PAPER No. 193.

CONCRETE TRACKWAY ON LAHORE MULTAN ROAD (ARTERIAL No. 4) MILE 2 & 3 IN LAHORE DISTRICT.

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Traffic on the miles immediately in the vicinity of Lahore on the Lahore Multan Arterial Road No. 4 is about 780 tons per day. In addition to the very considerable through traffic, there is 300 tons local traffic of incoming brick-laden bullock carts, from the brick kilns between miles 4 and 5 of this road.

The width of road in mile 2 prior to concrete work was 16 feet in the first 4711 feet, and 30 feet in the next 560 feet length, while mile 3 was 30 feet in the first 960 feet length and 16 feet in the next 1580 feet and 12 feet in the remaining 2740 feet. The last length was widened to 16 feet just before the track was laid. The road was not considered wide enough to carry the considerable local and through traffic consisting of heavy motor lorries, cars and bullock carts.

Moreover the type of road construction, *viz.*, tar surfaced water bound macadam, is not strong enough to carry the very heavy inward brick traffic as it caused rapid wear, bumps and pot holes, particularly on the incoming side of the road. The surface was soon cut up badly and it was difficult to maintain it up to the desired standard. In spite of the annual application of road tar the condition was not improved.

Experience has shown that tar or bitumen grouts or premixes are not suitable for the tropical heat of the Punjab, as the materials become too plastic in the hot weather and the bullock cart traffic pushes the surface into bumps and hollows. It has been noticed for the inward traffic into Lahore that once tarred water bound macadam begins to fail, the satisfactory remedy is either a cement concrete slab laid in tried sections or a thick wearing coat using bitumen as a binder.

Just beyond the Chauburjee gardens the traffic disperses in several directions, mostly along the Lake Road, partly along Bahawalpur Road, a small portion only proceeding along the Arterial Road No. 4.

It was, therefore, proposed to provide a cement concrete track on the inward side from milestone 3 to the junction with Lake Road (140 feet before furlong post ½) except for the portion opposite the Chauburjee gardens (Indian clerks' quarters) where the road has already been widened to 30 feet.

In view of the high initial cost of a Concrete road, 50% grant-in-aid from the reserve of the Central and rural fund was granted, and the balance was provided by the Punjab Government. In addition to the

breaking up of the metalled surface, the berms due to light friable soil were either extremely dusty or very muddy. It was proposed to replace the berm on the in-coming side by a cement concrete trackway so that the in-coming traffic would have a wider width of *pucca* surface free from dust or mud. The berm on the outgoing side has been left as it is as the carts generally travel empty while going out from Lahore. Subsequently it will probably have to be metalled and tarred.

The widening of miles 2 and 3 was designed on the assumption that the heavy inward bullock cart traffic would proceed along the concrete track leaving the tarred water bound metalling for all the fast traffic and the outgoing empty bullock carts for which the existing type of construction was strong enough. Accordingly the concrete track was proposed of different trial sections, as the strength required to carry the heavy inward bullock carts with narrow iron rims fitted to the wheels (say 50%) was not known.

Due to the very heavy cost of providing concrete trackway, seven different cross sections of 1080 feet each but the last one which was 74 feet less in length, were laid to carry the heavy inward traffic and to determine experimentally which would be the lightest suitable section. Cross sections Nos. 3, 5 and 7 were reinforced and the remaining were not reinforced. The concrete slab was laid 7 feet 8 inches wide giving 7 feet roadway and a kerb of 8″ thick cast monolithic with it.

The work done on this road consisted of various adjacent sections of roadway laid according to specifications as detailed on the drawings attached (Appendix A & B). The details of cost of various sections are given in the tables, (Appendix C & D).

All these sections of the trackway are given in the accompanying drawings.

So far there does not appear any sign of wear on these sections.

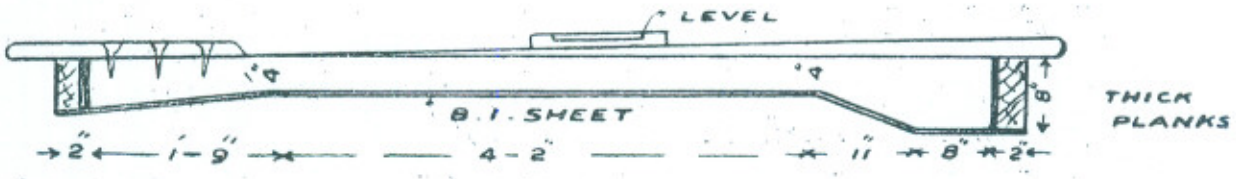
The tarred water bound macadam portion was open to traffic while the in-coming side berm was closed and excavated to prepare the profile for concreting.

Subgrade.

In the first instance trenches were dug approximately to the required depth. Necessary level pegs were fixed for the purpose in the trenches, 2″ thick templates of deodar wood faced with sheet iron on the top and bottom prepared to the exact cross section of the proposed track were securely laid in position at different places in the trench at right angles to the centre line of the road. The subgrade was then

trimmed to the proper required level. High spots were cut away and depressions or additional cutting if found were filled in with brick ballast and mud mixed together and thoroughly rammed with hand rammers after wetting. The sketch of the template used is given below:—

TEMPLATE USED IN PREPARING THE SUBGRADE



Side and Cross Forms.

After the subgrade was roughly prepared deodar wood planks 6" deep and 2" thick were laid longitudinally on firm soil along the edge of the existing metal with their top surfaces to the required level.

Similarly, along the line of the outer edge of the slab, planks 2" thick and of 8" or 10" depth as required by the section, were laid with the top surfaces quite flush. The ends of the forms were made to butt properly against each other and were securely fixed in position by steel pegs 5/8" diameter round steel bars 18" long and placed 3'—4" apart to resist the blows of the tamper and the pressure of the concrete.

The cross forms were made of well seasoned deodar wood 2" thick and to the correct section of the concrete slab. These were laid at both ends of the slab at right angles to the road and were suitably secured by means of steel pegs of 5/8" diameter round steel bars 18" long placed 3'—4" apart and made quite firm and rigid.

Originally it was proposed to lay 3" thick brick ballast where there was soft soil, but when eventually preparing the bed, the earth throughout was found hard and solid enough to carry the cement concrete slab without placing any brick ballast.

At one place over Bridge No. 4 in furlong 3 of mile 2, where the thickness of the slab at the gutter was $3\frac{1}{2}$" instead of $5\frac{1}{2}$" inches in the centre, due to cross fall for drainage and the arch masonry being close to surface, extra reinforcement of of M. S. round bars of $\frac{1}{4}$" diameter placed 3" centre to centre was used for strengthening it.

Another bad hole 4'×3' was discovered under slab No. 4 at 10 feet from the further end of the slab. It was due to a telegraph pole having been taken out. The soft and wet earth was taken out to a depth of 4 feet, filled with dry brick ballast and a little mud, well rammed, and the slab was reinforced with reinforcement $\frac{1}{4}$" diameter M. S. round bars

3" centre to centre. The preparation of the subgrade is the most important factor in the construction of cement concrete roads and the following points were kept in view in preparing it :—

(1) The subgrade was given an even and uniform bearing to the cement concrete slab throughout its extra length.

(2) Freshly dug trenches were well rammed and bad and spongy places were carefully looked after. The soft earth in these bad places was removed and brick ballast filled in and well rammed in layers of 6" thickness.

(3) The subgrade was slightly watered before laying the insulation layer of sand.

Insulation layer.

A half inch layer of ordinary river sand was spread evenly over the subgrade as an insulating layer. This is advisable as this allows the joints more freedom. The sand was well watered before the cement concrete was laid so that it would not absorb water from the freshly laid cement concrete. There was no excess of water, otherwise the excess would weaken the cement concrete.

Aggregate proportions.

The proportion of cement, sand and coarse aggregate was kept 1 : 2 : 4. The work was done departmentally and it was observed at the time of actual construction that whenever a layer of mixture having a little more water was laid, cement slurry appeared at the top and some of it was removed while the surface was floated with a straight wooden edge.

In some cases cement was measured by bags, each bag being taken at 110 lbs. *i.e.*, 1¼ cft., and in others it was measured by volume in a cubic foot measure. Sand and coarse aggregates were measured by volume in 1¼ and 1 cubic foot measures. Water was measured by volume in a one gallon measure. Pathankot sand free of all impurities and washed at the spot in big iron Karahs (a big pan) with clear well water was used.

Cement.

The Cement used was " Five River " brand. It was supplied in bags of 112 lbs. gross containing about 110 lbs. of cement.

Coarse and fine aggregates.

For the coarse aggregate, Pathankote Quartzite stone metal 1" to 2" gauge was used.

For the fine aggregate, ½" to 1" crushed chippings of Pathankot stone were used. In order to get the dense concrete 1 : 3 in ratio of ½" to 1" gauge Pathankot stone crushed *bajree* (chippings) was mixed with Pathankote stone metal 1" to 2" gauge so as to give a graded aggregate.

Proportion of aggregate and minimum volume of water.

Along with the proportion of the aggregate, the minimum volume of water used with a cubic foot of cement varied from 1½ to 2½ gallons according to the temperature. As the aggregates used were quite wet after having been washed in ordinary barrels, the proportion of water was very low. Clean water from wells was used for mixing the cement concrete.

At the commencement of the work trial batches of concrete were produced and the correct quantity of water was determined to turn out a plastic and washable mixture ; and later on every effort was made to carry on the system as described above.

Dimensions of slab.

As the track was only 7'—0" wide with 8" kerb, longitudinal joints were not considered necessary. The length of each bay along the length of the road was fixed as 30 feet and cemente concrete was filled at first in alternate bays, and about 4 to 7 days later into the intermediate bays.

The slab was laid in seven sections three of which were reinforced with round mild steel bars and the others had no reinforcement.

Joints.

As regards the expansion joints, straight butt joints running at right angles to the line of traffic were adopted as these are very effective and have the additional advantage of easy construction and better finish. In fact no gap was left but the groove was cut on the top to denote the position and the groove was filled with tar and sand. These joints were showing a very slight tendency to wear off at the edges where the tar and sand poured in the grooves had come out. To further check this tendency the joints were again carefully cleaned of all dust and a fine streak of tar heated to a temperature of 250°C run into the grooves and a fine layer of sand spread over it which is working very satisfactorily.

Thickness of Slabs.

4", 5" and 6" thick slabs have been laid in various sections as given below.

No. 1	..	4" thick.
No. 2	..	5" thick.
No. 3	..	5" thick, reinforced with two $\frac{1}{2}$" diameter mild steel bars laid under the kerb 2" from the end of the slab and 3" centre to centre.
No. 4	..	6" thick.
No. 5	..	6" thick, reinforced with one $\frac{3}{4}$" diameter mild steel bar at $2\frac{1}{2}$" from end of the slab.
No. 6	..	5" thick.
No. 7	..	4" thick reinforced with $\frac{1}{2}$" diameter longitudinal bars spaced at 12" centre to centre with $\frac{1}{2}$" diameter cross bars placed 2" apart.

The above will show that three sections were reinforced and the rest were not reinforced. As described above seven different sections of slabs were laid to determine experimentally which would suit the heavy inward bullock cart traffic.

The cost of reinforcement has been given as below :—

Section No. 3	..	Rs. 4-8 per 100 cft.	of concrete.
Section No. 5	..	Rs. 4-5	Do.
Section No. 7	..	Rs. 30-3	Do.

So far no difference has been noticed between the reinforced and unreinforced slabs and it is too early to give any opinion regarding the strength of the various types of slab.

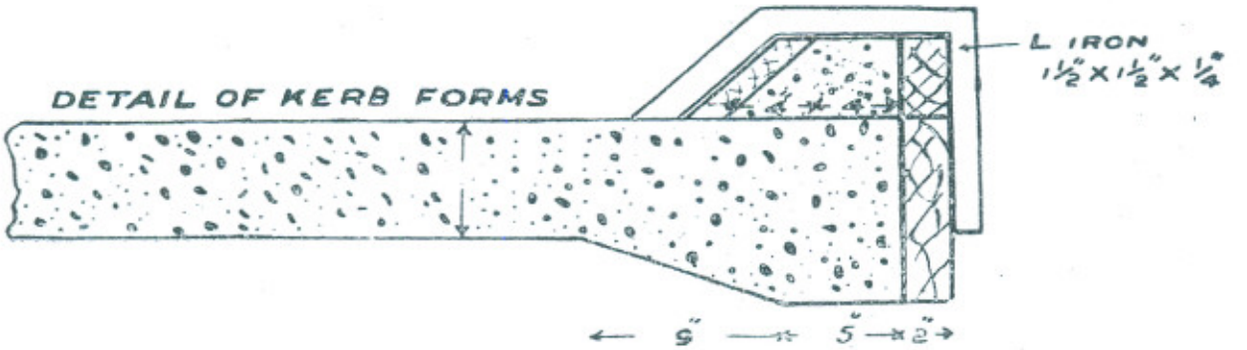
Weather conditions.

The work was started on the 11th February and completed on the 18th March 1935 and during this period the work was only held up for two days owing to winter rains and for three days for want of Pathankot sand in the last section. The temperature during this period was below 100° F.

Side kerb forms.

Forms made of deodar wood planks for the kerb were placed over the cement concrete immediately after laying the concrete up to the required level. Concrete was filled in from the top and well spaded and rammed with rambas and mild steel bars. The forms were strengthened

with L iron pieces $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{4}''$ placed at 18" apart to resist the warping of the planks (as in sketch given below).



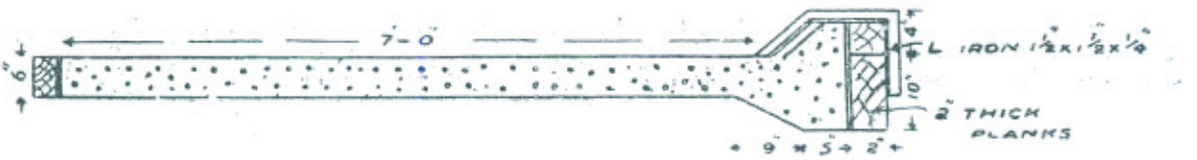
L. Iron pieces used for strengthening the forms were fixed flush with the top of the kerb. The top of the kerb was not kept smooth.

L. iron pieces were subsequently made longer and fixed 1" higher thus allowing the masons to work freely. The side kerb forms were removed 30 to 45 minutes after the concrete was filled in them. The length of these forms varied from 6 to 10.

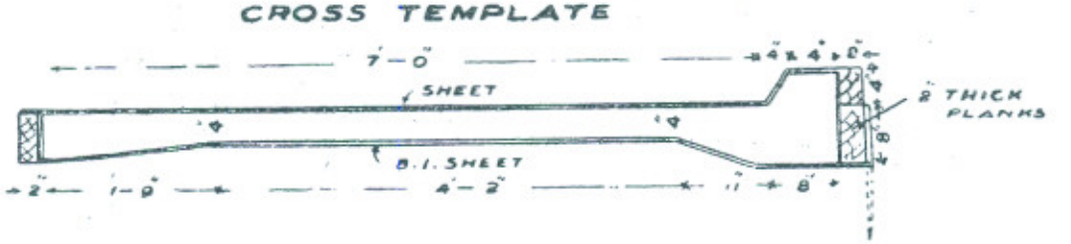
Longitudal and cross forms were removed after the concrete had been laid 24 hours. The laying of forms was done ahead and 3 to 6 alternate bays were kept ready for the following day's work.

This is an important item of work as the finished surface of the road greatly depends upon the rigidity. The wooden forms, though made of well seasoned deodar wood, gave some trouble at the start, due to the warping and sinking at the joints under the blows of the tamper. Those were faced by putting sheet iron pieces on the face (as in sketches given below).

SECTION OF SLABS Nos 4 & 5 SHOWING THE FORMS FOR SIDES & KERB.

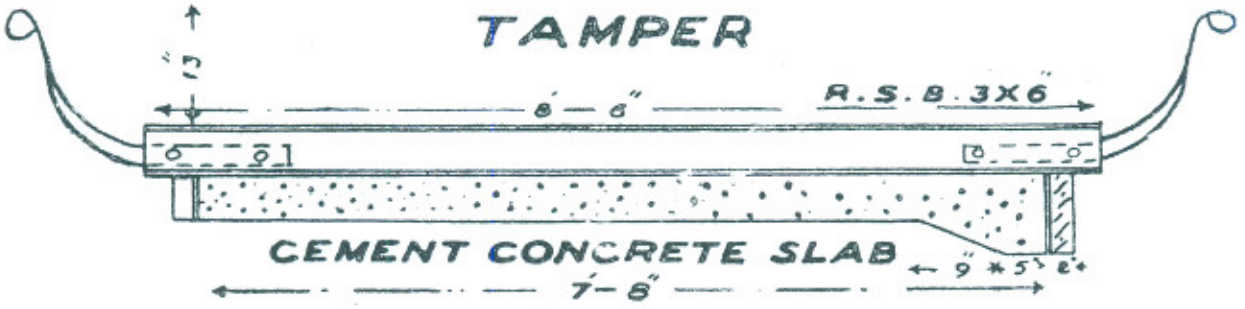


CROSS TEMPLATE

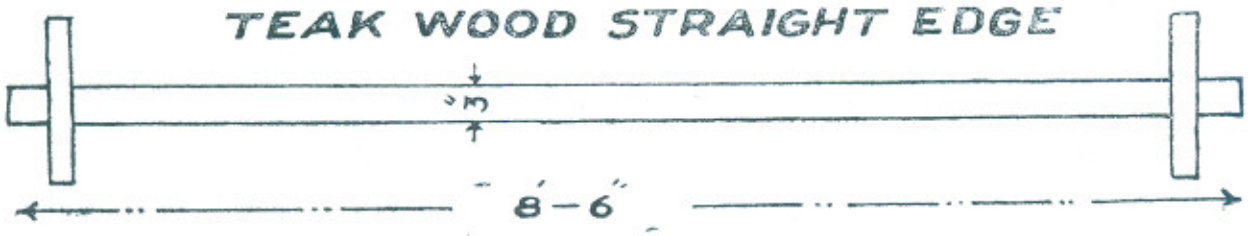


There were two gangs, one working ahead filling in the alternate bays and the second working behind filling in the intermediate bays.

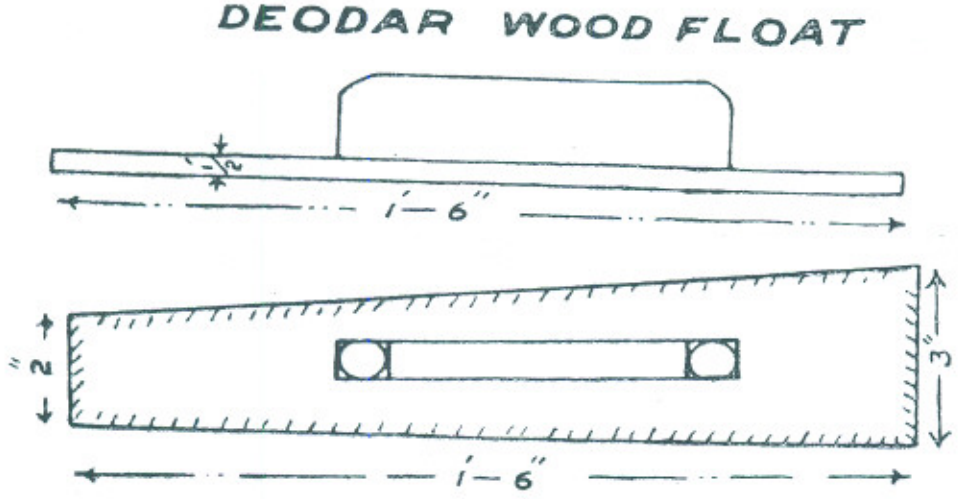
There were two tampers made of rolled steel beams each 8′×6″×3″ as per sketch given below for use on the work one with each gang. Handles at either end were provided to facilitate tamping operations and to give easy handling to the workmen using the tamper.



When the concrete was laid in about half the length of the slab, wooden side forms for the kerb were screwed on to the outer edge of the slab. Concrete was filled in from the top and spaded and rammed with rambas and mild steel bars. When the concrete was fairly set in 30 to 45 minutes, the side kerb forms were removed and the kerb properly finished to the correct section. To prevent the undulations in the top surface, the final finishing operations to bring the concrete to correct level and camber was done by means of a light teak wood straight edge 10 feet long 3″ wide and 2″ thick faced with a flat iron bar 3″×$\frac{1}{8}$″ underneath (sketch given below).

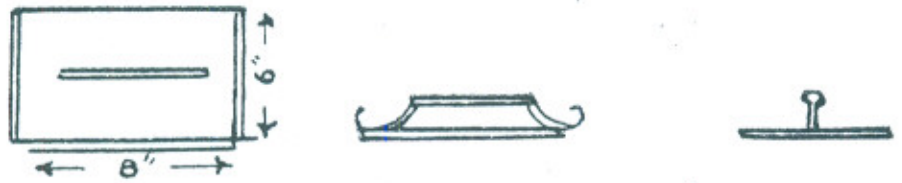


Any corrugations noticed subsequently were removed by means of deodar wood floats 18″ long (sketch given below).



Iron floats were used for rounding the edges and joints (sketch given below). The groove allowed was ½" deep.

IRON FLOAT TO ROUND THE EDGES OF SLAB



The tools required for a batch of four men employed on mixing operations are given below :—

Pickaxe	1
Shovels	2
Kassis	2
Water sprinkler	1
Water drum	1
Wooden measures	2

The Cement Concrete was laid departmentally. At the commencement of the work one cement concrete mixer of a batch type with a tilting drum, and two hand gangs were employed in filling up the alternate bays, but six days later, when the filling in of intermediate bays was started, one mixer and two hand mixing gangs were working ahead at the alternate bays, while three hand mixing gangs were working behind on the filling in of intermediate bays, till another mixer of batch type with fixed drum was obtained ; then the number of hand mixing gangs were reduced to two. Second machine did not work satisfactorily and the previous system of hand mixing had to be adopted. Both the mixers were of the capacity of 1 cft. of cement, 2 cft. of sand and 4 cft. of graded aggregates. In the last days the first machine working ahead also started to give trouble and would not work satisfactorily. The magnetos of both the machines were defective ; however the out-turn on the whole was very satisfactory and on average a batch of four men could mix 230 cft. of cement concrete per day. With the exception of 30 per cent of the Cement Concrete laid in the trackway the rest of the concrete was hand mixed.

Curing.

Immediately after finishing operations were completed, the concrete surface was covered with empty cement bags, and kept wet continuously for about 6 to 8 hours continuously. The bags were removed in certain

length till earth bunds were made next day; and earth bunds along and across the slab were started to be made next morning at the top of concrete, at sufficient intervals, dividing the slab into small rectangles 3′×2′ and filled with water and continuously kept wet for fourteen to twenty days after the concrete was laid, empty cement bags were used over the kerbs. Proper and effective curing was done as far as possible. One *bahashti* could control an area of 2500 sft. a day.

Cleaning, washing, and hardening concrete surface.

After curing the concrete for about 2 to 3 weeks the earth bunds were removed and the surface was cleaned and washed with clean water. When the surface was thoroughly cleaned and free from dirt, a solution of silicate soda (1 part of silicate of soda and 6 parts of water) was applied and continuously brushed over the surface to obtain even penetration. Three such applications were given at intervals of 24 hours keeping the surface covered between each application. One cwt. of sodium silicate was used to cover 300 sq. yards in three coats.

Drainage.

For drainage purposes a hole 3″ wide in each slab through the kerb was kept and in continuation of which cast iron pipes 3″ diameter are now being laid through the *kacha* foot path along the kerb.

Foot Paths.

The earth obtained out of the digging of trenches was used in making a foot path, 3′ to 4′ wide all along the kerb, for use of pedestrians.

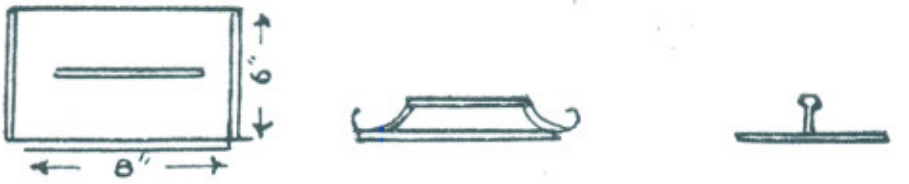
Space between the existing metal and the slab.

The space between the existing metal and slab varying from 4″ to 12″ in width, caused by irregularities in edge of metal and cutting of bricks of different size used as soling coat, was filled in, half with brick ballast and mixed with mud, and half with tar premixed metal *bajree* and rammed well in position. It was noticed that in some places newly rammed metal had sunk down and thus the edge of the slab was exposed and liable to break; such places had to be refilled with premixed metal and bjaree and the defects removed. It was rather very difficult to give a thorough ramming owing to narrow width; it is therefore suggested to use a quick-setting cement in future where such a work is undertaken.

Another difficulty experienced at the commencement of the work was the shifting of telegraph poles and stays, standing on the berms of mile 2 where the trackway was to be laid. However, it was overcome through the cooperation of the Telegraph Department.

Iron floats were used for rounding the edges and joints (sketch given below). The groove allowed was ½" deep.

IRON FLOAT TO ROUND THE EDGES OF SLAB



PLAN ELEVATION SECTION

The tools required for a batch of four men employed on mixing operations are given below :—

Pickaxe	1
Shovels	2
Kassis	2
Water sprinkler	1
Water drum	1
Wooden measures	2

The Cement Concrete was laid departmentally. At the commencement of the work one cement concrete mixer of a batch type with a tilting drum, and two hand gangs were employed in filling up the alternate bays, but six days later, when the filling in of intermediate bays was started, one mixer and two hand mixing gangs were working ahead at the alternate bays, while three hand mixing gangs were working behind on the filling in of intermediate bays, till another mixer of batch type with fixed drum was obtained ; then the number of hand mixing gangs were reduced to two. Second machine did not work satisfactorily and the previous system of hand mixing had to be adopted. Both the mixers were of the capacity of 1 cft. of cement, 2 cft. of sand and 4 cft. of graded aggregates. In the last days the first machine working ahead also started to give trouble and would not work satisfactorily. The magnetos of both the machines were defective ; however the out-turn on the whole was very satisfactory and on average a batch of four men could mix 230 cft. of cement concrete per day. With the exception of 30 per cent of the Cement Concrete laid in the trackway the rest of the concrete was hand mixed.

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length till earth bunds were made next day; and earth bunds along and across the slab were started to be made next morning at the top of concrete, at sufficient intervals, dividing the slab into small rectangles 3′×2′ and filled with water and continuously kept wet for fourteen to twenty days after the concrete was laid, empty cement bags were used over the kerbs. Proper and effective curing was done as far as possible. One *bahashti* could control an area of 2500 sft. a day.

Cleaning, washing, and hardening concrete surface.

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Another difficulty experienced at the commencement of the work was the shifting of telegraph poles and stays, standing on the berms of mile 2 where the trackway was to be laid. However, it was overcome through the cooperation of the Telegraph Department.

The approaches to Bridge No. 4 were raised at the bridge by about 1½" using Bitumals emulsion HX penetration to bring the road to the level of the slab and thus to adopt a method to avoid inconvenience to the traffic.

Completed Roadway.

Cross section of the roadway as completed showing thereon the new cement concrete track has been given, *vide* Appendix E.

APPENDIX C.

TABLE SHOWING THE COST.

Average cost of 100 *cft. of Concrete* 1 : 2 : 4 *mix with coarse and fine aggregates.*

Section No. I.—

		Rs. a.
Coarse aggregate 1" to 2" gauge	226 cft. at Rs. 22-2 per % cft.	50 0
Fine aggregate ½" to 1" gauge	75 cft. at Rs. 27-10 per % cft.	20 12
Pathankot Sand	151 cft. at Rs. 22-2 per % cft.	33 7
Cement	75½ cft., 63 bags at Rs. 2-8 bag	157 8
Washing of materials	452 cft. at Rs. 1-8 per % cft.	6 12
Labour for mixing and laying	327 cft. at Rs. 10 per % cft. ..	32 11
Labour for curing	800 sft. at Rs. 1-4 per % sft.	10 0
Laying forms in position	327 cft. at As. 12 per % cft.	2 7
Incidental charges such as night chowkidars etc.	Job at Re. 1 per Job ..	1 0
		314 9

		Rs. a.
Total for 327 cft. of finished concrete.	Say	315
Cost per 100 cft.	..	96
Cost per 100 sft.	..	48

		Rs. a.
Cost of Reinforcement used in slab No. 4	over bridge No. 4 and	47 5

Section No. II.—

Coarse aggregate 1" to 2" gauge	255 cft. at Rs. 22-2 per % cft.	56 7
Fine aggregate ½" to 1" gauge	85 cft. at Rs. 27-10 per % cft.	23 8
Pathankot Sand	170 cft. at Rs. 22-2 per % cft.	37 10
Cement	85 cft. 71 bags at Rs. 2-8 per bag	177 8

		Rs. a.
Washing of materials	510 cft. at Rs. 1-8 per % cft.	7 10
Labour for mixing and laying	369 cft. at Rs. 10 per % cft.	36 14
Labour for curing	800 cft. at Rs. 1-4 per % sft.	10 0
Laying forms in position	369 cft. at Rs. 1-12 per % cft.	2 12
Incidental charges such as night chowkidar, etc.	Job at Rs. 1 per Job	1 0
	Total for 369 cft. of finished Concrete ..	353 5
	Cost per 100 cft. ..	96 0
	Cost per 100 sft. ..	48 0

APPENDIX D.

Section No. III.—

	Rs.	a.
Cost per 100 cft. of Cement Concrete as worked for sections I & II. ..	96	0
Cost of Reinforcement per 100 cft. of Cement Concrete ..	4	8
	100	8
Cost per 100 sft. allowing an average thickness of 6" ..	50	4

Section No. IV.—

Cost per 100 cft. of Cement Concrete as worked for sections I & II. ..	96	0
Cost per 1000 sft. allowing an average thickness of 6" ..	48	0

Section No. V.—

Cost per 100 cft. of Cement Concrete as worked above ..	96	0
Cost of Reinforcement per 100 cft. of Cement Concrete ..	4	5
	100	5
Cost per 100 sft. allowing an average thickness of 6" ..	50	3

Section No. VI.—

Cost per 100 cft. of Cement Concrete as worked above ..	96	0
Cost per 100 sft. allowing an average thickness of 6" ..	48	0

Section No. VII.—

Cost per 100 cft. of Cement Concrete as worked above ..	96	0
Cost of Reinforcement per 100 cft. of Cement Concrete ..	30	3
	126	3
Cost per 100 sft. allowing average thickness of 6" ..	63	2

Note 1. Cost of Hardening Concrete with Silicate of Soda per 100 sft. .. As. 12

Note 2. Cost of excavation as worked out Rs. 10 per % cft.

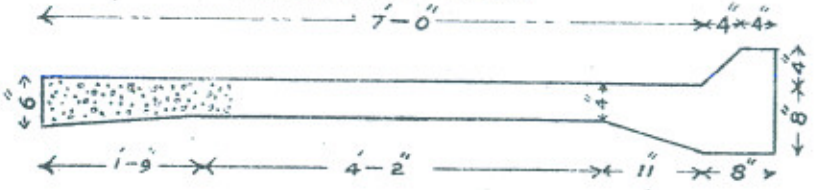
APPENDIX "A"

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DETAILS OF SECTIONS

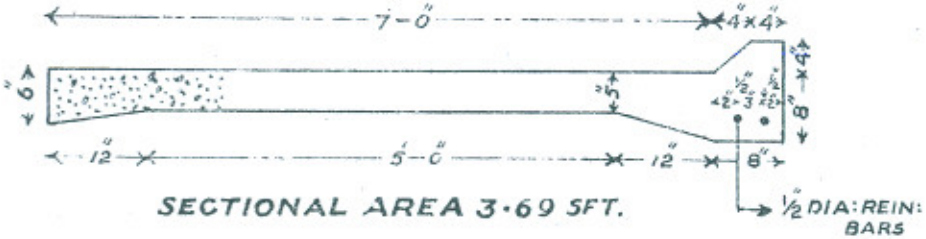
SCALE 1/2" = 1"

SECTION NO 1



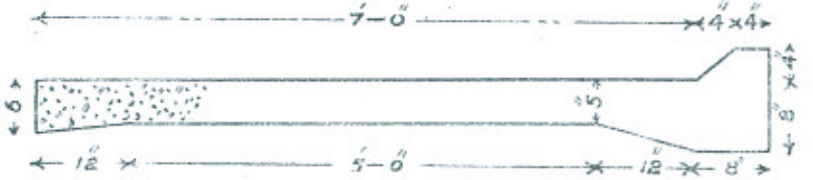
SECTIONAL AREA 3·27 SFT.

SECTION NO 3



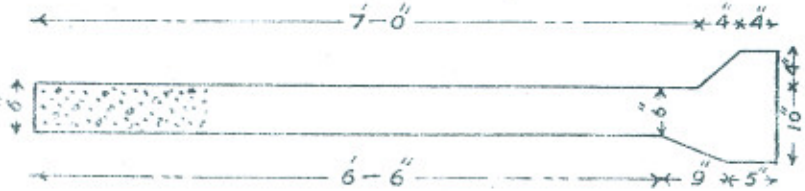
SECTIONAL AREA 3·69 SFT.

SECTION NO 2



SECTIONAL AREA 3·69 SFT.

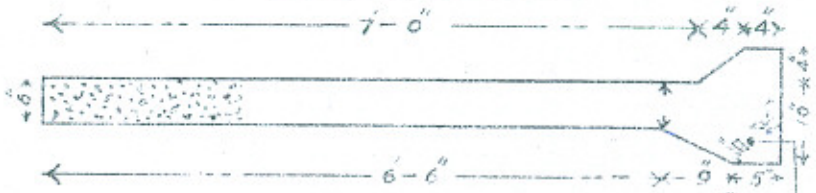
SECTION NO 4



SECTIONAL AREA 4·27 SFT.

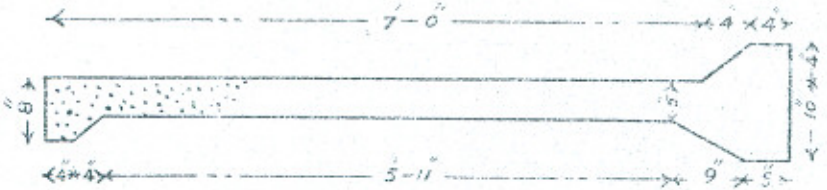
APPENDIX "B"

SECTION NO 5



SECTIONAL AREA 4·27.

SECTION NO 6



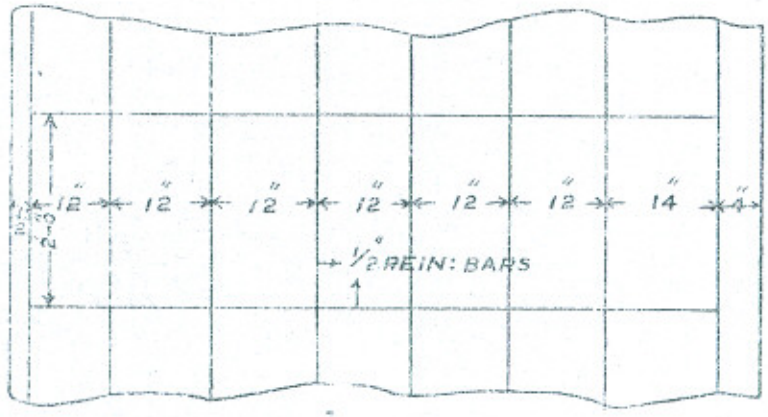
SECTIONAL AREA 3·80 SFT

SECTION NO 7



SECTIONAL AREA 3·19 SFT.

PLAN OF REINFORCEMENT BARS FOR SECTION NO 7

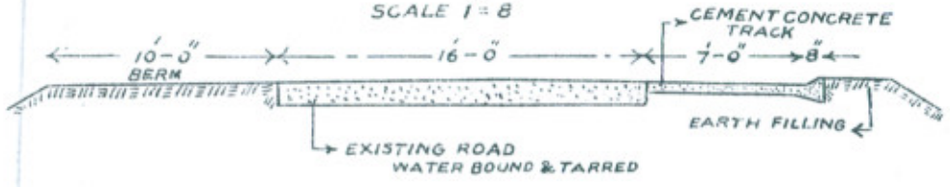


APPENDIX "E"

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CROSS SECTION

SCALE 1" = 8'



DISCUSSION.

In submitting the paper the author did not think it necessary to discuss the constructional use of cement. This material though sparsely employed before the advent of twentieth century, was gaining popularity every day for its adaptability and usefulness. As regards its technique, however, finality had by no means been reached, improvements in the manufacture of Cement and Steel and in the selection of aggregates were continually being made, and a truer experience was being obtained of the part played by the components of the structure as also of sound methods of calculation and execution. Though Concrete Engineering had been practised for many years in certain parts of the Punjab, it still was a comparatively new subject to the Province as a whole and most of the practical details had yet to be explored to suit the climatic conditions. It was mainly with this object in view that the paper had been put forth. Effort had been made to bring to light every constructional difficulty experienced during the experimental work undertaken by the Department. The author expressed a hope that the practical side of the subject had been made clear and particularly that the many essentials to good work, such as properly storing and proportioning of materials, proper washing of aggregates and adequate curing of Concrete after placing had been made explicit and easy to visualize.

The author referred to the following corrections to be made in the paper :—

Page 78. Para 3, ' for ' to be added after ' but ' in 2nd line.

Page 81. Para 3. Line 3. Read ' workable ' in place of ' workables.

Paga 4. Line 3, Omit ' e ' in Cement.

Page 82. No. 7.Read (2') apart and not (2") apart.

He thanked Mr. L. A. Freak, Executive Engineer, II Lahore Provincial Division, under whose supervision and guidance the work was carried out and to whom the whole success was due. He as well thanked Rai Sahib Lala Hari Chand of the Cement Concrete Association for his continuous visits and help.

Mr. **Brij Mohan Lal** found the first para. on page 81 little confusing, and wondered if it was meant to read as below :—

" For the fine aggregate, Pathankot sand was used. In order to get a dense concrete, $\frac{1}{2}$" to 1" gauge Pathankot stone crushed bajree (chippings) was mixed with Pathankot stone metal 1" to 2" gauge in the ratio of 1 : 3 so as to give a graded aggregate."

In appendices C and D, cost per hundred square feet of the road was not calculated correctly. As the square feet of roadway obtained

per 100 running feet length of road was 700 square feet, the total cost per 100 running feet under each section should have been divided by 7 to get correct cost per hundred square feet. Cost calculated in this way would work out to

	Rs. 45	in place of	Rs. 48 for Section I;
	Rs. 50-8	do.	Rs. 48 for Section II;
	Rs. 53	do.	Rs. 50-4 for Section III;
	Rs. 59	do.	Rs. 48 for Section IV;
	Rs. 61	do.	Rs. 50-3 for Section V;
	Rs. 52	do.	Rs. 48 for Section VI;
and	Rs. 57	do.	Rs. 63 for Section VII.

The difference in cost per hundred sq. ft. is appreciable in Sections IV, V, VII. It might be roughly said that the cost of a concrete road, would be about Rs. 50 per hundred sq. ft. and that of a Reinforced concrete one Rs. 60 per hundred sq. ft. For a 12' wide road, this would work out to Rs. 32,000 and Rs. 38,000 per mile respectively. For traffic amounting to 780 tons per day including only 150 carts, the expenditure looked excessive. It appeared that the actual traffic on the road was much more than shown in the paper. In England, traffic as heavy as 12000 tons per day had been observed on concrete roads. For a traffic of less than 1000 tons per day, even surface treated water bound macadam roads should be good enough. Contrary to what the author said in para. 4 of page 77 that tar or bitumen grouts or premixes were not suitable for the tropical heat of the Punjab, bitumen premixes however proved very successful at Delhi which was as hot as the Punjab. On the roads leading to Delhi goods yard and to Delhi Jumna Bridge, which carried a very heavy bullock cart traffic, much heavier than on Lahore Multan Road—2½" Shelcrete road costing about Rs. 25 per hundred sq. feet—half the cost of concrete road—was laid three years ago. These sections of road had shown no signs of wear or undulations or potholes and had not required any maintenance. The speaker believed that for an average heavy traffic of 1000 tons a 5"—3"—5" thick concrete road could be good enough and cost about Rs. 30 per hundred sq. ft.

Concrete roads have however one great advantage over bitumen roads in the fact that all materials used therein are produced in the Punjab. While a large mileage of cement concrete roads had been built in the neighbouring United Provinces of Agra and Oudh, Punjab had practically built none. The speaker advocated the use of Cement Concrete for the construction of roads carrying sufficiently heavy traffic, specially where good sand and stone were available closely. The experiments made on the Lahore Multan Road, were, therefore, in the right direction, and their results would be closely watched for future guidance.

Mr. **Murari Lal** found the author's statements in paragraph 4 of the page 77 that tar or bitumen premixes were not suitable for the

resultant damage being irreparable. He enquired what considerations had led to the leaving of no space for expansion.

Current practice in England was to attach considerable importance to such joints and, on occasions, to provide specially good concrete at the edges of joints and he doubted whether the trackways would last for, say 10 years, which should be counted on, bearing in mind the initial high cost of this type of construction.

The difficulty of heavy bullock-cart traffic might however be got over without the use of cement concrete, should the adoption of the pneumatic tyred cart become general.

Replying to the discussion, the **author** regretted the omission on page 81, line 2nd, in and of before and after the word ratio which seemed to be a misprint. He informed Mr. Brij Mohan Lal that the cost worked out under appendices C & D was for 100 c.ft. of cement concrete which included the cost of kerb as well, hence the calculations given were correct.

The traffic amounted to 780 tons per day per yard width, the metalled portion being 16 feet wide and the number of carts plying the road were as many as 1600 per diem and most of the carts being iron tyred which heavily loaded with bricks badly cut the road. Hence the provision of the cement concrete track was made to meet the intensity of traffic.

Thin coats of Bitumen were tried on G. T. road in the immediate vicinity of Lahore by well experienced firms and they did not prove satisfactory under the heavy traffic. The work carried out was an experiment to compare the cost and life with different constructions.

In reply to Mr. Murari Lal's querries, the author said his intention was to eliminate only the Specification of Bitumens which were tried and found unsuitable. In India as well as in other foreign countries experiments had been carried and certain formulas had been put forward to work out the thickness of the cement concrete roadway without going into the details and certainly advancement in this direction to suit the local conditions of traffic would be highly beneficial to the cause of road construction in this country.

Various thicknesses of the Slab at ends were designed to take over the extra shear near the unsupported edge.

The butt joints were not considered as unsupported as the hammer blow effect was not restricted to one slab but is borne by both adjacent slabs at the joint.

For a continuous work the steel forms were always preferable but for an experiment on a limited scale the cost was prohibitive.

Trial and error methods were adopted to get concrete of dense and workable consistency, the previous experience on the subject dispensed with the preliminary slump tests on cement concrete. The proportion of the two aggregates was determined by actual void tests.

The author informed Mr. G. R. Sawhney that the experimental stage of the cement concrete track was still intended to be continued on other roads to Lahore; the experience gained on this trackway would be fully utilized when designing other concrete roads.

The reinforcement was intended to guard against the tensile stresses which might develop when the sub-crust underneath gave way and the slab was left only at the edges.

He attributed one or two cracks along the edges in the last section in mile 3 of Lahore Multan Road to the passing of the 10 Tons Roller over the track while the concrete was not well set.

The required data was collected during the construction and the proportion of water was assumed for each particular mix depending on the quantity of water already existing in the aggregates.

The author did not find Sarkanda suitable for the intended purpose as it was soon crushed under the traffic.

In reply to Mr. G. H. Hunt, the author stated that the whole length of the road was not resumed as a continuous work, alternate bays were laid and enough time was left for the previous adjacent slab to set, before fresh concrete was laid. Concrete during the setting always shrank and this shrinkage was considered enough for subsequent changes due to temperature.