States of America almost all new roads were being made in cement concrete. As back as 1921 the United States commenced with a thirty-million-pound road construction programme in cement concrete as referred to in the *Indian Roads* of June, 1939, Art. XI, p. 60.

The question of excessive cost in initial outlay had already been dealt with by the Author in his Paper.

Replying to Mr. G. C. Khanna the Author stated that he had not advocated the general use of cement concrete roads throughout the Province but had only tried to indicate that if funds could be made available, cement concrete roads would in the end be cheaper than any other kind of road crust.

Of course, for light traffic the section of cement concrete road would also be thinner.

For the reconditioning of existing *kankar* or stone road, the cement concrete crust would be ideal for in that case it will require no foundation while in the case of new road it was somewhat doubtful if soling coat could be entirely omitted.

There was, however, a practical instance in which cement concrete has been laid directly on earth subgrade in Mile 2 of Lahore—Multan—Quetta Road, which was standing very nicely after seven years of its being laid. Even waterbound stone metal had been laid over earth subgrade in certain reaches of the G. T. Road between Lahore and Muridke and had been behaving quite satisfactorily. It was only a question of compaction of the subgrade either mechanically or under traffic and there appeared to be no harm in laying cement concrete over berms which had been under traffic for over half a century.

It was on this basis that the Author had omitted the soling coat in the analysis of cement concrete roads while making a comparison with other types.

Replying to Mr. Brij Mohan Lal, the Author thanked him for pointing out certain failures of bituminoustic pavement on the G. T. Road east of Lahore which helped to enhance the value of this Paper. Mr. Brij Mohan Lal agreed with the Author that the only economically suitable surface for heavy traffic is cement concrete. He, however, did not agree that widening of existing roads or construction of new roads should be done in cement concrete. But the Author believed that if this matter were reconsidered purely from an economic point of view, it would be evident that even for lighter traffic cement concrete will be the cheapest in the long run, for according to Mr. Brij Mohan Lal himself the difference in the annual liabilities of a concrete pavement and a waterbound macadamised surface is only Rs. 150 which is a paltry sum and which, too, will disappear when the concrete road survived a period of 20 years. Thereafter the annual liability in the case of a concrete road was practically negligible while that of a waterbound road never went below Rs. 600 per annum. Even when the concrete pavement failed by cracking under increased traffic in course of time, it would provide a suitable unyielding subgrade for any kind of resurfacing that might ultimately be required to be put over it. It is, therefore, obvious that irrespective of any traffic conditions, cement concrete proved to be the cheapest in the long run. The only stumbling block in the way of the realisation of this dream of having an out-and-out cement concrete road was its prohibitive initial cost, being twice as costly as the waterbound surface.

Many suggestions had been made to solve this ticklish problem of financing the costly project, but none appealed so much as the following device would appear to be. In this device the Government should call for tenders for constructing new cement concrete roads form firms and combines of high engineering repute and standing and offer them half the cost of the road in the first instance after the road has stood the traffic for say two years and payment of other half be

distributed over a period of say 20 years during which period the firm shall be bound to maintain and look after the road. Money is locked up these days and is lying unproductive. It is hoped that a number of firms would be only too ready to come forward to work these projects if invited. In this way the Government would have to spend in the initial stage just that amount which is required to construct a waterbound surface and thereafter the annual instalment of payment would not be more than what is required by way of maintenance of a waterbound surface. The advantage of this system will be that after 20 years the Government would possess cement concrete roads on which she would not have had spent more than its annual budget allotment and, what is more, it would have the best kind of roads on which future maintenance will be negligible. The Author was grateful to R. S. L. Kidar Nath, Executive Engineer, Gurgaon, for the above suggestion.

The following tabular statement will make the comparison more clear. Taking L. Brij Mohan Lal's figures of Rs. 25,000 for 6″—4″—6″ concrete road and Rs. 13,000 for 4½″ waterbound macadam for a mile 12-foot wide :—

	6″—4″—6″ Cement Concrete Road 1 : 2 : 4	4½″ waterbound macadam over 4½″ brick soling with 2 coats of tar.
	Rs.	Rs.	Rs.
Initial cost	25,000	..	13,000
Initial payment to firm or contractor		13,000	..
Balance to be paid		12,000	..
Payment of balance of cost with interest at 3 per cent. per annum in equated payments distributed over a period of 20 years ..		807	..
Maintenance charges per annum including establishment charges		50	700
Annual liability		857	700

NOTE.—The difference in annual liability is only Rs. 157 which, too, would disappear after the concrete road has survived a period of 20 years. Thereafter, the concrete road would all be a saving concern.